Connected Modeling: Design and Analysis of the Modeling Commons

Reuven M. Lerner
CCL, Northwestern University
reuven@lerner.co.il

Sharona T. Levy
University of Haifa
stlevy@construct.haifa.ac.il

Uri Wilensky
CCL, Northwestern University
uri@northwestern.edu

Abstract

Modeling is not just a scientific activity, but an educational one, and is naturally paired with the theory and practice of constructionism. To date, however, constructionist modeling environments such as NetLogo have focused on individual work, rather than collaborative modeling. In this paper, we describe our research efforts at making modeling a collaborative activity, using a Web-based tool we have called the Modeling Commons. Using a combination of design research techniques, logfile analysis, and social-network analysis, we have gained insights into the effective design of a collaborative modeling system, one which fosters the creation and growth of communities. Our logfile analysis indicates that social-learning theory, including legitimate peripheral participation, can be identified in such an online community. Finally, using social-network analysis, we are able to better understand the need for multiple channels of communication, in order to foster the creation of a fully connected community of modelers. We conclude by describing our future plans for the Modeling Commons, both as a software platform and as a tool for future research.

Keywords: Modeling, constructionism, collaboration, Netlogo, CSCL.

Introduction

Constructionism, conceived and articulated by Seymour Papert, argues in favor of learning through the creation and sharing of meaningful artifacts (1980). NetLogo (Wilensky, 1999), a constructionist agent-based modeling environment, is widely used by students and researchers to create and explore models of scientific, mathematical, and social phenomena, with recognized educational benefits (Jonassen, 2006; Riesman & Wilensky, 2006; Sengupta & Wilensky, 2006; Blikstein & Wilensky, 2009).

As a constructionist tool, NetLogo should foster not only the creation, but also the sharing, of models. However, NetLogo lacks built-in support for sharing or collaborating as part of the modeling process. Modeling is increasingly recognized as a collaborative effort (de Aennle, 2009), and while there is a strong online community of NetLogo modelers, analysis shows that most discussion in that community is about general modeling practices, rather than work on actual models.

Constructionism is not the only research tradition to suggest the importance of collaboration when modeling: Vygotsky (1978) argues that people achieve more when working with others than alone, describing the difference as the learner's "zone of proximal development." Schön offers multiple examples of "reflection-in-action," describing how a veteran guides and trains a newcomer with probing questions (1983).

Social learning theory takes this one step further, arguing that apprenticeship is a widespread and authentic method of learning, because the learner takes on increasingly significant roles

over time (Lave & Wenger, 1991). The idea that learning is social, rather than purely informational, is increasingly widespread among researchers, leading to such important learning paradigms as "cognitive apprenticeship" (Brown, Collins, & Duguid, 1989) and "communities of practice" (Wenger, 1998). The use of computers in general and the Internet in particular, as a means of facilitating collaborative work has been explored extensively in recent years by the CSCL ("computer-supported collaborative learning") research community (Stahl, 2006; Koschmann, 1994).

Our research aims to better understand the nature of collaborative modeling, and the ways in which it can affect participants, models, and the networks that connect them.

To further our understanding, we have created the "Modeling Commons," a Web-based system for collaborative modeling. The Modeling Commons allows NetLogo users to store models, to associate one or more documents with a model, to label a model with "social tags" (Smith, 2008), to discuss a model with other users, or to share a model with some or all of the others on the system. It also allows for the collaborative development of a model, much as Wikipedia makes it possible to collaboratively edit a document. Users of the Modeling Commons are connected to one another through the artifacts that they create, as well as the groups to which they belong and the social tags that they apply. Models are also connected to one another, through the people who create and edit them, the social tags that group them, projects containing multiple models, and "variations" of similar models that represent variations on a common theme.

We see the Modeling Commons as an infrastructure that allows us to better understand the nature of collaborative modeling, as well as changes in the people, models, and networks that will develop.

Methodology

We have employed three methods – design research, logfile analysis, and social-network analysis – in our work to date. Each has provided us with different insights into our research questions.

Design research (Brown, 1992; Collins, Joseph, & Bielaczyc, 2004) is a means of creating and improving a learning environment, which is often too complex to analyze or modify based on a single variable at any given time. Based on approaches from professional engineers and manufacturers, design researchers interview and watch their subjects using an environment. Through the subject's reactions, as well as their ability (or inability) to use the environment in defined circumstances, the designer makes appropriate modifications. By working through many such iterations, the designer is able to fine-tune the environment, improving its effectiveness. A side benefit is that through the interview process, a designer is better able to understand users' needs and motivations, which can influence and inform the design.

Our design research was influenced by the "clinical interview" (Ginsburg, 1997), and also by industry techniques for checking Web usability (Nielsen, 2000). Subjects were asked to perform specific tasks, describing their thoughts as they performed them. When the user had or provided a particularly useful insight, we would probe to identify the core of the problem. During the second round of the research, subjects were asked (after performing a series of tasks) to indicate, on a 5-point Likert scale, the importance they would attach to various features.

A second form of analysis takes advantage of the fact that Web-based applications log every action on the server, and can later be analyzed. Such analysis has been used in previous studies, allowing researchers to identify and analyze usage patterns (Levy & Wilensky, 2006).

Our research used logfile analysis to identify usage consistent with "legitimate peripheral participation" (Lave & Wenger, 1991). We are now using logfiles to find correlations between types modelers. In particular, studies of online communities have long distinguished between active users and "lurkers" (Nonnecke & Preece, 2000; MacDonald et al., 2003). Using logs, we can compare the behavior of lurkers with their more active counterparts, in modeling as well as discussions.

We are also using social-network analysis (Wasserman & Faust, 1994; Monge & Contractor, 2001), which characterizes relationships based on actual interactions, rather than formal roles and definitions. In this way, we can identify patterns that emerge from those users who have viewed, modified, discussed, tagged, and/or recommended a model — and we can look at the patterns that have emerged over time, identifying changes within the community associated with a particular model, or in the overall user base.

Among the measures that we are using to characterize these social networks networks are two devised by Krackhardt (1994), "connectedness" (i.e., whether any member of the network may reach any other member via defined connections) and "hierarchy" (i.e., whether there are certain members who have demonstrated a more central, dominant position). These measurements will help us to understand how connected a set of users is, and whether some users are more dominant than others in the community.

To date, we have engaged in three rounds of research. While we are still at the earliest stages, we believe that the results we have found to date indicate that collaborative modeling has much to teach us, as education researchers and as designers.

The first round, during the winter and spring of 2008, involved 12 subjects, all of whom used an early version of the Modeling Commons software. The emphasis during this round was on the design of the Modeling Commons software, both for overall usability and with an eye toward its collaborative functions. We interviewed three of the subjects, and received written reports from four others with their feedback and reactions.

The second round of research, during the fall of 2008, involved 24 subjects, all of whom were asked to use the Modeling Commons software in a variety of tasks. Ten of these subjects were interviewed in person, and were not only asked to perform specific tasks in front of an interviewer, but were also asked a series of questions about Modeling Commons features, answering on a 5-point Likert scale regarding their interest.

The final round, during the spring of 2009, involved 36 students in three classes, at two different universities in the United States. Participants were asked to perform a set of specific tasks, such as tagging and posting to discussion forums, but they were also expected to use the Modeling Commons to submit NetLogo-related coursework. The Commons was thus used for all of their storage and communication needs, giving us the first somewhat-natural usage of the software. During this period, a total of 90 models were uploaded to the system. We interviewed two of the instructors from these courses, asking them about the ways in which the Modeling Commons was (and was not) used.

Results and Discussion

Our design-research interviews consistently pointed to weaknesses in site navigation. For example, several users indicated that because discussions are model-centric, questions might only be seen by others viewing that model. Drawing upon previous work (Linn & Hsi, 2000), we allowed users to mark a forum posting as a question, making it visible on every user's home page.

Interviews also demonstrated the importance of privacy controls. Eighty percent of subjects indicated that "privacy", or the ability to restrict access to a model, rated either a 4 or 5 (out of 5) in importance. We modified the software to allow users to create groups, and to restrict access to models based on their group membership. This feature was used extensively by students and their instructors within the university courses, and we expect that it will remain popular in educational environments.

Logfile analysis demonstrates a correlation between the predictions of social learning theory and usage of the Modeling Commons. Based on this theory, we would expect users to view at least one model before uploading one themselves. And indeed, among the 36 participants in our third round of research, we found that the first act for 23 (63 percent) of them was to view models, with 15 (42 percent) going on to upload models afterwards. By contrast, only nine students (25 percent) uploaded models as their first act in the Modeling Commons.

Finally, social-network analysis of one of the classes that used the Modeling Commons shows that if we look only at model ownership and writing, there is almost no connectedness among the students (Krackhardt connectedness score of 0.097), as seen in illustration 1. We found that only one person worked on more than one model; the rest of the participants in the class worked exclusively on their own model.

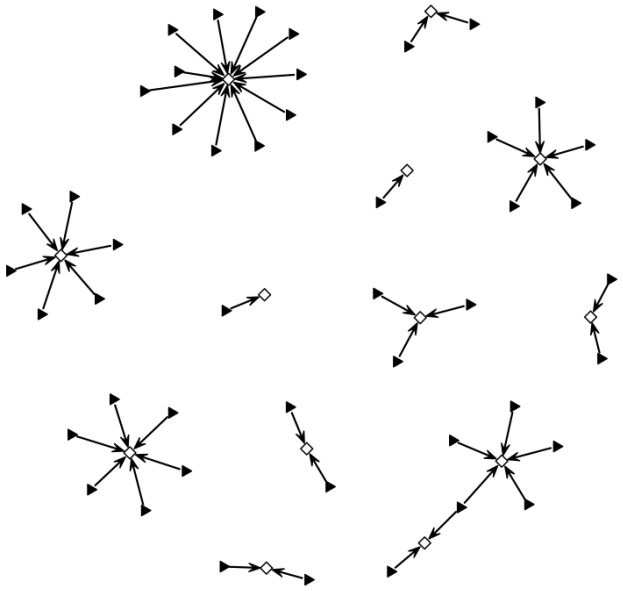

Illustration 1. Social network from one class, in which participants are linked via models they worked on. White squares represent people, while black triangles represent models.

We saw far greater connectedness (0.656) among the students when analyzing the network of those connected via social tags that they had applied (Illustration 2), and an even higher degree of connectedness when we looked at how members of the community were connected via discussion forums (0.862) (Illustration 3) – but only a subset of the community was involved with forums and social tags, which means that these measurements fail to reflect the community as a whole. And indeed, we saw a smaller degree of hierarchy in each of these (0.426 for social tagging, and 0.085 for forums) than with the original network based on model creators (0.271).

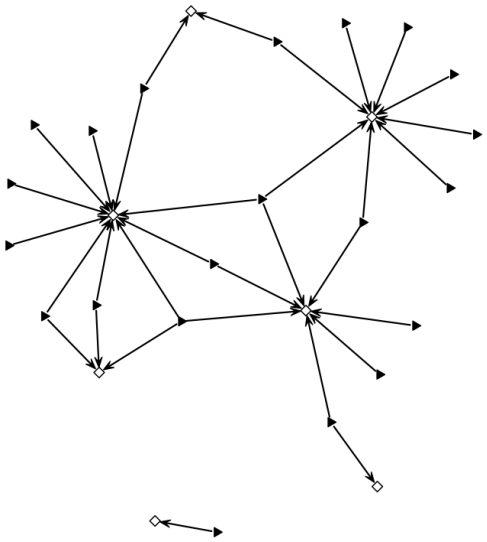

Illustration 2. Social network from one class, in which participants are linked via models to which they applied one or more social tags. White squares represent people, while black triangles represent models.

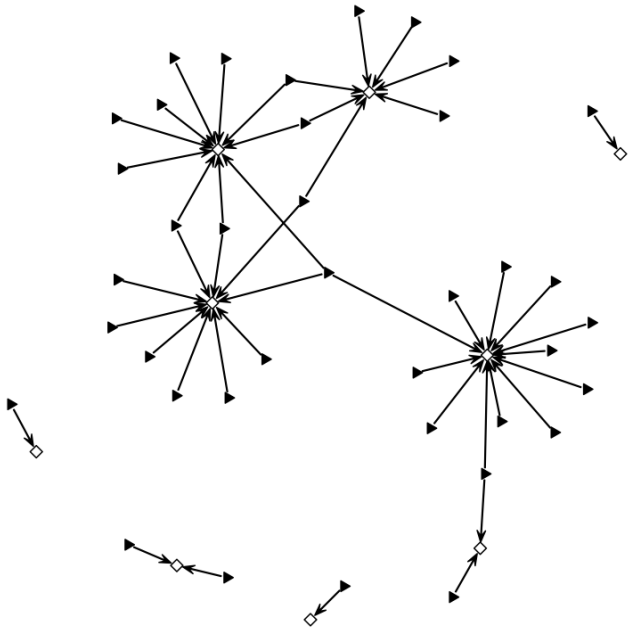

Illustration 3. Social network from one class, in which participants are linked via models they discussed. White squares represent people, while black triangles represent models.

When we combine all of these means of communication, creating a network that is based on all possible interactions (i.e., model creation, social tagging, and forum discussion), we get a completely connected network (Illustration 4), in which a large number of participants are connected to more than one model, and as such to numerous other community members. This additive network has a connectedness of 0.731, meaning that it is largely connected (the exception being students who did not seem to participate in any group activities), but also flatter, with a hierarchy score of only 0.030. This result would seem to imply that when we

consider an online community with multiple channels of communication, the true degree of connectedness does not lie in any one type of interaction, but rather in the sum total of interactions among the participants. In a community of modelers, where there are multiple means of interaction, it remains to be seen whether and how various paths should be weighted.

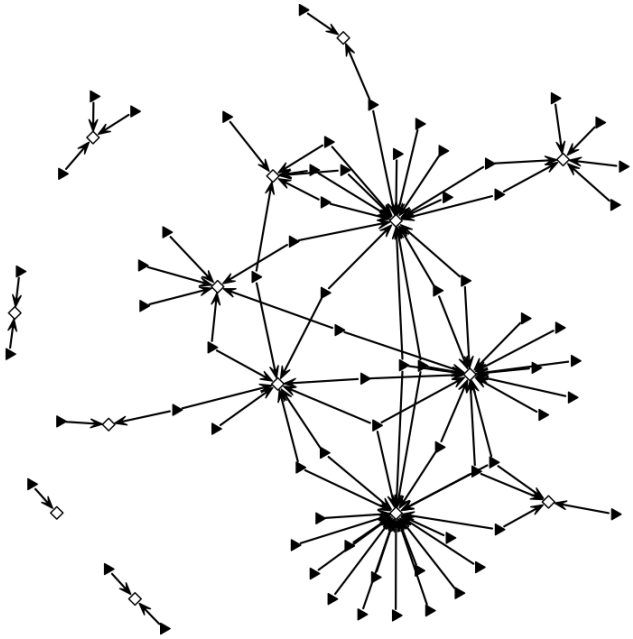

Illustration 4. Social network from one class, in which participants are linked via models on which they worked, commented, or tagged. White squares represent people, while black triangles represent models.

Conclusions

The Modeling Commons, while in its infancy, is already providing us with insights into the ways that modelers interact, and into the ways that we can design a platform that encourages them to work with one another. We are continuing to improve the software and our analysis methods, such that when we open the Modeling Commons to the greater NetLogo community, we will be prepared to understand the interactions and participation of the users, as well as the explicit and implicit networks that they form.

References

Blikstein, P. & Wilensky, U. (in press). An atom is known by the company it keeps: A constructionist learning environment for materials science using multi-agent modeling. *International Journal of Computers for Mathematical Learning*.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences*, *2*(2), 141-178.

Brown, J. S., Collins, A. M., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(1), 32-42.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *Journal of the Learning Sciences*, *13*(1), 15-42.

de Aennle, C. (2009). In simulation work, the demand is real. *The New York Times*.

Ginsburg, H. P. (1997). *Entering the child's mind: The clinical interview in psychological research and practice*. New York: Cambridge University Press.

Jonassen, D. (2006). *Modeling with technology: Mindtools for conceptual change* (3rd ed.). Upper Saddle River, NJ: Pearson Education, Inc.

Koschmann, T. D. (1994). Toward a theory of computer support for collaborative learning. *Journal of the Learning Sciences, 3*(3), 219-225.

Krackhardt, D. (1994). Graph theoretical dimensions of informal organizations. In K. Carley & M. Prietula (Eds.), *Computational Organizational Theory* (pp. 89-111). Hillsdale, NJ: Lawrence Erlbaum Associates.

Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Levy, S. T. & Wilensky, U. (2006). Gas laws and beyond: Strategies in exploring models of the dynamics of change in the gaseous state. Paper presented at the National Association for Research in Science Teaching, San Francisco.

Linn, M. C. & Hsi, S. (2000). *Computers, teachers, peers: Science learning partners*. Mahwah, NJ: Lawrence Erlbaum Associates.

MacDonald, J., W., A., F., D., Fox, H., MacGillivray, A., Reeves-Lipscomb, D. et al. (2003). Let's get more positive about the term 'lurker'. Paper presented at the CPsquare Foundations of Communities of Practice Workshop.

Monge, P. R. & Contractor, N. (2001). Emergence of communication networks. In F. M. Jablin & L. L. Putnam (Eds.), *The New Handbook of Organizational Communication* (pp. 440-502). Thousand Oaks: Sage Publications.

Nielsen, J. (2000). *Designing web usability: The practice of simplicity*. Indianopolis: New Riders.

Nonnecke, B. & Preece, J. (2000). Lurker demographics: Counting the silent. *Paper presented at the CHI, Hague, The Netherlands.*

Papert, S. (1980). *Mindstorms*. New York: Basic Books.

Riesman, K. & Wilensky, U. (2006). *Thinking like a wolf, a sheep, or a firefly: Learning biology through constructing and testing computational theories – an embodied modeling approach. Cognition and Instruction.*

Schön, D. A. (1983). *The reflective practitioner*. New York: Basic Books.

Sengupta, P. & Wilensky, U. (2006). NIELS: An agent-based modeling environment for learning electromagnetism. Paper presented at the AERA 2006, San Francisco, CA.

Smith, G. (2008). *Tagging: People powered metadata for the social web*. Berkeley, CA: New Riders.

Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge.* Cambridge, MA: MIT Press.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.

Wasserman, S., & Faust, K. (1994). *Social Network Analysis: Methods and Applications*. New York: Cambridge University Press.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press.

Wilensky, U. (1999). *NetLogo* [computer software]. Center for Connected Learning and Computer-Based Modeling, Northwestern University.