What Can Human Factors Tell Us about Designing for Technological Affordances in Teacher Education?

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Abstract: This paper will discuss the results of a human factors analysis that was conducted as part of a three-year study involving implementation of online learning in a teacher education context. The human factors analysis was based on a modified approach to Cognitive Work Analysis (MacKinnon, 2009) originally proposed by others in the engineering sciences (Rasmussen, Peijersen, & Goodstein, 1994; Vicente, 2003; 1999). This research expands on the notion of technological “affordances” which suggests that there is an interational relationship between people and tools (Gibson, 1986; Norman, 1988). Vicente (2003) calls this interaction a “Human-Tech” relationship, and argues that social variables - which he calls “constraints” - play an important role in determining the degree to which technology can help individuals carry out goals and priorities under contextually-variable conditions. The researchers will make a case throughout this paper for a view of technology integration that takes into account measures of affordances and constraints. The researchers suggest that one cannot really understand effective use of technology for learning without thinking about affordances, and affordances cannot really be measured without thinking about constraints associated with the learning context. Essentially, the point the researcher is making is that constraints help to define - and even shape - what technological affordances ought to look like. Therefore, the researcher begins to answer the important - and arguably unexplored - question of how the complexities of varying teaching and learning contexts ought to be used to inform design. Findings from the human factors analysis was used to support a design study involving the use of online technology in the context of a teacher education program. This presentation reports on findings from two research questions: 1) What does a Human-Tech approach to technology integration, implemented through the use of a modified technology design tool called Cognitive Work Analysis, reveal about the system constraints of a two-year graduate level teacher education program? and, 2) What are the technological design implications of a Human-Tech approach to technology integration for supporting student research in the context of a two-year graduate level teacher education program (the student research became the primary focus of the design study)? In this case, the human factors analysis lead to the design of an open online research support forum.

Keywords: Human factors, technology integration, teacher education, online research mentorship

Introduction

In this paper, the researchers argue that, in education there appears to be an over-reliance on models of technology integration that focus on cognitive attributes of stakeholders (i.e., students and teachers). A review of the literature on the topic of technology integration - or technology infusion - reveals that there is a predominance of frameworks that suggest that a lack of appropriate knowledge, skills and attitudes is primarily responsible for the relative absence of technology use in schools today. This is perhaps symptomatic of a more general emphasis in society on ‘changing the people to fit the tools’. According to Vicente (2003) “The prevailing role of technology in society treats people as stupid and sees ‘design for dummies’ as the solution to our frustrations and difficulties. It doesn’t treat people with the dignity that they deserve” (p. 299-300).
The problem of how to effectively integrate technology into complex learning environments requires a complex approach. Designers need to look beyond simply the psychological attributes of individuals for their design criteria and rationales for the failure of technology to thrive in education. A number of studies have pointed to contextual factors that likely have had an impact on research outcomes, yet these factors are typically treated as confounding variables or barriers to the study, rather than as factors that helped to guide design. Moreover, others have explicitly highlighted the important role of context in understanding how to leverage new and emerging technologies to support learning (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004; Koehler & Mishra, 2005; 2008). However, to date there has been little to guide researchers and teacher practitioners in selecting which aspects of context are of most relevance to technology integration, or how they ought to go about identifying these contextual factors as a way of informing design of new learning technologies.

A “Human-Tech” (Vicente, 2003) framework for understanding technology innovation and integration suggests that there are a multitude of contextual factors that may be relevant to design, including physical, psychological, team, organizational and political variables. Furthermore, Vicente offers a systematic way of identifying and organizing these variables so that they may be used to support design, through the implementation of a tool called Cognitive Work Analysis (Vicente, 1999) - see next section.

**Human-Tech Design**

This research expands on the notion of technological “affordances” which suggests that there is an interactional relationship between people and tools (Gibson, 1986; Norman, 1988). The researchers suggest that there is a need for a view of technology design and integration that takes into account measures of *affordances* and *constraints*. We argue that one cannot really understand effective use of technology for learning without thinking about affordances, and affordances cannot really be measured without thinking about constraints associated with the learning context; essentially, that constraints help to define - and even shape - what technological affordances ought to look like.

Vicente (2003) also argues that there is a similar interactional relationship between people and technology, which he calls a “Human-Tech relationship”. He explains that good Human-Tech relationships emerge when there has been careful consideration given to designing technology that fits with what we understand about the human factors of the people who are supposed to be using the technology. “If the human factor is taken into account, a tight fit between person and design can be achieved and the technology is more likely to fulfill its intended purpose” (p. 54). In a Human-Tech approach to design, the human factors are important because they identify what ultimately governs the behaviour of individuals. Therefore, knowing something about these human factors will help designers create technology that can take into account information that is likely to constrain action.

The framework that Vicente (2003) proposes for understanding human factors is the ‘Human-Tech ladder’. At the bottom rung of the ladder are *physical* human factors, which deal with things like “size, shape, location, weight, colour and material” (p. 61), including what we know about the average anatomy and physiology of most people. For example, most people could not lift a one ton object so any design that required a person to do that, would likely not be a good one. The next rung up on the ladder pertains to *psychological* human factors, which describe fundamental characteristics about the ways that people think and process information, including what we know about patterns of human thinking and processing of information (e.g., the average capacity of short-term memory). The next rung outlines *team* factors, which describe how individuals, or groups of people, “communicate with each other and coordinate their respective actions to achieve individual and common goals” (p 56). The fourth rung pertains to *organizational* factors, which describe how teams of people make decisions about, and communicate, things like collective goals, incentives and disincentives, policies, and procedures. Vicente also points out that organizational factors can affect behaviour at the lower levels of the ladder (e.g., scheduling
conflicts - at the organizational level - that lead to working overly long hours can contribute to fatigue, job dissatisfaction and resentment - at the psychological level). The final rung relates to political factors, which describe things like laws, regulations, political climate, "public opinion, social values and cultural norms" (p. 58).

**Cognitive Work Analysis**

For Vicente, Human-Tech design is carried out through the implementation of Cognitive Work Analysis (Vicente, 1999). CWA is typically carried out through data collection procedures such as observations, documentation analysis (review of key documents), informal conversations with stakeholders, and extended interviews with key stakeholders, prior to initiating design. All data is then merged and used to support development of the human constraint analysis. The most extensive methodological account of CWA, prior to this research, was described by Naikar, Hopcroft and Moylan (2005) in which the authors focus on analysis of the work domain component of the CWA model. Once data collection is complete, an analysis of the relevant human factors is carried out ("constraint analysis") and is then subsequently used to support socio-technical design for the particular system of interest (i.e., the one in which the CWA was carried out).

In the current study, a Human-Tech framework guided efforts to integrate technology into a two-year teacher education program, through a modified approach to Cognitive Work Analysis (MacKinnon, 2009) originally proposed by others in the engineering sciences (Rasmussen, Pejtersen, & Goodstein, 1994; Vicente, 2003; 1999). The authors are among the first to recently expand use of this tool to the learning sciences (MacKinnon, 2008; 2006; MacKinnon & Woodruff, 2008a; 2008b; 2008c; Nirula & Woodruff, 2008).

**Overview of the Study**

**Purpose**

One of the primary goals of this study was to explore the use of a Human-Tech framework - through the implementation of a modified approach to Cognitive Work Analysis (CWA) (Vicente, 1999) - to inform the design and integration of technology that could be used to support work carried out as part of a two-year graduate level teacher education program (MA-T). At the beginning of this study, there was some technology already in use in the program, such as email and discussion boards. In general, the MA-T program had adopted an infusion model to technology integration (technology is integrated into all courses, as opposed to a stand-alone course) however, the use of technology varied from instructor to instructor from no use, to full integration (Rowley, Dysard & Arnold, 2005).

**Context**

This study takes place in the Faculty of Education at a large urban university in Canada. The Faculty of Education offers four routes to initial teacher education, including a two-year consecutive program in which students graduate with a Masters degree in the area of Curriculum and Teaching (MA-T) - this program was the primary focus of this study. During the year in which the portion of the research reported here took place (2006-2007 academic year), there were a total of 30 participants (7 faculty members and 23 students), which represents 91% of the faculty and second-year student population (the second year students were of interest to the design study).

The MA-T program was an ideal context to begin looking at the potential of a Human-Tech framework to inform technological design in education, since it is a small program with less than 100 students and only 9 faculty members; while still a complex social context, this made it a relatively ‘closed system’ (Vicente, 1999) in which to investigate.
**Timeline of the Research**

The research was carried out over a three-year period, and included various phases (Table 1). It should be noted that while the word “phase” is typically meant to convey a temporal distinction, in this case the word is used to describe a distinction in research focus. Therefore, some of the phases overlap temporally.

**Table 1:** Timeline of the Research

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<tr>
<td><strong>Phase 1</strong></td>
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<tr>
<td>(Problem Identification)</td>
<td>Pilot work</td>
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<td></td>
<td>Informal observation and discussion in the MA-T program</td>
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<td></td>
<td>Identified problem focus for design study</td>
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<tr>
<td><strong>Phase 2</strong></td>
<td>Documentation analysis and first interviews</td>
<td>CWA interviews continued; surveys administered</td>
<td>Verification procedures</td>
</tr>
<tr>
<td>(Cognitive Work Analysis)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Phase 3</strong></td>
<td>Innovation 1 of the design study was implemented</td>
<td>Innovation 2 of the design study was implemented</td>
<td></td>
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<tr>
<td>(Design Study)</td>
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</table>

Although the CWA procedure was not fully completed by Sept 2006, the researcher decided to initiate the first iteration of the design study based on the information that had been gathered to date. It should be noted that under normal circumstances the CWA is completed prior to design. However, learning contexts differ in many ways from the contexts in which CWA was originally developed, and therefore it is necessary to make certain adjustments to allow for these unique circumstances (e.g., intermittent access to key stakeholders in a university setting due to the summer intersession break between the winter and fall semesters).

**Method**

This study followed a design research approach (Bereiter 2002a; Brown, 1992; Collins, 1992; 1999; Edelson, 2002; Woodruff & Nirula, 2005), which is ideally suited to studies that are embedded in complex social contexts since they take place in authentic learning environments as opposed to a laboratory setting.

Data collected as part of Phase 2 of the study was combined to form a human factors constraint analysis (i.e., a chart breaking down the individual contextual constraints that could be used to support technological design), which was then verified through an external audit, a check for inter rater reliability for the categories that were used, as well as a member check.

**Results**

**Overall Results of the Cognitive Work Analysis**

Once verification procedures for the content analysis of the CWA data had been completed and adjustments had been made to satisfy any auditor-researcher and/or rater-researcher...
disagreements, there were a total of 358 human factors constraints identified in the context of the two-year MA-T program. Using Vicente’s (2003) Human-Tech categories as a framework for the content analysis, 30 human factors were found to pertain to political constraints, 100 pertained to organizational constraints, 82 pertained to team constraints, 125 pertained to psychological constraints, and 21 pertained to physical constraints. Although all of the human factors constraints identified are likely to have an impact to some degree on any design, the researcher decided to focus only on a small number given the scope of the study. A total of 24 human factors constraints were addressed in the design study (Phase 3) which represents approximately 7% of the total constraints identified (Table 2). While the researcher kept other constraints in mind during the design, the 24 constraints mentioned above were the primary focus in the design study.

### Table 2: Summary of Human Factors Constraints Identified

<table>
<thead>
<tr>
<th>Constraint Category</th>
<th>Total Number Identified</th>
<th>Total Number (%) Addressed in the Design Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Political</td>
<td>30</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Organizational</td>
<td>100</td>
<td>6 (6%)</td>
</tr>
<tr>
<td>Team</td>
<td>82</td>
<td>5 (6%)</td>
</tr>
<tr>
<td>Psychological</td>
<td>125</td>
<td>13 (10%)</td>
</tr>
<tr>
<td>Physical</td>
<td>21</td>
<td>0 (0%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>358</strong></td>
<td><strong>24 (7%)</strong></td>
</tr>
</tbody>
</table>

Design Implications of the Human Factors Constraints

The Design Problem

In Phase 1 of the research, the researcher identified a problem in the MA-T program which focused on the student research projects. Informal conversation with stakeholders in the program had suggested that students did not feel they were sufficiently supported in carrying out their research projects, and the quality of the research in many cases was below what is normally expected within an academic program. Informal observation indicated that students primarily carry out their research independently, although they have some access to a research supervisor; the extent of this access varied considerably from none to regular access. Students mainly accessed their research supervisor through face-to-face meetings and/or email, although most had little to no contact with their supervisor during practicum (when data is typically collected). Furthermore, students did not tend to collaborate with their peers around their research; many did not know what others were working on, even when the problems they were working on (research topics) may have been similar or related.

The problem around the research projects in the MA-T program - in addition to broader problems of technology integration in support of learning in teacher education identified through a literature review - provided the main impetus for carrying out the modified CWA (Phase 2), and the eventual design of the open online research support forum as part of the design study (Phase 3).

Design Innovation Using the Human Factors Constraints

It is through the results of the human factors constraint analysis (Phase 2) that the bulk of the information from which the researcher made their design decisions in the design study were taken (Phase 3). Since it is not feasible in the scope of this paper to present all of the human factors constraints, their implications and the design strategies taken across both years of the design study, the authors have provided an example from within each of the three categories addressed (Table 3).
Table 3: Examples of Design Implications from the Constraint Analysis

<table>
<thead>
<tr>
<th>Constraint No.</th>
<th>Constraint Category</th>
<th>Description of Constraint</th>
<th>Description of Implications and Design Strategies Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Organizational</td>
<td>There is not a lot of time or opportunity built into the program for students to engage in independent study or carry out their research projects.</td>
<td>Implication(s): Students need to fit the research project around other program priorities.&lt;br&gt;&lt;br&gt;Design Strategy: An online research mentorship was designed - using Knowledge Forum® - so students can communicate with their peers and access help from doctoral research mentors, at any time (as they need it).</td>
</tr>
<tr>
<td>9</td>
<td>Team</td>
<td>Students often have little contact with the university and their cohort peers during practicum.</td>
<td>Implication(s): Students have little contact with their peers and the university at a time when many are collecting research data.&lt;br&gt;&lt;br&gt;Design Strategy: Students can access their peers, and online mentors at any time, through the online mentorship; including during practicum.</td>
</tr>
<tr>
<td>17</td>
<td>Psychological</td>
<td>According to F5, some faculty find it challenging to deal with the demands of a combination, pre-service and graduate program (e.g., practicum supervision and research support).</td>
<td>Implication(s): Some faculty may need help to manage some of the demands around research supervision.&lt;br&gt;&lt;br&gt;Design Strategy: Access provided to the online mentors and peers provides opportunity for students to seek help and feedback from multiple sources, rather than reliance on supervisor alone.</td>
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</table>

The Online Research Mentorship

Based on the problem identified in Phase 1 of the research, and design implications from the 24 constraints (Phase 2) selected for the design study, the researcher designed an online research mentorship (ORM) to help support students’ work related to their research projects as part of the MA-T program. The design strategies are organized according to Koehler and Mishra’s (2005; 2008) framework, which suggests that technology integration ought to consider three things: content, pedagogy and technology. It is important to note that, for the researchers, the meaning of ‘design innovation’ is entirely dependent on this interactional relationship between the social (content, pedagogy) and technological, which ultimately defines what any particular design affordance will look like.
Content Design

The ORM was designed to support the student research projects that the MA-T students carried out as part of their program requirements. Therefore, generally the content of the ORM focused more broadly on elements of research practice (e.g., literature reviews, methodology). However, specifically the students worked in smaller research groups that were organized based on their research topics so that students could collaborate on related content problems. Therefore, the particular conceptual artefacts - or knowledge artefacts - pertaining to the design innovation depended on what the students were investigating.

Pedagogical Design

The ORM was implemented through one of the required, or core, courses that students are expected to take during their second year in the MA-T program, to help decrease the likelihood that students would see the ORM as an “add on”, or something extra that they had to do, above and beyond their normal (and intensive) program expectations. The instructor for the course and the researcher collaborated with one another to create course-based supports for the students’ research that could also tie into the content of her course (Psychology), based on what was known through the CWA.

Mini Research Summaries

One of the designs that the instructor and researcher implemented was a research assignment in which students would submit mini summaries of each component of their research project (i.e., topic, literature review, method, etc.). One mini summary was to be submitted approximately every month, and could include connections to principles of learning that the students were covering in their course. For example, the mini literature review might include a section on how a particular learning theory has informed their research topic. Students could then submit their summaries to the ORM (since the ORM could be accessed directly from the course discussion forum - also Knowledge Forum®) for instructor feedback and grading, and as an opportunity for additional formative feedback from their mentor. The goal of this assignment was threefold: 1) the monthly due dates were meant to help students thinking about and work on their research project in small sections over time, rather than leaving it until the end of the year, 2) to give students regular feedback on their ideas related to their research and 3) to provide an opportunity for students to consider how their research connected to the larger body of literature on learning and development (which was covered in the course).

Research Conference

The second strategy developed by the researcher and the instructor was to hold a research conference at the end of the year, in which students could present a short summary of their research to their peers, the mentors and faculty from the MA-T program. Prior to the design study, students in the MA-T program had never had the opportunity to present their completed research to their peers and faculty. Each student was responsible for preparing a five-minute presentation and a short abstract summarizing their project and findings. The objective for the researcher conference was twofold: 1) to give students the opportunity to share (and celebrate) their research with the broader MA-T community, and their mentors, and 2) to emphasize the importance of dissemination as part of academic practice around research. Students were also given copies of a proceedings booklet that contained all of the research abstracts from the projects that students had completed over the year.

Technological Design

The ORM was supported through an online discussion forum technology called Knowledge Forum®. This software was designed to support a knowledge building pedagogy (Scardamalia,
2002) and has many features that can be used to engage in collective forms of inquiry. However, the researcher had a lot of flexibility in deciding which components of the program would be used, and ultimately what the inquiry workspace would look like. The following sub-sections describe the ways that the researcher designed the online space of the ORM.

Online Research Groups

The Knowledge Forum® software was used to create a shared space in which small numbers of students could work in online research groups on the research they were carrying out - most of which is classroom-based research. The small research groups were made up of second year students from the MA-T program, who were working on similar or related problems for their research projects as part of their initial teacher education. Each online research group also had a doctoral research mentor - an experienced educational researcher - that had volunteered to help support the students through the process of carrying out their research, and to encourage ongoing discussion related to the common area of interest in which the students were working. Although the online mentorship primarily focused on the small research groups, the open design of Knowledge Forum® also allowed students to access and contribute notes in other research groups. Therefore, in the ORM students could read all notes posted by their peers, both within and outside their research group. Students could also respond to any note in the ORM. The goal of the small research groups was to encourage students to collaborate with their peers around common, or related, problems. However, the purpose of leaving the research groups open to others to read and contribute notes, was to also encourage students to see the work they were doing as related to the work that others were doing in the context of the larger learning community.

Email Notifications

Knowledge Forum® comes equipped with an email notification system that can be programmed to send an email message to individuals in the ORM when new activity occurs (i.e., a note is posted or edited by one of the members). The researcher programmed the email notifications to be sent out every 24 hours, if there was new activity in the research groups. These notifications were sent to the research group members and to all the mentors, and they summarized new activity across all of the research groups. In these notifications, students and mentors would see the title of the note, the name of the person that posted it, the date it was posted, and a small excerpt (approximately 30 to 40 words) of the note. Individuals could then connect to the ORM directly from the email notification if they wanted to continue reading the contents of the note. The goal of the email notifications was twofold: 1) to encourage students to read notes of other members of their research group, and also other research groups if applicable to their own work, 2) to serve as a reminder of the overall research work that was happening within their learning community.

Conclusion

This paper presents findings from a human factors analysis that was used to support a design study involving the use of online technology in the context of a teacher education program. In the paper two research questions are explored: 1) What does a Human-Tech approach to technology integration, implemented through the use of a modified technology design tool called Cognitive Work Analysis, reveal about the system constraints of a two-year graduate level teacher education program? and, 2) What are the technological design implications of a Human-Tech approach to technology integration for supporting student research in the context of a two-year graduate level teacher education program (the student research became the primary focus of the design study)? In this case, the human factors analysis lead to the design of an open online research support forum. In the conference presentation, the authors will conclude with discussion of some of the results from the design study involving the open online research support forum.

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