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Design of an Environment for Learning about Topology and Learning about Learning

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Abstract

Studying peopleś thinking, particularly when both c̈ognitiveänd äffectiveäspects are of interest, requires a setting conducive to in-depth exploration of the participantsd́ialogue and actions. This need has implications for the duration of the study and for the nature of the environment in which the inquiry is conducted. The researcher must be able to spend a good deal of time with the participants, encourage or design problem scenarios that will tend to surface certain kinds of thinking, and develop a relationship with the participants that allows for the exchange of relevant information. This paper describes how these requirements were addressed in an environment in which young people learned about knots and the topological relationships they embody. The experimental design that I launched, and which the participants appropriated and modified, consisted both of knots and of a social substrate that encouraged the lively exchange of ideas about them.

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Imagine that you are in an inner-city elementary school – a gray building with graffiti on the walls, long hallways populated by lines of children, distorted sounds coming from the public-address system, people chattering, computers humming. Amid the noise is the clutter of busy classrooms and senses of urgency alternating with times of thoughtful quiet. One of the doors is decorated with a sign that boldly announces the room as "The KNOT LAB." You enter, and find children playing with string, writing letters, watching videos, climbing to tack knots on display boards, arguing over the use of the video camera, working together on stories about knots, and otherwise immersed in activities related to their study of knots. They are surrounded by their own constructions: three of the four walls boast large, colorful displays showing knots in various stages of formation, dangling from tree branches, tacked to accompanying pieces of writing, sewn on cardboard, and drawn on various pieces of paper. Books and other printed materials about knots are strewn about, and pieces of string are everywhere. You have entered a "thinking environment" dedicated to learning about knots and to reflecting on that learning.

What you do not see are aspects of the environment that are equally important, but reside elsewhere. Miles away, an older child waits for the end of his school day so he can meet with me in a video editing room where we will answer letters, in written and video form, which the younger knot-tyers have entrusted me to give to him. I am the courier; he is the "knot expert." A Boy Scout and now, to some, a TV star, he takes his responsibility seriously and tries to answer the detailed questions that the other children pose. Eventually they will all meet, when he comes to the "Knot Fair" that culminates the project.

This scenario evolved over five months' time and enabled study of developments in twenty fifth-graders' understandings of principles of topology. Knots are a class of objects well suited to this focus. They have inspired a branch of formal mathematics, "knot theory," in which topologists seek algebraic means of identifying the vast number of combinations of intertwinements similar to what we call "knots." But these are also among the most common of everyday objects: pervasive through time and cultures, knots have become part of our arts, mythologies, and symbol systems, in addition to our mathematics, physics, and practical work.

Piaget and Inhelder (1967) recognized such advantages in their studies of small children beginning to understand the relationships of proximity that constitute topology. Of interest were the homeomorphisms that can be discovered as the forms are stretched or twisted: do the deformations retain the proximities, separations, or orderings? When and how do children recognize these homeomorphisms?

In pilot studies preceding the research described here, participants focused on such deformations, but also learned to tie certain knots and developed graphic and verbal representations of the tying processes. Although these notations illuminate varying conceptions of the knots, it became clear that the depth of familiarity I was hoping to study would require a lengthy period of immersion, as well as an environment enabling a wide range of choices of knots, approaches to learning them, and media for expressing ideas about them. The longer duration also allowed time for relationships to grow among participants and with the researcher.

The Piagetian research tradition is known for its emphasis on the selection and design of settings and scenarios in which a certain line of exploration and questioning will yield information about children's understandings of a specific topic. More recently, "post-Piagetian" writers have acknowledged the importance of social and cultural factors involved in learning, by extending the discussion of design to entire environments that consist of people, projects, and places in which the activity happens (Ackermann 1987, 1989, 1990; Papert 1980, 1984, 1987, 1990 "Unified"). Such environments grow through extended periods of time, making it possible to examine cultural influences on the construction of ideas as well as the subjects' personal involvement with the ideas.

These environments have come to be called "learning environments" or, acknowledging the researcher's participation and the double purpose of the work, "environments for learning and research" (Ackermann 1987). In a further attempt to emphasize the participants' examination of their own learning, I have dubbed the Knot Lab a "thinking environment." Characteristic of my approach were a certain wariness about the potential influence of my interventions, willingness to change hypotheses or courses of action as the project developed (Berg and Smith), and dedication to the task of developing a "thick description" (Geertz 1973) of the children's work and thinking (Strohecker 1991). The setting had to be flexible enough for the project to evolve in response to ideas and events that occurred during its course. I presented an initial context for learning about knots, which we gradually modified as the children became immersed in the project.

To begin, I described a Boy Scout who wanted to be their "pen pal" through exchanges of videotapes. This Boy Scout would demonstrate how to tie various knots and respond to questions from the other participants as the project progressed. He was an older child who was himself in the process of learning to tie certain knots. I assumed the roles of facilitator and "courier," the person common to each end of the communication, who videotaped the sessions and arranged for the children and the Boy Scout to see each others' video mail.

Videotaping the exchanges between the children provided a means of recording visual and aural data, and also stimulated the children's excitement about the project. They enjoyed "seeing themselves on TV." The inevitable self-consciousness that resulted among the participants supported a theme of becoming aware of one's own thinking processes so that they can be made available to others – in this sense, the children were also researchers, and several came to think of themselves in this way.

This "video correspondence" served a kick-off purpose but did not define the scope of the project, which quickly took on a life of its own. Most dramatic in its evolution were gradual shifts from an emphasis on video as an instruction and communication medium, to the children's initiation of their own activities and greater use of paper correspondence. The children worked individually or in teams, initially within four separate working groups. As the end of the project approached, distinct boundaries between these groups relaxed and increasingly frequent but casual merging of the groups occurred. With this change came increases in the incidence of borrowing of ideas and of collaboration between members of initially different working groups. The children were building not only understandings of certain knots, but a culture dedicated to learning about knots and thinking.

Three important elements of the research occurred through the working sessions: they formed a period of culture-building and of immersion in thinking about the knots, so that discussions in the form of the "final interviews" fit within a context that all the children shared; the working sessions, in their own right, generated data on thinking about knots; and in the course of these sessions, many of the children built up a relationship with me that came to involve comfort and trust. Gradually through the course of the project, and in the final interviews, many of the participants were willing to show and explain to me what they thought. We had taken an approach that assumes that people will have different ways of thinking about aspects of knots, and which values these differences. Although many of the children seemed hesitant at first, they came to accept that this approach was genuine – that they weren't going to be told they were wrong or stupid if they risked articulating what they thought.

The Knot Lab, as a center of this approach, became a place where the participants began having dialogues and debates about different ways to think about knots (and eventually, other issues in life, too). Many children engaged in "dialogues" with themselves – that is, they developed a form of critical thinking in which they would launch an interpretation of a knot and then retract or modify it as they continued the exploration. It was not unusual for a child to arrive at an understanding very different from the one she had started with, and to describe the initial interpretation as being "wrong." This form of self-critique was refreshing for its lack of the punitive overtones that can stem from incorporation of voices of authority who emphasize mistakes as being problematic.

The environment became particularly supportive of conducting a study through participant observation. There was so much going on that my presence could not help but blend in with the activity. Of course, as an older person whose involvement with the project extended beyond the Knot Lab, my role was different from that of most of the participants. Still, they understood and shared my interest in looking at *learning* as well as at knots, and we exchanged ideas about knots, school, our personal lives, practical considerations in the use of various media for communicating about knots, and so on.

For each participant, the number of working sessions ranged from ten to twenty during the course of the project, and these sessions ranged from one to three hours in duration. At the end of the study, I had an individual meeting with each participant. We conversed while the child tied various knots, compared two similar knots, and arranged a set of knots into groups according to perceived similarities. These comparative techniques were useful in eliciting understandings of relationships among parts of the configurations. Importantly, the immersion in Knot Lab projects that preceded the interviews had the effect of preparing the children for these detailed discussions.

In comparing the Square and Thief knots, several children acted on the suggestion that they imagine themselves to be a small ant crawling along the surface of the knot. This is a technique that Piaget and Inhelder had used in their studies of younger children working with simpler knots. It proved helpful in assisting these older children to imagine a change of scale (which was both spatial and temporal) in which portions of the knot could be considered separately, making more manageable the problem of finding one's way through the complicated configurations. Without this change of context, many of the children would have found difficulty in describing some of the differences.

I collected data through note-taking, audiotaping, videotaping, and tangible projects that the children produced. Sources of information included conversations with the children (and with their teachers); the children's video and paper correspondence with the Boy Scout; their written descriptions of knots, illustrated stories, instructions, etc.; and the bulletin-board displays that they constructed.

Video was a key element of the Knot Lab. The idea of the "video pen pal" was one that the children accepted and played with immediately. The "video correspondence" launched the project and provided a way for the kids to get involved quickly. It also encouraged communication about knots and a degree of self-consciousness not just about one's own appearance, but about how to describe knots and issues related to them. This aspect of self-reflection should not be underestimated. The video correspondence also established the presence of the camera as an everyday element of the research situation, so that its use as data-collecting device became relatively unobtrusive.

Several important questions emerged as I looked at the data: How did the children describe knots and tying maneuvers? What difficulties did they encounter? What strategies did they use for getting out of difficult situations? What knots did they perceive as being similar or related, and why?[1]

Thinking about knots tends to elicit a wide range of diversity; the methods and materials used in this study enabled understanding of particular ways in which general patterns of thought may become mobilized within the mind of an individual.

References

Ackermann, E. 1987. "Helping Children Become Epistemologists." Epistemology and Learning Group, MIT.

Ackermann, E. 1989. "Circular Reactions and Sensori-Motor Intelligence: A Discussion on Piaget's Theory of Early Cognitive Growth." Epistemology and Learning Group, MIT.

Ackermann, E. 1990. "From Decontextualized to Situated Knowledge: Revisiting Piaget's Water-Level Experiment." *Constructionist Learning*. Epistemology and Learning Group, MIT.

Berg, D. N., and K. K. Smith. 1985. *Exploring Clinical Methods for Social Research*. Beverly Hills: Sage Publ.

Geertz, Clifford. 1973. *The Interpretation of Cultures*. New York: Basic Books.

Papert, S. 1980. *Mindstorms: Children, Computers, and Powerful Ideas*. New York: Basic Books.

Papert, S. 1984. "New Theories for New Learnings." *School Psychology Review*.

Papert, S. 1987. "About Project Headlight." Cambridge, MA: Epistemology and Learning Group, M.I.T.

[1] Discussions of the major findings are in preparation for publication elsewhere, but the most complete report is in (Strohecker 1991).

Papert, S. 1990. "A Unified Computer Environment for Schools: A Cultural/Constructionist Approach." Proposal to National Science Foundation. Cambridge, MA: Epistemology and Learning Group, M.I.T.

Piaget, J., and B. Inhelder. [1948, 1956] 1967. *The Child's Conception of Space.* Trans. F. J. Langdon and J. L. Lunzer. New York: W. W. Norton.

Strohecker, C. 1991. *Why Knot?* Ph.D. diss., Massachusetts Institute of Technology.

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