Computational Literacy and Mathematics Learning in a Virtual World: Identity, Embodiment, and Empowered Media Engagement

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Abstract: We are engaged in the on-going development of a computer-supported collaborative learning environment within a virtual world and use it as a setting for studies exploring relationships between student mathematical cognition, computational literacy, and identity. Our design research is informed by the work of Gee (video games), diSessa (computational literacy), Cole (mediated collaboration), Abrahamson (embodied design for mathematics learning), and Lee (cultural modeling). Within the constructed virtual ecology, we are conducting an ethnographic study of a technologically enabled learning environment with real students bearing virtual identities. The participants are physically remote but embody characters with personae of their own making in playful activities that foster intrinsic motivation and bear mathematical and computational integrity that transcends the medium. Collecting both real and virtual data of a group of at-risk urban high-school students working in Teen Second Life, we examine for changes in participants' cognitive–affective dispositions toward mathematical practice and identity.

Our objective is to build an online, computer-supported constructionist learning environment wherein students engage collaboratively in mathematics problem solving activities and develop programming skills. Learning programming skills, a key aspect of developing computational literacy, empowers students to become computational producers and not just consumers (diSessa, 2000; Gee, 2003). This paper reports on our first steps toward creating the online environment: We describe the rationale of our project and its initial implementation. In this study, we focus on the concept of 'recursion' that is key to computer science. Participants ground this concept through computationally constructing the 3D *Fractal Village*, which they inhabit. Fractals are inherently rich visual-spatial representations that, moreover, offer a wide range of cultural entry points (Eglash, 1999). Thus, participants are to appropriate STEM content by constructing immersive aesthetical public-domain artifacts (Papert, 1991).

After researching various possibilities, we chose a digital environment called Teen Second Life, a proprietary virtual 3D world owned by Linden Laboratories (LindenLabs, 2007), as a platform for implementing our project. It is a sister virtual world to the adult world of Second Life. Teen Second Life, a cutting edge multi-user domain (MUD), provides:

(1) a rapidly growing environment with currently millions of unique users (Reuters, accessed 03-19-2007).
(2) a safe environment for minors in a virtual world (adult facilitators must undergo security checks and have no access to the teens' mainland, but only to delimited islands).
(3) infrastructural scripting support that utilizes the Linden Scripting Language. The Linden Scripting Language is designed to be inviting for beginner programmers. For example, many open source library facilities are available, and the virtual-world graphical user interface allows an individual to instantiate objects and directly connect scripts to them.

Theoretical Framework

Socio-cultural accounts of learning (e.g., Cole, 2006; Lave & Wenger, 1991) highlight the roles of artifacts in the mediation of practice-based knowledge. We view the development of fluent, generative participation in mathematics practice as necessitating an agency that goes beyond consuming ready-made tools (Veeragoudar Harrell, 2007). Thus, whereas we intend for users to initially participate peripherally by using ready-made computational objects, as the users gain comfort with the environment they will learn to program custom-made objects.

Intrinsic to the experience of avatar-based participation in virtual environments is the projection of self. Gee (2003) describes this experience as that of coming

> to project one's values and desires onto the virtual character….seeing the virtual character as one's own project in the making, a creature whom I imbue with a certain trajectory through time defined by my aspirations for what I want that character to be and become (Gee, 2003, p. 55).

Thus, relatively unshackled by real-world personal and social constraints, the avatar-based participant can experiment with new practices and dispositions. Specifically, we hope to foster opportunities for participants who harbor negative dispositions toward mathematics in the real world to experiment with an alternative view using constructed identities in a playful, immersive virtual world (see also Powell, 2004).

Design

Visitors to Fractal Village meet a facilitator–avatar who welcomes them with a variety of "fractal seeds" (see Figure 1, below, top-left image)—computational objects for personalizing and nurturing fractals (e.g. trees, art). Completed fractals can be set to change color, size, texture, etc. every time they are touched or at set time intervals. Moreover, a sample object reveals for inspection its underlying implementation (including the recursive procedures).

Figure 1. A facilitator welcomes visitors with fractal seeds (top left). Users customize seed parameters such as size, orientation, texture, color, and movement in space (top right). Fractal seeds are grown into large structures, such as a cylinder tree (bottom left and center). A strong woman avatar flexes her muscles after building her fractal tree (middle right). Having contributed to the flora of the virtual environment, she then turns to improve the aesthetics of the village by building a giant fractal-foot sculpture (bottom right).

When a critical mass of participants is present, activities begin with participants discussing the future of their village and then assigning individual roles and objectives so as to orchestrate prospective construction. During the activities, participants interact, e.g., by sharing code, opining on the aesthetics, and negotiating space. At the end of the process, participants present their constructions and critique their peers' work. Essentially, participants evaluate whether or not the objects created by their peers are in fact fractals. This involves a joint discussion of the components of fractals (recursion and scaling in particular). Thus, with the support of the facilitator, mathematical properties embedded in the fractal objects become articulated through normative vocabulary and constructs.

We foresee a major design challenge is participant heterogeneity in skill, accumulated experience in the village, familiarity with emergent practices, and hours of operation. Moreover, participation should be engaging and rewarding for a visitor who operates in the environment for either 5 minutes or 5 hours. We are hoping to establish international round-the-clock rotating core leadership, such that experienced users are always available to welcome beginners, mentor them, and offer feedback on their initial construction.

Research Question

The Fractal Village project is situated in a larger on-going research program that examines relations between mathematical artifacts and student agency. In a previous study (Veeragoudar Harrell, 2007) we examined cognitive, affective, social, and technological factors contributing to students' mathematical agency. In particular, we suggested that by decoupling mathematical representations from the media in which they are embedded, we can pursue empirically a more nuanced understanding of students' dispositions toward mathematical practice and thus possibly inform the design of computer-based learning environments that support mathematical agency. Findings suggested that students operate differently with representations depending on the media in which they are embedded and that some media are more conducive to mathematical agency. The current study further pushes our line of research by focusing on a more complex medium in which participants' affective as well as cognitive experience may differ radically from traditional school settings. How might students' experiences in a virtual mathematics laboratory affect their dispositions toward mathematical practice? In particular, how might working in Fractal Village impact students' mathematical agency?

Data Collection and Analysis

We have negotiated access to a group of high-school mathematics students and have procured virtual real estate (an "island") where we are creating the technological infrastructure of Fractal Village. We will collect data of student activity, both off- and on-line, including student interviews, video data of real-student participation, streaming screen captures of virtual participation, and classroom-, student-, and teacher interviews. In addition, we will save students' virtual constructions. Data analysis will follow social-science qualitative-analysis methodologies—the project is innovative, and we expect that appropriate analytic approaches will emerge (Glaser & Strauss, 1967) as we conduct the study and begin to understand better how issues of agency play out in virtual collaborative practice.

Demonstration

A demonstration of Fractal Village is planned for CSCL 2007. Attendees will be able to connect as characters within the space, manipulate seed fractals and construct their own recursive artifacts. Also, we will show live activity online and display participant artifacts, sample feedback, and analyses of the learning trajectories.

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