Distributed Cognition and Interactions in the Context of Bioengineering Design

Vanessa Svihla, Anthony J. Petrosino, and Kenneth Diller, University of Texas
Email: vsvihla@hotmail.com, ajpetrosino@mail.utexas.edu,
kdiller@mail.utexas.edu

Abstract: Distributed cognition is ubiquitous in design practice, yet most studies of design occur in isolation, resulting in a sequestered view. We examine in-situ student teams learning to design in a culturally-diverse bioengineering course, exploring students' negotiation of roles and differing interactions in a distributed cognition system. Via triangulation of quantitative and qualitative data, we examine how students learn to design. Characteristics of authentic student design experiences have emerged and have implications for teaching design.

Introduction

Given increasing reliance on physically distributed collaboration, it is critical to understand design as collaborative activity and to examine different interactions such that we may prepare learners for the complex and global community they will enter. Design offers the opportunity to study problem solving that is situated and contextualized, ill-structured (requiring preference and judgment and involving multiple solution paths to multiple possible solutions), dynamic, iterative, and complex (multivariate, with interconnections between variables) (Jonassen, 2000). The problem and solution co-evolve (Cross, 2002). Good design is tied to good problem scoping (Atman, Chimka, Bursic, & Nachtmann, 1999), which involves defining the problem. Expert designers take a broad approach (Cross, 2002), relying on procedural strategies, whereas novice designers rely on declarative knowledge and a depth-first approach (Ho, 2001). Experienced designers pay better attention to the customer needs, logistics, and constraints in the design task (Bogusch, Turns, & Atman, 2000). As designers become solution focused, they populate the design process with dynamic, temporary sub-goals (Cross, 2002).

Design is a social, collaborative process (Brereton, Cannon, Mabogunje, & Leifer, 1996; Wood, 2003) in which distributed cognition - problem solving occurring across individuals and tools - is critical (Hutchins, 1995; Salomon, 1993). Each team member has different technical skills and values such that the resultant "design is an intersection—not a simple summation-of the participants' products" (Dym, Agogino, Eris, Frey, & Leifer, 2005). Learning in design may be cast as legitimate peripheral participation in a community of practice (Lave & Wenger, 1991), especially for college level design education. Understanding how and why groups differ, such as in how group members take up good ideas (Barron, 2003) is an important part of understanding how design may be learned. Design has primarily been studied in sequestered tasks and with isolated designers, leading to an impoverished understanding of design processes and of how design may be learned. By considering how real design teams learn, we may have a broader understanding of the diverse practices in design, and also understand what might hinder learning in this context. By focusing on how interactions differ within and across teams, we may locate patterns that afford innovative, distributed design learning.

Methods and Participants

The participants of this study are cohorts of senior bioengineering students enrolled in the capstone, year-long design class at a large public university (Cohort One: N= 56, 40 males; Cohort Two N=54, 27 males Cohort 3: N=63, 47 males). Design teams were composed of 3 to 5 students and organized such that non-native English speakers (15-30% of each cohort), were distributed across groups. Students complete a preliminary project, then for the remainder of the year complete designs sponsored by industry and hospitals. The preliminary project for Cohort 1 involved designing a digital stethoscope, whereas for Cohorts 2 and 3 the teams selected biomedical devices to redesign, such as nicotine patches and blood glucose meters.

Various data were collected to surround the research questions: Survey data address prior experiences, course experiences, and beliefs about design and collaboration; a subset of teams was followed closely, providing detailed views through observational, video and audio data, class artifacts, and interviews. Because data are naturally nested, analysis of quantitative data employed Hierarchical Linear Modeling (HLM). For Cohort Three, data for Social Network Analysis have also been collected to answer emergent questions about the role of differing interactions across groups. When considering how groups differ, it is critical to consider how the *design problems* differ and to consider the problem as defined *by the team*. To this end, bioengineering professors scored the problem definitions and final designs according to how efficiently the students employed relevant factual and conceptual knowledge, and to what extent the problem as defined and final solution were innovative. These dimensions have been productive in the study of trajectories towards expertise (Schwartz, Bransford, & Sears, 2005).

Discussion

Understanding why groups differ has proved challengingt as various common predictors have not been significant (Rivale, Martin, & Diller, 2006). The expert sorting indicates that both project difficulty and performance vary. Early efficiency does not correlate to final design innovation. This finding is compelling because it runs counter to how we generally teach: develop content and skills before having opportunities to apply them. Comparing Cohorts reveals significant differences in correlations among innovation and efficiency. Further exploration is needed to determine the source of this variance.

Coding and HLM analysis of the pre, mid and post tests revealed significant differences: For Cohort One, there is a troubling decrease in "representation of customer needs" at the mid-test, whereas for Cohort two there is an increase. Students who completed a preliminary project in which they had to determine how to redesign a device had significantly higher gains than students who completed a more kit-based design task (t = 3.256, p = .003). Students attend to customer needs when they feel authentically engaged in design. Incorporation of customer needs involves multiple-perspective taking and is a critical aspect of design. The Constructivist Learning Environment Survey yields an understanding of practices in the classroom. HLM results of the CLES indicate the design course allows students to question their learning more than prior coursework tends to ($t = 3.515$, $p = 0.002$), perhaps because they are responsible for their own learning, and students report greater personal relevance ($t = 3.181$, $p = 0.003$) resultant from engaging in authentic design experience.

We also consider, in this on-going research, how differing interactions provoke different design experiences and consider intersections with innovative design. As part of our on-going efforts, we examine how teams break ill-structured problems up into sub-problems, and how they seek resources and make use of the experts available to them. Analysis of observational data has revealed preliminary modes of distributed cognition: "over-divide and conquer" and "everyone does everything" neither of which leverage distribute cognition, and "divide-enough and conquer" and "everyone participates" which do.

Implications

This research has implications for how design is taught; by allowing students to have voice by *selecting* a device to redesign, the students recognize the importance of customer needs. However, we must still account for variance across teams. Understanding how teams interact differently can help us to provide explicit models for productive group interactions. Next steps include employing Social Network Analysis as a bridge between whole-class and case-study data, and continuing to analyze the observational data.

References

Atman, C. J., Chimka, J. R., Bursic, K. M., & Nachtmann, H. L. (1999). A comparison of freshman and senior engineering design processes. *Design Studies, 20*(2), 131-152.

Barron, B. (2003). When Smart Groups Fail. *Journal of the Learning Sciences, 12*(3), 307-359.

Bogusch, L. L., Turns, J., & Atman, C. J. (2000). Engineering design factors: how broadly do students define problems? *Frontiers in Education Conference, 2000. FIE 2000. 30th Annual, 2*.

Brereton, M. F., Cannon, D. M., Mabogunje, A., & Leifer, L. J. (1996). Collaboration in Design Teams: How Social Interaction Shapes the Product. In N. Cross, H. H. C. M. Christiaans & K. Dorst (Eds.), *Analysing Design Activity* (pp. 319-341). Chichester: Wiley.

Cross, N. (2002). *Creative cognition in design: processes of exceptional designers.* Paper presented at the Fourth conference on Creativity & cognition.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education, 94*(1), 103-120.

Ho, C. H. (2001). Some phenomena of problem decomposition strategy for design thinking: differences between novices and experts. *Design Studies, 22*(1), 27-45.

Hutchins, E. (1995). *Cognition in the Wild*: Cambridge, MA.: MIT Press.

Jonassen, D. H. (2000). Toward a Design Theory of Problem Solving. *Educational Technology Research and Development, 48*(4), 63-85.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*: Cambridge University Press.

Rivale, S. R., Martin, T., & Diller, K. R. (2006). *Gender Differences in Adaptive Expertise: Evaluation of a challenge based HPL biomedical engineering curriculum.* Paper presented at the 9th International Conference on Engineering Education, San Juan, PR.

Salomon, G. (1993). *Distributed Cognitions: psychological and educational considerations*: Cambridge University Press.

Schwartz, D. L., Bransford, J. D., & Sears, D. (2005). Efficiency and innovation in transfer. In J. Mestre (Ed.), *Transfer of learning from a modern multidisciplinary perspective* (pp. 1-51). Greenwich, CT: Information Age Publishing.

Wood, W. H. (2003). Integrating Social Issues into Design Theory. *International Journal of Engineering Education, 19*(1), 35-40.