Extending the 'Cognitive Dimensions' Framework with a 'Communicative Dimensions' Framework*

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1. Abstract

An end user visualization environment aims to empower end users to create graphical representations of phenomena within a scientific domain of interest. Research into end user visualization environments has traditionally focused on developing the human-computer interaction necessary to enable the quick and easy construction of domain-specific visualizations. That traditional focus has left open the question of how such environments might support human-human interaction.

Especially in situations in which end user visualization environments are enlisted to facilitate learning and to build design consensus, we hypothesize that a key benefit is their ability to mediate conversations about a scientific domain of interest. In what ways might end user visualization environments support human communication, and what design features make them well-suited to do so?

Drawing both on a theory of communication, and on empirical studies in which end user environments were enlisted to support human communication, we have recently proposed a provisional framework of six 'Communicative Dimensions' of end user visualization environments: programming salience, provisionality, story content, modifiability, controllability, and referencability. To illustrate the value of these dimensions as an analytic and design tool, we use them to map a sample of publicly-available end user visualization environments into the 'Communicative' design space. By characterizing those aspects of end user visualization environments that impact social interaction, our framework provides an important extension to Green and Petre's [2] 'Cognitive Dimensions'.

2. Background and Motivation

End user visualization environments couple an end user visualization language with a graphical user interface for constructing and viewing visualizations in that language. The traditional aim of such environments has been to empower end users quickly and easily to construct graphical representations (both static pictures and dynamic visualizations) of phenomena within a scientific domain of interest. For example, AgentSheets [3] empowers teachers and students to write their own graphical scientific simulations; Open Data Explorer [4] helps scientists to construct sophisticated three-dimensional scientific visualizations; ALVIS [5] enables computer science students to create "low fidelity" visualizations of computer algorithms under study; and DENIM [6] allows website designers to quickly create sketched visualizations of websites with which clients can interact.

In line with its goal to empower end users quickly and easily to create visual representations of domain phenomena, past research into the usability aspects of end user visualization environments has focused squarely on the problem of *human-computer interaction*. This focus is well reflected by Green and Petre's [2] *cognitive dimensions* framework, which characterizes the effectiveness of programming environments (of which end user visualization environments are a subset) largely in terms of their influence on at least four aspects of individual performance and experience: *program comprehension*, *learnability*, *error rates*, and *programming comfort*. For example, design decisions made along the *abstraction gradient* dimension impact the learnability and error-proneness of an end user environment, while design decisions made along the *progressive evaluation* dimension impact programming time and effort, along with the programmer's subjective experience of comfort.

While research in such fields as computer-supported collaborative work and learning has examined extensively

* This position statement is a collection of excerpts from my newly-published journal article "Using End User Environments to Mediate Conversations: A 'Communicative Dimensions' Framework" [1]. Because the work is relevant to that being done in the Cognitive Dimensions Community, and I would like to attend the VL-HCC '05 CD workshop in order to disseminate the work and exchange ideas with other researchers in the field.

the impact of differing communication media on *human-human* communication (see, e.g., [7]), research into end-user and visual programming environments has virtually ignored the role of end user environments in facilitating such communication. Yet, especially in the literature on the use of end user visualization environments for learning and software design, the ability of end user visualization environments to mediate conversations about a particular domain of interest would appear to be a key benefit. For example, through his development of an end user environment for programming graphical simulations of Newtonian physics, Roschelle [8] came to see the utility of such an environment not in terms of its ability to transfer physics knowledge to learners, but instead in terms of its ability to act as "a resource for managing the uncertainty of meaning in conversations, particularly with respect to the construction of shared knowledge" (p. 1). Likewise, in developing Chemsense, an end user environment for programming chemical simulations, Schank and Kozma [9] focus on the value of the environment to enable learners to become competent with the representations of the discipline, which fundamentally entails an ability to engage in disciplinary discourse.

End user technology for constructing representations of software would appear to have similar benefits. For example, acknowledging their central role in mediating conversations about software design, Damm et al. [10] constructed a collaborative, sketch-based environment for constructing UML diagrams on electronic whiteboards. Likewise, in two related lines of work, Landay and colleagues [6, 11] explored sketch-based systems with which user interface and web designers can construct low fidelity prototypes to present to clients for feedback and discussion.

As these lines of research illustrate, end user visualization environments can play an important role beyond their role in facilitating the construction of visual representations: namely, they can mediate meaningful human discussions about a domain of interest. This potential role, which existing analytical tools in human-computer interaction (e.g., the 'Cognitive Dimensions' framework) fail to address explicitly, raises three key research questions:

1. In what ways might end user visualization environments impact human communication?
2. What general characteristics of end user visualization environments influence their ability to facilitate human communication?
3. What specific design features might make end user visualization environments well-suited to facilitating human communication?

To address these questions, I have proposed a framework for analyzing the ability of end user visualization environments to support human communication. My framework identifies six 'Communicative Dimensions': *programming salience*, *provisionality*, *story content*, *modifiability*, *controllability*, and *referencability*. Both in the spirit of, and an extension to, Green and Petre's 'Cognitive Dimensions', these dimensions are intended to serve as a vocabulary with which designers can discuss and weigh the communicative impact of design choices.

3. Further Information

The preceding sections reproduce the abstract and introduction of an article on 'Communicative Dimensions' recently published in the *Journal of Visual Languages and Computing* [1]. For further information on the 'Communicative Dimensions' framework, read the article, which not only theoretically motivates and empirically grounds the framework, but also illustrates the utility of the framework by using it to analyze five publicly-available end-user visualization systems.

4. References

[1] C. Hundhausen, "Using end user visualization environments to mediate conversations: A 'Communicative Dimensions' framework," *Journal of Visual Languages and Computing 16* (3), 2005, pp. 153-185.

[2] T. R. G. Green and M. Petre, "Usability analysis of visual programming environments: A 'cognitive dimensions' framework," *Journal of Visual Langauges and Computing 7* (2), 1996, pp. 131-174.

[3] A. Repenning and T. Sumner, "Agentsheets: A medium for creating domain-oriented visual languages," *Computer 28*, 1995, pp. 17-25.

[4] D. Thompson, J. Braun, and R. Ford, *OpenDX: Paths to Visualization*. Visualization and Imagery Solutions, Inc., Missoula, 2000.

[5] C. D. Hundhausen and S. A. Douglas, "Low fidelity algorithm visualization," *Journal of Visual Languages and Computing 13* (5), 2002, pp. 449-470.

[6] J. Lin, M. Newman, J. Hong, and J. Landay, "DENIM: Finding a tighter fit between tools and practice for web site design," in *CHI 2000 Conference Proceedings*. ACM Press, New York, 2000, pp. 510-517.

[7] D. E. Damien, A. Eberlein, M. L. G. Shaw, and B. R. Baines, "Using Different Communication Media in Requirements Negotiation.," *IEEE Software 17* (3), 2000, pp. 28-36.

[8] J. Roschelle, "Designing for conversations," presented at AAAI Symposium on Knowledge-Based Environments for Learning and Teaching, Stanford, CA, 1990.

[9] P. Shank and R. Kozma, "Learning chemistry through the use of a representation-based knowledge building environment," *Journal of Computers in Mathematics and Science Teaching 21* (3), 2002, pp. 253-279.

[10] C. H. Damm, K. M. Hansen, and M. Thomsen, "Tool support for cooperative object-oriented design: Gesture based modeling on an electronic whiteboard," in *CHI 2000 Conference Proceedings*. ACM Press, New York, 2000, pp. 518-525.

[11] J. A. Landay and B. A. Myers, "Interactive sketching for the early stages of user interface design," in *Proceedings of the ACM CHI '95 Conference on Human Factors in Computing Systems*. ACM Press, New York, 1995, pp. 43-50.