Cognitive Work Analysis and Design Research: Designing for Effective Human-Technology Interactions Using Handhelds in Elementary and Middle School Literacy Support Classrooms

Presentation Format: **Paper (Short)**

Author: **Latika Nirula**

Department(s) and Affiliation(s):

Human Development and Applied Psychology, OISE/University of Toronto
Institute for Knowledge Innovation and Technology, OISE/University of Toronto

Email: **lnirula@oise.utoronto.ca**

Abstract

This paper explores how Cognitive Work Analysis (CWA) can be an effective approach for analyzing, designing, and evaluating complex sociotechnical systems such as elementary and middle school literacy support classrooms adopting new handheld technologies. CWA should be seen as an integral precursor to any design research iteration, enabling the identification of key constraints in order to design effective innovations in collaboration with the classroom teacher that optimize human-technology interactions. Through the addition of CWA, we may determine why new technologies may fail in their implementation in schools or do not have the level of impact on student learning they purport. This paper suggest how CWA informs the iterations of design and the interpretation of results of studies involving handhelds in elementary and middle school literacy support classrooms, our understanding of the human-technology interaction in this context, and implications for the design of educational technological interventions.

1. Introduction

It is anticipated that over the next decade, devices with personal, portable, and wireless affordances will become ubiquitous and pervasive among learners (Chan et al., 2006). As schools move to adopt handheld technologies within their teaching and learning practices, understanding why such technological interventions are met with varying success becomes critical in adequately addressing design issues within such environments. The success of the human-technology interaction in schools rests upon a careful and considerate examination of key constraints impacting implementation at all levels –including students, teachers, school administration, social/political considerations and the school environment itself. This paper explores how a constraint-based approach to evaluating technological interventions is critical in designing and evaluating design research investigations. This paper describes how a series of design research studies involving the introduction of handheld computers within elementary and middle school literacy support classrooms are informed by such an approach.

Evaluations of the success or failure of human-technology interactions in the educational technology literature often occur post-hoc, however the institution of schooling is influenced by several levels of constraints that may inhibit the implementation of mobile technology. Learning technology researchers have pointed to some of the challenges or constraints that schools face through survey and interview data (Shin et al., 2007). However, this information does not typically cycle within or influence directly the design of our school-based technological interventions.

Outside of cognitive work analysis, researchers have already argued that mobile devices can address some of the known technological constraints in educational settings: For example, handheld computing devices address the need for a one-to-one ratio (one student to one electronic device) necessary for supporting pervasive technological innovation (Brown, 2001); and with their lower costs (Pownell & Bailey, 2000), mobile features which support peer collaboration (Woodruff & Nirula, 2005) and individual reflection and refinement of ideas (Nirula et al., 2003; Soloway, 2002). Furthermore, these devices have been shown to support the learning of students within Special Education support settings, enabling the adaptation of the technology to the student's

individual needs, reducing stigmatization of the student's learning difficulty and enabling a less intrusive use of technology in the classroom (van't Hooft & McClain, 2005). Given their unique features and potential learning benefits for learners of varying needs, handhelds have become popular devices to explore when considering the design of new technological and pedagogical innovations. However, handheld mobile technologies must also be subject to systematic evaluations prior to implementation in order to identify and limit potential constraints that may negatively impact the success of their implementation in schools. As educational contexts vary, the need to identify the conditions that best support human-technology interaction in order to predict and plan for more effective educational human-tech interactions becomes vital. Through adopting *Cognitive Work Analysis* (herein referred to as CWA) as a critical element of the *design research methodology*, we may be able to surmise why new technologies fail in implementation or do not have the level of impact on student learning they purport. CWA may hold the key to developing more effective educational technology interventions, by systematically addressing potential constraints within the design phase.

2. Cognitive Work Analysis within Design Research

CWA (Rasmussen et al., 1994; Vicente, 1999) has been shown to be an effective approach to adopt in analyzing, designing, and evaluating complex sociotechnical systems (Vicente, 1999). This modified CWA approach for educational settings, as described in this paper, is based primarily upon seminal work of Kim Vicente at the University of Toronto. His work in Human Factors Engineering has been adapted to the educational context in order to follow a design approach that begins by understanding a human or societal need, and then tailoring technology to reflect various human factors. Vicente (1999) describes the human-technology interaction in terms of several key conceptual distinctions. I have maintained most of Vicente's terminology, however have adapted some phrasing to follow more consistently with the educational context and "Knowledge Economy" (Bereiter, 2002a) literature. Vicente (1999) describes five key components in his cognitive work analysis framework: (1) Work Domain –how the system may be controlled, independent of any particular "knowledge worker" within the school, their tasks or goals (this involves identifying constraints independent of any particular task, event, or goal); (2) Control Tasks –the activity that is required in a work domain (using a given set of physical resources); (3) Strategies –the cognitive task procedures that move the learner from an initial state of knowledge to a more advanced state of knowledge; (4) Social- Organizational –how work and goals are distributed across knowledge workers, and how communication and cooperation occur; (5) Worker Competencies –considers how knowledge workers' cognitive and psychological attributes and capabilities influence how teaching and learning occurs. The involvement of school administrators, teachers, and students is critical in adequately identifying potential constraints for the human-technology interaction involving handhelds.

CWA can be an important complement methodologically to *design research* as describe by Bereiter (2002b). Bereiter (2002b) describes four key features that constrain the design research methodology in educational research: (1) design research must be carried out collaboratively with educators; (2) investigators must also be participant-researchers –with the pretence of objectivity abandoned in order for the researcher working to make something happen; (3) the immediate goal of the research is to find

some form of solution created out of an analysis of recent failures; and, (4) design research is guided by the vision of sustained innovations dependent upon new goals emerging from continual performance analysis. Within design research, CWA should be seen as an integral precursor to any design iteration, as key constraints are identified and considered in collaboration with the classroom teacher in order to design effective innovations using handhelds in the classroom. CWA of a school would involve the identification of key constraints that face *stakeholders* –groups of people with differential goals and perspectives of the same design problem (Burns & Vicente, 2000). The 'design problem' described in this paper is that of literacy support classrooms dealing with the introduction of handheld computers to support collaborative knowledge building and reading comprehension. I suggest how the addition of a CWA would inform the interpretation of the results of these studies, our understanding of the human-technology interaction in this context, and the implications for the design of educational technological interventions.

3. Methods: Designing and Conducting CWA Interviews

CWA focuses simultaneously on the task that stakeholders perform, the environment in which it is carried out, and the perceptual, cognitive, and ergonomic attributes of the individuals who perform the task (Fidel & Pejtersen, 2004). Understanding the contextual environment of the study prior to any technological intervention becomes critical in uncovering the constraints that affect the human-tech interaction at these levels.

Based upon the work by Naikar and colleagues (2005) for conducting Work Domain Analysis, I describe the following adapted methodological guidelines for designing and conducting CWA used in both elementary and middle school settings utilizing mobile, handheld computers to support students' knowledge building and reading comprehension. The following steps preceded these design research studies in order to optimize success of each designed innovation using the handhelds:

1. Observation of the school and classroom procedures under naturalistic conditions and obtaining relevant policy and curricular documentation.

2. Individual CWA interviews with teachers, school principal and participating students.

3. Focused field observations of participating students and teachers interacting with existing technologies in the school and classroom.

4. "Think Alouds" with children and teachers where they described how they use various technology and strategies for learning.

5. The researcher provided a composite report summarizing the various aspects of the CWA captured within the interviews, observations and 'think-alouds'. Participants verified that the summary accurately described their work environment and its constraints and added any aspects that were missed or inaccurately captured.

6. The researcher and teacher collaboratively devised a small activity that introduced the handheld computers to the students.

In this study, CWA interview data was collected from stakeholders from two school sites. Stakeholders included the school principals, the classroom teachers, the technology teacher for the school, and the participating students. Questions span Vicente's (1999) five key components of a CWA. Data derived from interview questions with the students included: their educational goals, how they perceive their classroom set-up influencing their learning and ability to use the computers in their classroom, and descriptions of strategies they utilized when encountering difficulties in their learning or independent usage of technology. The CWA interview with the classroom teacher asked about the challenges or difficulties he faces when making use of technology in his classroom, in order to gain insight into constraints that exist at the *worker competency* level. I gained insight from the principal into how decision-making for the introduction and maintenance of computer technology in the school happens at the *social-organizational* level. Data obtained from the CWA interviews informed the design and evaluation of subsequent innovations using handheld computer within this research context.

4. Using Human-Technology Interaction Analyses to Identify Potential Constraints

Post-analysis from an earlier study conducted using handheld computers in a grade two knowledge building classroom (Nirula et al., 2003) suggested how the addition of a CWA would influence the design of future iterations and our current design research investigations in literacy support classrooms. In this previous study, students chose to develop collaboratively created notes that presented ideas about scientific phenomena to their class using the available desktop computers in the classroom, despite the availability and familiarity of the infrared 'beaming' features of their handhelds to facilitate such an activity. It is unclear without having conducted CWA interviews and think-alouds with these students as to why desktop computers were more preferable in this case over the available handheld computers. Also, the classroom teacher described her difficulties with the small-screen size of the handhelds, making it difficult for her to use and conceive of student activities using the handhelds without researcher collaboration. Surprisingly, the children did not seem to be deterred by the screen size while being observed using the handhelds, and did not report in follow-up interviews any negative experiences due to the small handheld screens. It must be further understood under what conditions the small screen size of the handhelds becomes a constraint for these young learners.

The current studies build upon this work, by addressing these constraints where applicable and identifying other potential constraints preceding the each design iteration within the design research investigations. Previous research has raised the awareness of the differential constraints identified by stakeholders in the human-technology interaction. Currently, through design research studies underway, I am investigating how handheld technologies may be supportive of elementary and middle school students identified as having difficulties with reading comprehension. CWA interviews have been conducted in two school sites (one elementary school and one middle school) with students receiving literacy support in order to develop design iterations that specifically address key constraints revealed in these interviews with stakeholders.

5. Results

Preliminary analyses from CWA interviews with these teachers and their students with reading comprehension difficulties revealed the importance of conducting individualized training sessions using the handhelds given the unique and varying learning challenges of the students and their differential experiences with technology. The conditions under which students found it ideal to use technology in their classroom were revealed through the CWA and formed the basis of how technological and pedagogical innovations were developed. For example, at the middle school site, students described how prior experiences with technology (i.e., desktop computers) supported the organization of their ideas for assignments and projects. Design and use of handheld applications and pedagogical supports were therefore developed to scaffold idea formation and development –a feature of technology use that students highlighted as beneficial to their learning.

CWA also provided support for using handheld technology in these settings, over other forms of portable technology, such as laptop computers. In the elementary school, which already has laptop computers available for their students, the teacher described in his CWA interview the challenges introduced in trying to configure the classroom furniture and students to support meaningful engagement and use of the technology for student learning within their classroom. This was also evident through researcher observation, where students worked typically in isolation when laptops were made available, and were unlikely to reconfigure themselves or the technology to collaborate with one another, even when it might benefit their learning. Innovations designed that used handhelds enabled greater flexibility and introduced ease in collaboration through increased face-to-face peer interaction mediated through infrared beaming.

My cognitive CWA interview with the elementary school principal pointed to the constraints that teachers face when attempting to use existing technology in the school due to the "shared" nature of these resources and their perception of their availability and difficulty of use. These results have had direct bearing on the development of training sessions that introduce both the students and staff to the new handheld technology in a positive manner in order to eliminate or minimize constraints stakeholders have identified.

6. Implications for the Design of Educational Technology Interventions

A constraint-based approach to examining the complexity of human-technology interactions becomes critical in the design of educational interventions that reflect real-world schools. CWA enables us to identify the priorities for schools, given the goals and constraints of each stakeholder.

CWA results should directly be considered in the design of pedagogical innovations and must influence how the implementations of new, mobile, technologies within classrooms happen. For example, CWA may illuminate the conditions that best support the adoption of a knowledge building approach to learning by examining the constraints faced by the system as a whole. We may therefore explore the unique features of the technology at hand that enable knowledge builders to strategically pursue their knowledge advancement goals (Scardamalia, 2002) through our considerate design decisions.

Furthermore, the results of a CWA may hold explanatory power for each iteration of design, as we may understand why certain innovations were more effective than others in our ability to control for identified constraints through our technological and pedagogical design decisions. We may strategically and systematically tackle 'easily controlled' constraints (e.g., provide teacher training on an unfamiliar software application or pedagogical strategy at the "Worker Competency" level) in order to maximize our potential for an effective human-technology interaction. Conversely, our inability to control for other constraints (e.g., timetabling decisions mandated by the Ministry of Education revealed by the school principal) may explain the limitations our innovations may have in a particular school setting or learning context.

Although educational researchers are rarely involved directly in the design of hardware, data from CWA may provide them with the necessary platform from which to suggest recommendations, and prompt developers to consider schools explicitly within their design decisions. Further, I argue that CWA should be seen as a vital component in the development and testing of educational software applications, as this process may point to political, organizational, team, psychological and physical human factors (Vicente, 2003) that may impede technology usage and implementation in schools. Therefore educational researchers may be valuable collaborators for software engineers, by offering reasons for breakdowns within the human-technology interaction that have great bearing on design decision-making.

7. Conclusions

These studies suggest that CWA is a promising complement to the design research methodology. Design of innovations should systematically address key constraints of stakeholders in order to optimize the success of new, mobile technologies in complex and challenging settings, such as the knowledge building classroom.

8. References

Bereiter, C. (2002a). *Education and Mind in the Knowledge Age*. Mahwah, NJ: Lawrence Erlbaum Associates.

Bereiter, C. (2002b). Design research for sustained innovation. *Cognitive Studies, Bulletin of the Japanese Cognitive Science Society, 9*(3), 321-327.

Brown, M. D. (2001). *Handhelds in the classroom*. Retrieved 20 February, 2004, from http://www.education-world.com/a-tech/tech083.shtml

Burns, C. M., & Vicente, K. J. (2000). A participant-observer study of ergonomics in engineering design: How constraints drive design process. *Applied Ergonomics, 31*, 73-82.

Chan, T., Roschelle, J., His, S., Kinshuk, Sharples, M., Brown, T., et al. (2006). One-to-one technology-enhanced learning: An opportunity for global research collaboration. *Research and Practice in Technology Enhanced Learning, 1*(1), 3-29.

Fidel, R., & Pejtersen, A. M. (2004). From information behaviour research to the design of information systems: The cognitive work analysis framework. *Information Research, 10*(1), paper 210 [Available at http://InformationR.net/ir/10-1/paper210.html]

Naikar, N., Hopcroft, R., & Moylan, A. (2005). Work domain analysis: Theoretical concepts and methodology. *DSTO Systems Sciences Laboratory*, DSTO-TR-1665.

Nirula, L., Woodruff, E., Scardamalia, M., & Macdonald, P. (2003). Handhelds in a grade two classroom: Innovations to support knowledge-building and epistemic agency. In K.T. Lee & Mitchell (Eds.), *Proceedings of the International Conference on Computers in Education 2003*, (Additional pp. 22-26). Hong Kong: ICCE 2003.

Pownell, D. & Bailey, G.D. (2000). Are you reading for handhelds? Using a rubric for handheld planning and implementation. *Learning and Leading with Technology, 30*(2), 50-55.

Rasmussen, J., Pejtersen, A. M., & Goodstein, L.P. (1994). *Cognitive Systems Engineering*. New York: Wiley-Interscience.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal Education in a Knowledge Society* (pp. 67-98). Chicago: Open Court.

Shin, N., Norris, C., & Soloway, E. (2007). Findings from early research on one-to-one handheld uses in K-12. In M. van't Hooft (Ed.), *Ubiquitous computing book.* Erlbaum.

Soloway, E. (2002, December 3). *Supporting science inquiry in K-12 using palm computers: a palm manifesto*. PdaEd.com. Retrieved 12 December 2002, from http://www.pdaed.com/features/palmmanifesto.xml

van't Hooft, M. A. H., & McClain, K. (2005). Beam me up! Using handhelds computers with elementary students. Learning and Leading with Technology, 33(1), 26-29.

Vicente, K. (2003). *The Human Factor*. Toronto: Vintage Canada.

Vicente, K. J. (1999). *Cognitive Work Analysis: Towards safe, productive, and healthy computer-based work*. Mahwah, NJ: Lawrence Erlbaum Associates.

Woodruff, E., & Nirula, L. (2005). Design research in the elementary school classroom. In C. Howard, J. Boettcher, L. Justice & K. Schenk (Eds.), *Encyclopedia of Online Learning and Technology*, 2 (pp. 510-517). Hershey: Idea Group.