THE JOURNAL OF THE LEARNING SCIENCES, *10*(3), 281–322

Constructivism in Practice: A Comparison and Contrast of Apprenticeship and Constructionist Learning Environments

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This article compares and contrasts 2 summer camps. Future Camp 97 is based on assumptions consistent with constructionism and Scientists Apprentice Camp 97 consistent with legitimate peripheral participation. These 2 learning environments create an opportunity to do an empirical, as opposed to a strictly theoretical, comparison of what has been frequently lumped under the term *constructivism.* The goal of this article is twofold: First, to move the discourse away from comparing constructivist learning environments solely to traditional learning environments. The 2nd goal is to move away from talking of a single constructivist learning environment, and instead to explore the nuances of learning environments based on different theoretical assumptions. Toward these ends, we analyze 2 summer camps in terms of theoretical assumptions, community and groups, participant roles, practices, and other evidence of learning. We conclude with a discussion of similarities and distinctions between these 2 learning environments, highlighting issues of ownership, authenticity, power, and task structure.

Using constructivist and situated notions of what it means to know and learn, many educators are suggesting the creation of learning environments that support the nat-

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ural complexity of content, avoid oversimplification, engage students in knowledge construction, and present instruction in real-world contexts (Land & Hannafin, 1996; Roth, 1996). Rather than presenting instructional treatments, the goal is to establish rich learning environments where learners engage in domain-related practices to carry out socially negotiated tasks (Barab, Hay, & Duffy, 1998; Cognition and Technology Group at Vanderbilt, 1992; Hannafin, Hall, Land, & Hill, 1994; Jonassen, 1991; Spiro, Feltovich, Jacobsen, & Coulson, 1991; Young & McNeese, 1995). Despite the theoretical appeal of learning environments conceptualized from a constructivist or situated framework, the empirically based discussions of actual instantiations seem to be less prevalent. Further, *constructivism* has become an umbrella term that encompasses many different types of learning environments (see Duffy & Jonassen, 1992), even when they are predicated on vastly different theoretical assumptions (Barab & Duffy, 2000).

In this article, we distinguish between models predicated on *constructivist* (e.g., constructionism) and situated *cognitivist* (e.g., apprenticeship learning and legitimate peripheral participation) frameworks. We argue, primarily from an empirical perspective, that constructionist learning is vastly different both theoretically and practically from apprenticeship learning. Although both approaches share characteristics (i.e., learning occurs within a context of use, learning is frequently collaborative, learning as authentic, learning as inquiry-based not transmission-based), they also embody many important differences.

Our research is grounded in two different camps taking place in the summer of 1997. The first camp, Future Camp 97 (FC97), was a constructionist-based camp whose stated goal, in the camper brochure, was to develop learning experiences that were “using technology for exploration, discovery, and invention.” Learners in this camp used state-of-the-art virtual reality (VR) technology to construct a virtual world in one of three projects: Virtual Solar System, Virtual Statehouse, and Virtual Theater project. The second camp, Scientist’s Apprentice Camp (SAC), was an apprenticeship-based camp that matched learners with nationally recognized scientists. Students worked alongside scientists to conduct authentic research projects in state-of-the-art laboratories. There were research projects in the science disciplines of chemistry, computer science, geology, physics, and psychology. The final project of SAC97 was a presentation of their research to a community of their peers, mentor scientists, friends, family, and interested members of the public.

Our goal in this article is both to articulate and refine what we view as constitutive of a constructionist and of an apprenticeship learning environment, discussing the relative strengths and weaknesses of both. We begin with a discussion of the originating theories that drove the design of each environment (constructionism and legitimate peripheral participation). From here, both of the learning contexts and the methods used for data analysis are described. A detailed comparison and contrast between these two learning environments is then offered. Of prime importance are data related to types of communities that were formed, the roles of the different participants (i.e., learners, teachers, and experts), practices in which the learners engaged, and other evidence of student learning. Finally, we reflect on the distinctions between the two learning environments, with the aims both of refining theories and guiding future efforts at operationalizing them into real-world learning environments.

CONSTRUCTIONISM AND THE CONSTRUCTIONIST CAMP

Constructionism is a theoretical framework that comes out of the work of Papert in the research and development of the Logo programming language (Papert, 1980). Constructionism builds on constructivism in that it distinguishes itself from more traditional instruction, in part, by the degree of active learner engagement as well as the assumption that learners have the ability to create meaning, understanding, and knowledge. Students are not passive receptacles of the knowledge that teachers impart. Instead, Papert argued that not only must knowledge be built by the learner, but that these processes occur most "felicitously" when learners are engaged in the construction of an artifact or shareable product. Thus, constructionism (e.g., the construction of a Logo program) allows learners to develop their own reasoned interpretations of their interactions with the world. Perhaps more important, constructionist learning environments allow learners to share and collaboratively reflect on these cognitive artifacts.

Papert's notions of constructionism have been applied to many different types of learning environments. Within Papert's Epistemology and Learning Group at the Massachusetts Institute of Technology, there have been projects involving learners' design of instructional software (Harel, 1991), instructional games (Kafai, 1995), complex systems (Resnick, 1996), and more recently, scientific instrumentation (Resnick, 1999). Outside of the group, there have been other projects that build on similar constructionist framework with multimedia documents (Hay et al., 1994), expert systems (Jonassen, 1996), scientific computational models (Hay, 1999; Jackson, Stratford, Krajcik, and Soloway (1996), and virtual worlds (Winn, 1997). In each of these projects, the central goal of the learning experience was the creation of an external, shareable product.

From a constructionist framework, technology is recast: Instead of the metaphors of content delivery for learning, the constructionist metaphor casts technology as a cognitive medium. It becomes a medium for intellectual expression and exploration. For example, Winn used VR technology to help learn about the wetland cycle (Osberg, Winn, Rose, Holander & Hoffman, 1997) and AIDS (Bricken & Byrne, 1993). Using state-of-the-art tools, learners developed virtual worlds on PCs and then used head-mounted displays to view and navigate through their created worlds.

FC97–Camp Description

FC97[1] was a 1-week summer camp for high school students at an urban Midwestern university campus (see Barab, Hay, Barnett, & Squire, 2001, for a more complete discussion). Learners worked on academically diverse projects (government, science, or drama) and engaged with state-of-the-art hardware and software to design and develop their own virtual worlds. FC97 involved students building one of three different VR worlds: a virtual tour of a State House, a virtual solar system, or a virtual theater. FC97 was a part of a larger private, government, and university partnership to bring a technology center and museum to the downtown.

The camp was held on campus in a generic university classroom that was temporarily turned into a high-end computer lab. Each group was assigned two mentors: one education graduate student and one technology-related graduate student. The duties of the education mentors were to facilitate and guide the process of building virtual worlds and the mentors were not chosen based on their expertise in the content domain. The duties of the technology mentor were to facilitate and instruct learners and troubleshoot technology problems.

The campers were divided up into three groups of six high-school learners based on their interests, with the six learners working on the solar system being the focus of this comparison. Learners worked for approximately 3 hr on their projects and then ate lunch as a group, during which further project-related discussions continued. Following lunch, learners worked for another 4 hr. On the final day, parents and siblings, university personnel, the mentors, and other interested members of the surrounding community were invited to watch each group deliver a 15-min presentation to demonstrate their worlds and share their experience. This presentation culminated FC97 and served two educational functions. First, it gave the learners a clear deadline and focus to their projects. (The camp director used the phrase “real programmers deliver” early and often to focus them on their deadline.) Second, it gave the learners a clear audience for their work—their families.

The Solar System group created a virtual model of the solar system in which they modeled each of the planets and their major moons. World development began with students working in pairs to rotate the planets and their moons on

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[1]The camps were sponsored through the Future Park™ partnership between the White River State Park Development Commission and Indiana University/Purdue University, Indianapolis Schools of Education and Science. Silicon Graphics and Apple Computer were our corporate sponsors.

their axes, then to revolve the moons around the planets, then to revolve each planet and their moons around the sun. Lastly, student pairs connected their individual planets together into a complete solar system and put it on the World Wide Web for others to explore. This project involved working on visualization problems that occur in the vast space of the solar system, requiring that they solve problems of physical and time scale using information that is available on the Web along with other mentor-supplied resources. The final project represented a full-scale model of the solar system, including rotating planets around their axes and orbiting all nine planets around the sun, with a select sample of the major moons rotating and orbiting around the planets.

FC97 Data Collection Methods

For this study, our research design was informed by naturalistic research in education and sociology (Guba & Lincoln, 1983; Knorr-Cetina, 1981; Latour, 1987). Both naturalistic and quantitative data were collected to gain a holistic vision of FC97 (Scriven, 1983; Stake, 1983). We modeled our data collection focus on Roth's (1996) work. Our goals were to collect data that documented learner practices (e.g., tool use, problem solving, student inquiry) and resources (e.g., concepts implemented, tools); capture various discourse among learners and among learners and teachers; document the progress of learner projects; follow the same learners, artifacts, actions, and procedures over time; and support and refute emerging hypotheses about how practices, resources, task constraints, task manifestations, and learner understandings evolve over time.

The data were collected through the use of video cameras. Each of three groups had two cameras directed at them and a roving camera was directed at "interesting" events, people, and objects. We had two researchers, one who was both designer and participant observer and the other who was solely an observer. In daily meetings between the two researchers, field notes, student interviews, and teacher observations were discussed to generate assertions used to direct data collection efforts the following day. In addition, learner and teacher interviews, document analysis, field notes, and open-ended Web-based test items were administered at the beginning and end of the camp.

We had a particular interest in capturing how different types of practices and understandings emerged, evolved, and diffused within the context of the camp. To get at these, we developed a methodology designed to capture various practices (instructional, tool-related, modeling-related, science-related, and group-related practices), resources, student products, and conceptual understandings, referred to as tracers (Barab, Hay, Barnett, & Squire, 2001; Barab, Hay, & Yamagata-Lynch, 2001). This methodology is based on the actor-network approach (Latour, 1987; Roth, 1996), and

> involves selecting the phenomenon of interest (e.g., artifact, understanding, belief) and following its history by generating a network consisting of various nodes (interactions among actors) and links (connections among the nodes), representing the historical development of each *tracer*. Consistent with the actor-network theory, no one actor, whether it be the computer, teacher, other resources, or student, is given a priori priority over others in explaining the development of the tracer. (Barab, Hay, Barnett, & Squire, 1998, p. 13)

Using this approach we were able to gain a rich description of the historical development of various practices, understandings, use of resources, and student products.

APPRENTICESHIP LEARNING AND THE APPRENTICESHIP CAMP

Apprenticeship learning has its roots in the pre-industrial agrarian age, where an apprentice would work alongside a master to learn a trade. This practice lives on in many forms, and it still predominates in the skilled trades of electricians, carpenters, pipe-fitters, and so on. Lave and Wenger (1991), after examining five apprenticeship situations, noted that in the successful cases there was little observable teaching, yet large quantities of learning. In these examples, the practices of the community created the potential "curriculum"—in the broadest sense. In their view, "learning is not merely situated in practice—as if it were some independently reifiable process that just happened to be located somewhere; learning is an integral part of generative social practice in the lived-in world" (p. 35).

Broadening apprenticeship into a new "analytical viewpoint on learning," Lave and Wenger (1991) recast it as legitimate peripheral participation, a generative social practice that is the process where a beginner, novice, or "newcomer" is gradually enculturated, with the goal of becoming an expert or "old-timer." This process is most noted by the newcomer's movement from the periphery of the "community of practice" to that of becoming a more engaged, inclusive, and central part of that sociocultural practice. Lave and Wenger did not reify or attempt to fix practice or its center, but rather pointed out that "legitimate peripheral participation refers both to the development of knowledgeably skilled identities in practice and to the reproduction and transformation of communities of practice" (p. 55). Whereas there is no single core or center, there are multiple and varied ways to engage the complex, differentiated nature of communities.

Founded in this ethnographic work and that of a number of other researchers (Hutchins, 1993; Lave, 1988; Rogoff, 1990), apprenticeship has had a recent resurgence in educational thought and has been caught up in the constructivist paradigm shift (Barab & Hay, in press; Brown, Collins, & Duguid, 1989; Collins, Brown, & Newman, 1989; Hay et al., 1998) for the education of K–12 students. The goal is to release apprenticeship from its historical connotations (association with skilled laborers and sometime oppressive relationships) so that it may become a valuable educational practice for cognitive learning in the information age. Central to this perspective is the belief that learning through apprenticeships can, and often does, reach beyond the physical skills associated with a craft and into the cognitive skills normally associated with conventional schooling (Brown et al.; Collins et al.; Lave, 1988; Lave & Wenger, 1991).

Collins et al. (1989) introduced the idea of cognitive apprenticeship as one means of realizing the learning potential of apprenticeship in the cognitive domain. The notion of cognitive apprenticeship includes the development of learning contexts that model proficiency, provide coaching and scaffolding as students become immersed in authentic activities (fading scaffolding as students develop competence), and provide opportunity for independent practice so that students gain an appreciation of the use of domain-related principles across multiple contexts. In these contexts, the goal is not simply to apply principles successful in apprenticeships, but actually to transform the culture of schools so that students can (a) appreciate the purposes and uses of the knowledge they are acquiring, (b) actively use knowledge as opposed to passively receiving it, and (c) learn the varying conditions in which the knowledge can be used. Brown et al. (1989) described it as follows: “Cognitive apprenticeship methods try to enculturate students into authentic practices through activity and social interaction in a way similar to that evident—and evidently successful—in craft apprenticeships” (p. 37).

According to Brown et al. (1989), some of the advantages and points to consider in the designing of apprenticeship learning contexts include “the centrality of activity in learning and knowledge, … the inherently context-dependent, situated, and enculturating nature of learning, … the paradigm of situated modeling, coaching, and fading, … [and] learning within the nexus of activity, tool, and culture” (p. 39). Frequently these learning contexts also emphasize a collaborative (co-labor) aspect to learning. This emphasis on collaborative or cooperative learning is consistent with other research from a sociocultural perspective (Brown & Campione, 1990; Rogoff, 1990; Vygotsky, 1978).

The apprenticeship and specifically the cognitive apprenticeship theory base provide the framework out of which the SAC97 was constructed.

SAC–Camp Description

During the summer of 1997, six groups of inner-city, middle school students (Grades 6–8) attended SAC97 and selected an apprenticeship in which they worked with one practicing K–12 science teacher and one mentor scientist. The camp was designed to match inquisitive, highly motivated middle school students and teachers with researchers in a university School of Science at an inner-city campus. Participants worked in groups of four as they conducted scientific research under the expert mentorship of a practicing scientist and with the guidance of a K–12 teacher. Students were presented with an authentic research problem and had hands-on experience with state-of-the-art instrumentation and equipment. They learned how to state a hypothesis, conduct experiments, collect and process data, and integrate their findings into a presentation suitable for a scientific conference.

The goal of SAC97 was similar to many university-based camps across the nation that are run for motivated middle and high school students; that is, to develop excitement about doing science and the promotion of science as a career option through exposure to authentic research projects and state-of-the-art laboratories. A secondary goal of SAC97 was for students to gain valuable, hands-on experience with the latest in general-purpose technology used by scientists. SAC97, by one name or another, has been run by the directors of the camp for more than 10 years. Its fundamental pedagogical assumption was that apprenticeship was the best type of learning experience; however, in past years, apprenticeship was operationalized as simply putting students into a real laboratory with a practicing scientist.

Findings and general perceptions of the previous years were that this method—simply putting students into scientists' labs—was not effective. Scientists tended to focus on mastering basic factual knowledge and therefore tended to lecture to the campers for the first days of the camp. Campers' final projects tended to be simple restatements or parroting of this factual knowledge. Scientists, it was found, often talked or demonstrated science, but students did not engage in legitimate peripheral participation in the scientist's community of practice. In 1997, the planners of SAC97 made the first intentional use of the educational theory and literature of apprenticeship learning environments. There were a number of modifications made to the structure and the preparation of SAC in 1997. These areas included preparing the scientists, the scientists creating Web sites for apprentices, using teachers as go-betweens of apprentices and scientists, using preparation and reflection time for apprentices before and after lab times, and training teachers in both technology and apprenticeships. Many of these improvements were supported through an electronic performance support system that we called the Apprentice's Notebook, and which is fully described elsewhere (Hay et al., 1998).

Twenty four students participated in one of six projects based on their interests (chemistry, biology, computer science, geology, physics, or psychology). For this article, the students working on the Long-Term Consequences of Drug Exposure During Development are the focus. This group investigated the consequences of stimulant drug (methamphetamine) exposure at various periods during rat development to model the stages of human pregnancy. During this project, the apprentices studied adult rats that were exposed to methamphetamine during the first week of life. In particular, the apprentices determined if exposure to methamphetamine during development changed the rats' sensitivity to the drug in adulthood. Rats were tested to determine if they showed an enhanced response (known as sensitization) or a blunted response to methamphetamine.

Camp directors assembled a team of six teachers and six scientists to be a part of SAC97. Each group of four apprentices was assigned a lead scientist and a teacher. The lead scientist was a volunteer faculty member conducting active research at the university. The scientist arranged a short-term investigation that could dovetail into their own ongoing scientific research. They then provided the lab facilities, instrumentation, materials, and lab assistants. The teachers were compensated for their work at the SAC97 and were with the learners throughout the entire 2 weeks of camp.

Each day began with a brief discussion as groups met to talk about their expectations during their time with the scientists. Students and teacher then spent 2 hr directly apprenticing with the scientist in the scientist's laboratory. During this time, students took pictures using a digital camera, collected notes on the research, carried out laboratory practices, engaged in discussions with the scientist and each other, collected data, and eventually submitted data for analyses. Following this laboratory time, students had lunch as a group. The second half of the day consisted of the separate groups meeting to discuss data, followed by an approximately 2-hr period in which students used an electronic notebook designed for this study. Using the electronic notebook, students entered data (including pictures and field notes), posed questions to scientists using a chat interface, searched the World Wide Web for relevant data, read host scientists' notes, and worked on their final presentations. A portion of this time was used to teach students how to use presentation software, prepare presentations, speak publicly, search the World Wide Web effectively, and electronically pose and respond to host scientists' questions. On the final day, parents and siblings, university personnel, the scientists, and other interested members of the surrounding community were invited to watch each group engage in a 15-min presentation regarding their experiences and findings.

Scientist's Apprenticeship Camp Data Collection Methods

For SAC97, our research design was also informed by naturalistic research in education and sociology, and we had the same data collection goals as those articulated for FC97 (see Barab & Hay, in press, for a more in-depth discussion of this camp). However, our data collection methodology was slightly different. As in the first context, one researcher was both designer and participant observer for the camp; in addition, two researchers acted as observers. These three researchers were each assigned to follow two groups, half of the day on each group. Each of the three researchers collected field notes, videotaped students while working in their respective laboratories, and conducted interviews. In daily meetings among the three researchers, field notes, student interviews, and teacher observations were discussed to generate assertions used to direct data collection efforts the following day. Teachers were also equipped with beepers, and at random times during the day they were beeped and expected to fill out one of two questionnaires designed to evaluate students' participation within the community (Barab & Hay, 1998). In addition, student and teacher interviews, document analysis, field notes, and open-ended Web-based test items were administered at the beginning and end of the camp.

COMPARING AND CONTRASTING THE CAMPS

Now that we have established our originating learning theories (constructionism and apprenticeship) and the resultant learning environments (SAC and FC97), we turn to a detailed comparison and contrast of these two constructivist learning environments. Our goal here is to both articulate and refine what we mean by a constructionist and apprenticeship learning environment, and to look for relative strengths and weaknesses of each approach from their common theoretical grounding.

For this comparison, the two researchers went through field notes, student interviews, teacher observations, data analyses, and manuscripts (Barab, Hay, & Yamagata-Lynch, 2001) related to the two camps to generate assertions and direct further avenues for analysis. We developed these general assertions into more detailed terminology that we found helpful in the understanding of both the commonalties and the differences of apprenticeship learning environments and constructionist learning environments. In this way, and consistent with other descriptions of qualitative analysis, we engaged in a dialogue among the data and previous research and theory so that we could identify the salient issues that had both local and broader relevance (Guba & Lincoln, 1983). In addition to empirical analysis of our particular data, we also examined the literature to ensure that we were focusing on issues that were fundamental to constructionist and apprenticeship learning environments. The issues most prominent at the end of this search (and which structure this comparison/contrast) were as follows:

- What were the types of communities or activity groups formed?
- What were the roles of the various participants?
- In what practices did participants engage?
- What did students learn?

Each emergent issue relates to a particular construct and/or viewpoint (i.e., communities, roles of participants, and practices) that is steeped in the theoretical literature of both constructivist and situated cognition (see Table 1 for a comparison outline that is described more fully later). We continue by defining, justifying, and grounding each identified issue. Then we describe, compare, and contrast the

TABLE 1
Cross-Group Comparison of Camps

	Future Camp (Constructionist)	*Scientist Apprenticeship Camp (Apprenticeship-Based)*
Community/group	Primary identification: Learner-controlled activity group	Primary identification: Community of scientists Secondary identification: learner-controlled activity group
Roles		
Learners	Primary role: VR world builder	Primary role: Apprentice to scientist Secondary Role: Student-directed presenter
Teacher	Education mentor, technology mentor	Student–scientist go-between, promote preparation and reflection, facilitate the creation of presentation
Expert	Embodied in VR tools, consultant (minimal)	Lab director, scientific community representative
Practices	Type: Generative Constraints: emergent	Type: Replication Constraints: Community norms
Learning	Improved understanding of solar system, state government, and theater; quality student-produced worlds	Increase in understanding of scientific method, no difference in applying scientific method, quality learner presentations

Note. VR = virutal reality.

issue within each of the two learning environments. Finally, we reflect on the distinctions, with the aims of refining the theories and guiding future efforts and at operationalizing them into real-world learning environments. Because of space limitations, we focus these sections on one project group in each camp (Solar System group in FC97 and Long-Term Consequences of Drug Exposure During Development group in SAC97). These project groups were selected based both on their ability to elicit certain germane points and the fact that they are both science-related projects.

What Were the Types of Communities or Groups Formed?

One of the central constructs in both constructivist and situative learning theory is the community. We, as did Barab and Duffy (2000), make a distinction between communities of practice and activity groups, both of which are examined here. Lave and Wenger (1991) discussed the community of practice as follows:

> [It does not] imply necessarily co-presence, a well-defined identifiable group, or socially visible boundaries. It does imply participation in an activity system about which

> participants share understandings concerning what they are doing and what that means in their lives and for their communities. (p. 98)

Effective participation in the real world is the general goal of all education. Community of practice represents a specific construct for the goal of education. According to Barab and Duffy (2000), communities of practice have several key features. First is “shared understandings” that are embodied within the workings of the community. This may or may not be constituted in a codified knowledge base, but serves to identify community members from nonmembers. Second is a significant history and future. Communities of practice are developed, evolve, and change over a rich history that has an eye to continued evolution into the future. Third is a combination of the first two. Communities must have a way to reproduce. That is a mechanism to bring in new members that will contribute, support, and lead the community into the future. Lave and Wenger referred to this “reproduction” of the community as learning through enculturation. Communities of practice then have a history that has generated an embodied knowledge base that can be reproduced through an enculturation process to ensure its future.

In this comparison of learning environments, there are a number of important issues to be addressed when examining communities of practice. Among them, it is important to look at the presence or absence of a community of practice. If it is present, then how do learners come to know that community, how are the community members and their resources represented in the environment, what does the community mean to the learners, how do learners see themselves in relation to the community, and what is the learners’ potential for membership in that community? These are important questions in their own right, but carry additional importance because of the community’s potential as a source of authenticity. Underlying these questions are vital questions related to authenticity: authenticity of the practices to real-world practices, authenticity of the outcomes to real-world issues and users, and authenticity of the experience to the student (Barab & Hay, in press; Barab, Squire, & Dueber, 2000; Shaffer & Resnick, 1999).

An activity group can be distinguished from a community of practice in that it is a temporary coming together of a group of learners around a shared task intentionally designed to support learning (Barab & Duffy, in press). Activity groups frequently have no direct connection with, or impact on, a community of practice, only indirect connections through access to reports on or from the community or the ability to use community resources, artifacts, or tools. This is not learning in an embodied, authentic culture at the “elbows of the master,” but rather learning with a temporarily formed group of peers. These groups are formed to take advantage of the learning potential afforded by collaborative interactions that Brown et al. (1989) identified as central to situated learning. We use these two notions, communities of practice and activity groups, to articulate what communities were present in these two participatory learning environments.

Communities and Activity Groups in FC97 (The Constructionist Camp)

Two activity groups were formed in FC97. The group students primarily identified with was the three project groups (Solar System, Statehouse, and Theater). These groups were the central focus of FC97, and learners spent approximately 80% of their time in their project group. This time was spent defining, planning, designing, problem solving, developing, managing, and evaluating their projects. There was great membership pride in each group. Group members and mentors would talk to each other, on task and off task, during most of their nonworking times.

The secondary activity group was the entire camp. Learners spent approximately 15% of their time as a member of this group. This group was based on both co-presence and the general theme of VR. Their time in this group was spent in two ways. First, were three formal presentation times, where students would share the current state of their projects with the other groups. The first two presentations were held around the computers in the camp room at the end of the day. The last presentation was held in an auditorium in front of the entire camp, family, university officials, and members of the public. The second way learners met as part of this group was through informal discussions that happened during breaks and at lunches.

There was no community of practice in FC97. In fact, there was no direct connection between the communities of practice that existed outside of the walls of FC97 (three-dimensional animators, World Wide Web or Virtual Reality Modeling Language [VRML] experts, astronomers, etc.) to the groups that formed inside the camp. The only exception was the indirect representation for some limited resources that were brought into the camp (an astronomy textbook, a solar system Web site, a Cosmo Worlds tutorial, etc.). In a very real way, the camp participants were a world unto themselves, cleaved of meaningful relations with the authentic community.

Communities and Activity Groups in SAC97

The community of scientific practice was the primary focus of SAC97 learners. This was the time that learners worked directly with practicing scientists in their laboratories. Although only comprising just over 20% of the scheduled time of SAC97, it was the unmistakably the center and focus of all activities at SAC97. The practicing scientist served as both a representative and guide into this community of practice. This relatively small time commitment is important, because the scientists were volunteers and extremely busy. It was the assumption of the directors that any successful apprentice program must guard against requiring huge amounts of time from the scientists. The clear design goal was to maximize the impact-to-time ratio.

There were also two activity groups in SAC97. The primary group, in terms of time, was composed of the student research groups. These groups, of four to five students each and led by a high school science teacher, spent 65% of the camp time together. When they were not working with the mentor teacher, they were surfing the Internet for information on their project, planning for their final presentation, or handling the data they collected during that day. The secondary activity group was formed by the entire camp. As in FC97, learners spent approximately 15% of their time in this group. This time was spent in two ways: in the final, formal presentation, where students shared their projects with all campers and their parents, and in informal discussions, which occurred during breaks and at lunches.

Comparison and Contrast of Activity Groups and Communities

Activity groups were extremely important to both of these constructivist learning environments, and they can be seen as one of the central features of the constructivist learning environments. However, there were commonalties and differences in the ways activity groups and communities were used, identified with, and maintained that help us further refine what we mean by activity groups and communities. The first commonality was the time spent by students in the primary group. In both camps, these groups of students (activity groups) took the majority (SAC, 65%; FC97, 80%) of the camp time. The second commonality was that these activity groups were controlled primarily by the learners, and in both camps, these groups were responsible for the construction of the final product. In FC97, this final product was the VR world, and in SAC97, it was the final presentation. Although there was some direct instruction of learners in each of the camps in these groups, in SAC97 more than in FC97, for the large part and especially at the end of the camp these groups were under the control and direction of the students. It was their group. Although there was a mentor present, they were only facilitators of the final product, not the directors.

There were four major differences in the primary groups of students. The first one was the view learners had on where the “real work” was done. At first glance, it is easy to make the assumption that this was in the primary group of students, because that was where students spent the majority of their time working on their main product. That assumption would be correct for FC97, but it would not be consistent with our observations and interview data collected for SAC97. In SAC97, learners clearly saw the real work being done in the labs of the scientist, and thus the real work was done within the community of scientific practice, not the activity groups. This was due primarily to the power of the lab, the mentor scientist, the scientific practices, and the clear sense of authenticity felt by the students. The activity group’s activities were based in classrooms, led by classroom teachers, and involved more typically classroom practices; thus there was less sense of authenticity felt by the learners.

This leads us to the second difference, where was the learners' primary identification? Learners from FC97 identified with the primary activity group (the project teams). As mentioned previously, learners would "hang out" in these teams when there was no structural or practical reason to do so (e.g., after camp hours or during lunch). Learners in the SAC97 primary identified with the scientists and the communities of practice they represented, not with their activity groups. They clearly saw themselves as apprentices working with the master scientist, whereas FC97 learners saw themselves as an independent project team with two facilitators. In both camps, learners would chafe and complain whenever they were not in these roles. In FC97, learners would stay late and skip lunch just to return to the activity groups, and SAC97 learners would become irritated if the teachers or directors infringed into their time with the community of practice.

The third distinction between FC97 and SAC97 was the relation between learner control and group identification. Learner control and learner-centered instruction have been promoted in current learning theory (Presidential Task Force on Psychology in Education, 1993), and according to current thinking one would expect that learners would identify most strongly with the groups in which they were in control. This was true in FC97 primary activity groups. Learners took complete control and ownership over this group and its goal. However, in SAC97, this was not the case. In the community of scientific practice, learners are not in control, nor central to the community—they are peripheral. The practice and its embodiments, the scientist and their labs, were at the center. In SAC97, the scientist directed almost every aspect of the research methodology. The practice was often very precise, demanding, and nonnegotiable.

The final distinction between the different groups in these constructivist learning environments goes back to the original distinction between a community of practice and an activity group. In both camps, learners formed temporarily constructed student-based activity groups. These groups were somewhat artificially constructed by the directors of the camps, embodied no rich domain-specific history, and were somewhat arbitrary in their groupings. What was unique about the SAC97 was a strong connection to the enduring, historically rich, and purposefully constituted specific groups that were larger than the camp itself. To some degree, the SAC97 participants inherited this history and identity.

WHAT WERE THE ROLES OF THE VARIOUS PARTICIPANTS?

We identified and analyze three kinds of participants: experts, teachers, and learners.

Experts' or "Old-Timers'" Role

The notion of "old-timers" is taken from the apprenticeship literature. Lave and Wenger (1991) described old-timers as the people at the center of the community of practice. These people are the practitioners in the domain and are the primary, but not only, connection to the community of practice. Although old-timers do have educative functions, as Lave and Wenger noted, they are not certified teachers; however, because they are experienced with both formal and tacit knowledge of the practice, they are mentors to the "newcomers." The question is: How do educators incorporate the educative function of old-timers? There are at least three options: (a) teachers can become more like or become old-timers themselves, (b) they can develop methods to include old-timers into their classrooms, or (c) they can continue on the same path that uses the resources of a community without the full connection with the authentic community. None of these three approaches should be considered to be the ways things ought to be, but rather they are options when creating a learning environment.

Experts' or old-timers' roles in FC97. Experts who know such things as VRML programmers, QuickTime VR programming, theater direction, animation production, astronomy, or government played a role in creating the constructionist camp by being resources for the camp designers. However, because of economic and logistical factors, they did not interact significantly during the camp itself. Within the constructionist camp, there was essentially no expert participation.

Experts' or old-timers' roles in SAC97. In SAC97, on the other hand, practicing scientists were major participants. The scientists' stated role was to bring learners into their labs and empower them to conduct "real science experiments." The camp took advantage of the scientists' experience and the laboratory environment that they had created based on careful planning, years of doctoral study, the development and execution of a successful research agenda, securing grants, publishing research, selection as a professor, setting up physical labs, selecting tools and resources, training graduate assistants, and most important, doing science. These scientists defined all of the basic elements in this learning environment. The power and the scope of the scientists' laboratories should not be underestimated. The equipment and tools the learners used represented an investment of hundreds of thousands of dollars by the university and the researchers' funding agencies. These facilities were directly connected to the scientists and created for the apprentices an aura of importance and respect.

Scientists were clearly in control of the goals, the learner practices, and the setting. This control should not be cast in the binary opposites of learner control or teacher control we often find in the constructivist learning theory; but rather, control should be viewed in the well-worn path of community control and the scientist's commitment to have a voice in that community. Scientists had clear ownership of the data that students collected, not because they simply wanted the learners to learn or get it right, but because it was their data. It was a part of their practice with their communities. A learner's mistake of procedure was not simply a matter of a lower grade, but could result in a significant setback to a scientist. For example, the scientist mentoring the Long-Term Consequences of Drug Exposure During Development group was allocated only so many rats by the university and only so much methamphetamine from the U.S. Drug Enforcement Administration for her study. If students made mistakes at any step with the experiment, the scientist lost the hard-won resources that were at the center of her research and her career. Mistakes by the learners meant a diminished capacity to contribute and therefore to maintain the scientist's role within the scientific community of practice.

Lave and Wenger (1991) told us that a master's role in "conferring legitimacy is more important than the issue of providing teaching" (p. 92). This seems to be the power of old-timers in SAC97. That they contributed their laboratory, their ongoing research, and their in-situ guidance allowed learners to engage in real science, not simplified science filled with prerequisites and abstract formalisms. This was the power of old-timers in SAC97.

Discussion of experts' role in FC97 and SAC97. The comparison and contrast between FC97 and SAC97 in terms of the role of old-timers is straightforward. In FC97, the old-timers did not play a central educative role; they played virtually no role at all. Meanwhile, in SAC97, old-timers played the a central educative role. It is interesting to highlight once again that although apprentices' spent only 20% of their time with the scientist, the physical and human resources they made available and the practices learners could observe provided legitimacy to their endeavor and the feeling that they were doing science.

Teachers' Roles

The popular slogan for the role of teachers is something like this: "Go from the sage on the stage to guide on the side." What this means is that in a constructivist learning environment, the teacher should not think of himself as the conveyor of knowledge. He does not need to be all-knowing and to control all aspects of the classroom. Rather, the teacher should become a facilitator of the knowledge construction process, directing students down profitable paths, modeling an engaged mind, problem solving with students, and providing a rich context with needed resources. Both constructionist and apprenticeship learning environments challenge the traditional teachers' role. In this article, we explore how these facilitation roles were undertaken by situated teachers.

Teachers' role in FC97. There were two mentors for each of the three groups in FC97. They were labeled *education mentors* and *technology mentors*. The education mentors were School of Education students: both were graduate students in Instructional Systems Technology, and one was a practicing teacher. None of the three were experts in the domains (theater, state government, astronomy); however, all were trained in working with content experts and the development of instruction. The technology mentors were graduate students who were hired as training, support, and problem-solving experts in the domain of the technology hardware and software. The mentors' goals were to facilitate the setting of the project goals and constraints, create a productive environment, and then serve as a resource through the project duration. In the Theater and Statehouse groups, mentors quickly slipped into the "affordance" background of the project environment. That is to say, after helping learners set the initial project goals, mentors gave little direct structure to the course of these projects. Students took control, and the mentors became resources and guides to the learners. However, in the Solar System group, both mentors struggled with their roles within a constructionist learning environment. They never fully gave up control of the learning environment and thus never slipped into the affordance background. Mentors also performed custodial functions of escorting learners to and from lunch, and so on. However, there was no need for enforcement of discipline by the teachers. This was a fairly remarkable occurrence for a group of high school students in the summer.

Teachers' role in SAC97. There was one teacher assigned to each of the six groups. They were all science teachers from local middle and high schools. They served both in-lab and out-of-lab roles in SAC97. In the lab, the teachers served as a liaison between the students and the scientists. When the scientist explained concepts or asked questions and it was clear that the learners did not understand, for example, the teacher would paraphrase the scientist's comments for the learners. This method served a number of functions. It promoted effective communication. It also promoted connection between the scientist's discourse and the learners' discourse in a way that was both sensitive to the real problem (it did not "dumb down" all communications, just clarified confusing ones) and performed an educative function so that students could learn the discourse of the scientist. Finally, it performed an educative function for the scientist so that he or she could learn how to communicate better with middle school learners. The paraphrasing also occurred in the opposite direction, when the students asked questions of the scientist. It served basically the same functions: promoting communications, modeling quality questioning, paraphrasing student questions, and was educative for the scientist.

The teachers' roles outside of the lab were more diverse. Beyond the custodial roles of getting apprentices to and from lunch, going to the labs, and back to the computer room, teachers played three out-of-lab roles in SAC97. The first was preparing the learners for their time with the scientists. It was stressed to the scientists, teachers, and campers that the most critical time they had during the week was their time with the scientist, and that the teachers should have prepared the apprentices such that they were ready to "hit the ground running." There were specific times set aside before each lab activity for this purpose. This would include reviewing the lab-based activities of the previous day, reading and reviewing preparatory Web-based material provided by the scientist, a dry run-through of the activities of that day, and definition of roles for each learner (e.g., data recorder, photographer, computer controller, etc.). The second out-of-lab role of the teachers was to help learners reflect on and process their experience with the scientists. This included times where students went over what they did and learned during lab time, as well as times where the students entered data that they had collected (measurements, pictures, graphs, etc.) into an on-line database. Finally, the most time-consuming out-of-lab role the teachers had was the facilitation of the apprentice research presentation, which was the culminating event of SAC97. The research presentations were the most emphasized outcome of the apprentices' 2 weeks at SAC97. Directors put pressure on apprentices and teachers to create a high-quality 10-min PowerPoint presentation of their research. Teachers facilitated the organization of the presentation, collection of resources, technical aspects, and accompanying speeches. Apprentices had "dress rehearsals" on the day prior to the final presentation that were critiqued by the directors.

Discussion of teachers' role in FC97 and SAC97. There were several commonalties and differences in the roles of the teachers in FC97 and SAC97. In both camps, teachers largely took the role of "guide on the side." In both camps, there were times when the teacher was the authority figure, however for the majority of the time, there was a clear learner-centered atmosphere. They supported learners in their involvement in authentic tasks that were under the learners' control. Teachers were used as resources to solve emergent problems as learners pursued goals of which they had ownership.

There were two major differences between the two camps with respect to the teachers' role. The first was the consistency of the teachers' role as a guide on the side in FC97. After the first hour of introduction, teachers were guides. Although the types of guidance changed, the role was consistent. In SAC97, there was a dramatic shift in roles between the community-centered activities conducted in the scientists' labs and the learner-centered activities of the computer classroom. In the labs, teachers were fellow learners and mediators between the learners and the scientists, whereas in the computer classroom, they performed almost exactly the roles that the FC97 teachers performed. The second major difference was in the level of activity of the teacher. In FC97, teachers faded into the affordance background to such an extent that, at the end, if an outsider had walked into FC97, they would have wondered why the teachers were even there. In SAC97, teachers were actively facilitating the process throughout their time with the students, pushing and prodding them to complete the project, checking details, helping organizing presentations, finding lost images or data, and so on.

Learners' Roles

The publication of the Presidential Task Force on Psychology in Education (1993) principles of learner-centered learning was meant to dramatically shift the focus in the classroom away from teacher-centered didactic, lecture-based instruction to instruction centered on the learner. Articulations of constructionist and apprenticeship instruction share that learner-centered approach, but not in exactly the same ways. Our analysis of FC97 and SAC97 demonstrates ways in which these learner-centered principles were enacted, how they played out, and when they were not appropriate at all.

Learners' roles in FC97. The learners' role in FC97 was designed to be open-ended and emergent, focusing on socially negotiated outcomes within the particular project framework that was set up for them. Learners across all three projects were to be clearly in charge of the project after the first day, which was the day the project framework and the parameters were discussed. The learners' roles were diverse and multiple. We characterize them into three primary roles: executive role, inventive role, and construction role. Executive roles include the activities of project planning and management. The executive role took over after the high-level goal was presented: create a virtual solar system, create a virtual play, and create a virtual tour of the statehouse with the tools provided. In the executive roles, learners controlled goal setting, task identification, planning, plan revision, and monitoring progress within a new and ill-defined project. Both planning and revising goals were important components of the executive role. This was exemplified by the Theater group, which was initially more concerned with aesthetic appeal and realism. Their initial plan and tasks were structured to accomplish the goal of having characters walk realistically. Their strategy was to use each other as models to determine how to make a character walk. However, by Days 4 and 5, realism was secondary to the need for completion. Time became the more salient constraint on defining this practice, with one student suggesting, "why don't we simply have Mr. White slide across the stage. … At this point I'm less concerned with how it looks. I just want to get him from one side of the stage to the other." The executive role was strong, but flexible to meet the constraints of their environment.

The inventive role included such things as inventing practices, constructing new knowledge, and transforming found knowledge into knowledge that was usable in their project. The inventive role was necessary in the context of the ill-defined project. In all three projects, there was no expert to show the campers how to "do it." They had to be inventive to accomplish the goals. As outlined in the Practices Section, the "level of detail practice" (LOD–P) in the Solar System group is a good example of learners who were fully immersed in the inventive role. The construction role consisted of the entire range of construction activities of creating a virtual world. This includes collecting raw materials (images for the statehouse, video audio files for the play, etc.), assembling them into prototypes, evaluating them, modifying them, and finally constructing the final products. The construction roles were always directly connected to the executive roles and utilized the products of the inventive roles.

The extent, duration, and importance of these roles were socially negotiated within each project group and facilitated by the mentors. The roles were not clearly demarcated in time or place and the learners easily moved between them. In fact, they are more analytical categories than specific roles the learners would immediate identify with.

Learners' role in SAC97. The learners had two distinct roles in SAC97. The first and primary role was as the scientist's apprentice, and the second was as a presenter of scientific research. These two roles were conceptually related in the minds of both the students and the directors of the camp; the roles were markedly distinct in terms of what the learners did, who facilitated them, the legitimacy of what they did, and the outcomes.

In the primary scientist's apprentice role, learners had little control over the core research questions, basic goals, assumptions, parameters, practices, or resources that were used. They entered the ongoing practice of a scientist conducting research experiments that were a part of the scientist's research agenda. The role was clearly that of an apprentice (newcomer) working with a master (old-timer) in a very structured community of practice where the practices they engaged in were extremely well defined. Their roles were to quickly understand the conceptual framework of the master and to learn the practices. These practices were exacting and nonnegotiable. Apprentices had no latitude in changing the techniques, instrumentation, site, or subjects. Apprentices developed these practices through a process of watching the masters perform the practice and then a slow appropriation of the individual steps of the practice. Once the practices were performed to the master's satisfaction, both the scientist and the teacher would often engage the learners in a discussion of "Why do we do it this way?" Some steps in these practices may not have even been appropriated by the learners, because of difficulty, time constraints, or other issues (e.g., injecting methamphetamine into the rat). The learners' role, when they were in the lab working with the scientist, was strictly defined by the scientist.

In the secondary but related role, learners engaged in active and planned reflection on the experience they had in the laboratories. This occurred throughout the camp, but was focused in three major activities. First was the postlaboratory experience. As we discussed earlier, this was the time immediately after the lab experience where learners uploaded the digital photographs they had taken, entered information (data, graphics, notes, etc.) into the digital logbook, and discussed the experience in a teacher lead groups. The second reflection time was the prelaboratory experience when learners discussed what they were going to do that day in the lab. This was often accompanied by reflection of previous lab experiences. The final reflection time was in the creation of the final project, fully discussed later, where learners reflected on the entire process and reconstructed it within a complete PowerPoint presentation.

The final major role incorporated the executive and constructive roles of the FC97 learner, but it was tightly focused on the goal of creating a modern-day scientific presentation to the camp director's satisfaction. This involved the practices of PowerPoint presentation development, World Wide Web searching, public speaking, producing visuals, journal writing, and delivering scientific presentation. Learners' roles were markedly different here from those in the laboratory when they were working with the scientist. There was a mixture of relatively passive lecture and demonstration instruction with active presentation development and practice times focused on these practices. The lecture and demonstration instruction times were often led by a nonscientist and were done in 60-min periods.[2]

Thus, the learners' role was to take in the information or skill and apply it to their presentation. In their active presentation development roles, learners had considerable control and ownership over their work. They used the teachers and the scientists as just-in-time consultants to meet their own needs and goals. This consultant–client relationship was markedly different from the mentor–apprentice relationship that was seen in the lab. This consultant–client relationship took the form of aid, not strict adherence to a particular practice. Doing poorly would reflect on both the scientist and the teacher, however in stark contrast to the lab work, a lackluster presentation would not impact the scientist's research in the slightest.

Discussion of learners' role in FC97 and SAC97. The similarities and differences between the learners' role in FC97 and SAC97 are more complex than the other roles. In both camps, learners were put into the executive and construction

[2]These lecturers were neither experts nor teachers as we have identified them earlier. They were outside consultants who presented how-to lectures on a variety of issues (e.g., Web use, PowerPoint use, presentation skills, etc.).

roles that fostered control of project direction and outcomes. This was done throughout the entire camp in FC97 and only in the Presentation Role in SAC9797. A difference was in the time that the campers spent in these roles. The learners in the FC97 were in these roles the vast majority of the time and in SAC97, were in these roles about half the time. Another distinction is the consistency of the learners' role. In SAC97, learners had to manage two roles. In the apprentice role, learners were clearly newcomers with little project control. In the learner-centered presenter role, they were in charge of creating a scientific presentation for an audience. This was decidedly different in FC97. In FC97, learners maintained a singular identity as creators of their virtual worlds.

The range and exact nature of roles were much broader, more emergent, and more open to negotiation in FC97 than in SAC97. The only things that were predetermined in FC97 were the projects, the hardware and software, and other resources. In SAC97, roles were defined by the practices of the particular science and scientist and pre-existed well before there was a SAC97. That is, the roles were defined for methodological reasons, not for educative ones, although they served that function well in SAC97. Lave and Wenger (1991, p. 97) described this structuring property that practices have as a "learning curriculum;" they contrasted this to the "teaching curriculum" used in the classroom. Even when executive and construction roles of the SAC97 campers were similar to those in FC97, in the presentation phase of the SAC97 camp, the roles were similar to more traditional student practices (i.e., presenting their work to the class). In fact, learners had an argument with the directors about the authenticity of these presentations, which is evidence that they did not truly believe the legitimacy.

The final distinction between FC97 and SAC97 was the predominance of the inventive roles in FC97 and the lack of it in SAC97. FC97 was driven on the learners' inventive solutions and adaptations of practices and plans. In the two predominate roles in SAC97, there was no or little inventiveness. For an apprentice, inventiveness is left up to the expert/master. All the inventive ideas about goals, strategies, and solutions where developed by the experts. As a presenter, didactic instruction removed much of the inventiveness from the creation of the presentation. The presentations tended to be rather straightforward depictions of the process they went through in the labs and the presentation of their findings.

In What Practices Did Participants Engage?

Comparing and contrasting the practices of FC97 and SAC97 forms the centerpiece of this article for two reasons. First, the focus on practices represents a conceptual shift that is central to constructivist learning theory, broadly defined. The focus changes from a learner "'receiving' a body of factual knowledge about the world; to activity in and with the world" (Lave & Wenger, 1991, p. 33). Second, although the other sections detail the resultant structures (communities and roles) and outcomes (learning; see next section), this section exemplifies how campers in FC97 and SAC97 came to learning and participating in meaningful activities.

Therefore, in this section, we explore the practices in which learners in these two camps were engaged and how those practices emerged, evolved, and diffused within the communities in a greater level of detail than the other sections.

Practices of FC97

The emergent practices of FC97 are among the most interesting and expansive to describe. Thus, we once again focus on the Solar System group as an example of practices in FC97. The Solar System group's emergent practices involved using Cosmo Worlds in the construction of their solar system. We have identified and explicated three broad categories of the practices of the Solar System group in FC97 (Hay & Barab, 1998a, in press). The first category of practices consists of the static modeling practices, which are practices related to the creation of the static geometry of the model. These include the creation of basic object, object orientation, object size, and position. The second category of practices is the dynamic modeling practices. These practices added motion, such as modeling planetary rotation and planetary orbit, to the learners' solar system model. The final category of practices that emerged in the Solar System group was the practices of model visualization. These practices, such as model visualization practices of planet texturing and creating level of details, focused on how learners presented their models both to themselves and to their intended audience. We present only the LOD–P for illustrative purposes here. The LOD–P is interesting because it is one of the core conceptual practices of the solar system model. It was also selected because of its complexity and its inventiveness. It is complex because learners needed to understand and solve the problems associated with representation of the vastness of the solar system. The LOD–P was inventive because learners repurposed a standard VR tool, Level of Detail (LOD) Tool, to address a goal for which the tool was not originally intended and in a manner that no one has done in the past. The LOD Tool is used by VR world builders to reduce the computational demands of creating a world. In the Solar System group, they used LOD not to deal with computational problems, but rather visualization ones. Toward the end of the camp, learners were confronted with two related visualization problems that they needed to overcome. The first problem was that if campers created a scale model of the solar system and pulled back to a perspective where they could see the entire solar system, they could only see the sun and the largest planets, and even they appeared as small specks on the screen. The second problem was the time-scale problem. How could they create one standard time scale that would work for the entire solar system? These two conceptual difficulties created a major crisis in the project. After an appropriate time to explore the issues on their own, a mentor introduced the concept of LOD through a just-in-time lecture. The just-in-time lecture explained the technical concept to the members of the group, but did not discuss how to operationalize the concept, a skill that, in this case, the mentor did not have.

The entire group then explored the operationalization of the LOD concept on their computers. In pairs, learners began to use the design of the tools as a resource to understand the process of creating LOD for a particular object. That is to say the tool provided scaffolding within its interface that embodied both the practice and concept of LOD. It was the learners' challenge to use the interface as a resource to operationalize the elements of LOD that were presented to them in the just-in-time lecture. These elements included multiple representations of an object, selecting the range of distances that were appropriate to use for each object, and so on. There was quick success. Tim and Mark called the mentor over and showed him their product. It was doing something, but they could not make sense of their product. The mentor coached them by asking questions about their product. "Describe the behavior." "How did you accomplish this?" "Where does the new LOD come in and why?" While this was going on, Tom and Jim discovered how to do LOD and called the mentor over. They explained it to the mentor, and he then called over all the students, so Tom and Jim could demonstrate how to construct LOD for the entire group and serve as a resource and coaches for the rest of the camp.

Once the group had developed an understanding of LOD, they, in a intentional, goal-oriented manner, grabbed onto the concept and used LOD to address the two visualization problems. They did this by adopting two previously rejected representations (a huge label the size of 100 suns, and the most realistic model of a planet) and blending them into an integrated solution to the distance problem. Now they could create two different representations of a planet (i.e., a huge label "Venus" and the model of Venus) and use the concept of LOD to integrate them into one. The results were that when the viewers looked at the entire solar system they could see the label of the planet, and as they zoomed in on the planet, they would see the realistic textured planet. The tool-related practice developed after the LOD concept was introduced into the community. The practice was created, evolved, and disseminated through the community through the learner, with only facilitation, but not direct action of the mentor. The use of the LOD Tool and the LOD practice demonstrated deep understanding of the underlying complexity of representing the vast size, distance, and time scales of the solar system.

Practices in SAC97

We have written more extensively on the practices of SAC97 (Barab & Hay, in press). The practices of SAC97 are organized into three categories: laboratory practices, presentation practices, and apprentice support practices. Laboratory practices are the practices learners engage in during their time in the scientists' labs. These practices were highly specific to the particular type of science, although they were based on the well-worn path of the community of practice and under the control of the scientist. The second category of practices, presentation practices, were directed by the learners and included practices of constructing of their presentations. This included collecting presentation elements, formatting elements, planning presentations, and constructing the presentations. The final category of practices that emerged in SAC97 was the practices of apprentice support. These practices focused on engaging learners in practices that would improve the educational experience and make them more effective in the labs and in constructing their presentation. These apprentice support practices were largely directed by the teachers and included practices of pre/postlab experiences, the apprenticeship notebooks, and the photography. Due to space limitations, we focus on the laboratory practices. The choice of laboratory practice or the other practices in SAC97 was made for several reasons. First, they were the most definitive of both the camp and of the underlying theoretical perspective (legitimate peripheral participation, LPP). Second, they were the most complex practices and they were the most unique to the SAC97. They included complex data collection, treatment preparation, computer visualizations, and analysis. Looking across the entire camp, laboratory practices were diverse and numerous; however, within each group there was a set of fixed practices based on the nature of the research. The group we discuss is the Long-Term Consequences of Drug Exposure During Development group, the students who investigated the consequences of stimulant drug (methamphetamine) exposure at various periods during rat development to model the stages of human pregnancy.

There were three types of practices of the apprenticeships in the lab: treatment preparation practices, data collection practices, and data analysis practices. The treatment preparation practices involved the mixing of the methamphetamine dosage to inject the rats for the behavioral study for that day. This practice was extremely exacting because of the importance of the dosage to the experiment and the fact that methamphetamine is a controlled substance. The practices included using a balance to measure quantities of methamphetamine (less than 1 g), logging the amount used for the experiment, calculating how much water to use with the methamphetamine, measuring sterile water, mixing the solution with a centrifuge, weighting the rats, calculating the dosage for each rat, and finally injecting the rats with the methamphetamine.[3]

[3]University policy stated that only people trained in animal handling could handle and inject the rats. This training was beyond the scope of the Scientist's Apprentice Camp, so the scientist handled all the animals in this research.

The data collection practices involved the students collecting both subjective and objective data on rat behavior. The subjective data collection practices involved apprentices making visual surveys of rat behavior for 1 out of 5 min for 12 times during 1 hr of observation after the rats were injected with the methamphetamine. The objective data collection practices were conducted at the same time and involved two lasers crossing the clear plastic cages. A computer would record when the rats walked in front of the lasers as an indication of relative movement (e.g., a rat that is running from side to side constantly would register high values for this measure). Apprentices would collect and organize these coding sheets and computer printouts to compile a notebook that contained all their data. The data analysis practices were conducted on the final day of work with the scientist when apprentices entered their data from their notebook into the data analysis software package to test their hypothesis. They looked for a number of relations and developed relevant graphs that showed their results.

Comparison and Contrast of Practices

There was similarity in the practices of FC97 and SAC97. As described earlier in each of the project descriptions, the culminating activities (presentation to parents) in FC97 and SAC97 were very similar. Further, and consistent with constructivist learning environments more generally, both camps were designed to engage learners in doing science, as opposed to hearing about science.

The differences illuminate several fundamental distinctions between apprenticeship and constructionist learning environments. First, the goal of SAC97 learners was to practice replication. From the practices of data collection through the presentation, learners were first shown how to do it and then expected to replicate the practice. The practices in FC97 were largely emergent. Mentors and students did not have practices to replicate and were often thinking through the implications of any particular practice during the camp. The LOD practice is a good example: Nobody in the camp knew the correct practice. However, when it emerged, there was an urgent demand for its diffusion throughout the group.

The second difference in the practices of these two camps was how practices were introduced to the learners. In FC97, the practices were emergent, based on the learner-defined goals. Practices came from the need to solve the learner-defined subgoals, many of which were themselves emergent. In SAC97, practices were introduced to the learners based on either community structuring (in the case of the treatment preparation, data collection, and data analysis) or the directors' structuring (in the case of the presentation). The practices were introduced based on the learners' position within the community. As learners became accomplished in the peripheral practices they began to take over more central practices.

The final difference was what we might call the probability of success. Projects in FC97 had a lower probability of success, because they relied on newer tools, emergent practices, and high amounts of student control. This led to the emergence of numerous ineffective practices. In fact, as mentioned earlier, the Solar System group had difficulties completing their goal because of these ineffectual practices. On the other hand, SAC97 practices had a high probability for success because of the relied on tried-and-tested tools, proven practices, and community control.

WHAT DID STUDENTS LEARN?

Our final issue relates to opportunities to collect direct evidence of student learning. In both camps, there were pre- and postmeasures administered to students to assess gains in content knowledge related to the particular projects they were engaged in during the camp. Additionally, we examined the quality of the students' final presentations for SAC97 and the quality of the completed projects for FC97.

Learning in FC97

One measure of learning was in terms of student differences with respect to knowledge of concepts and terms related to the three projects. Specific pre and post questions for the Solar System group included the following: What is a model and why are they important? What do you need to know to create a scale model of the solar system? What causes the seasons? What are the sizes of the planets and what is their distance from the sun? What is a lunar eclipse? Collapsing across groups, there were significant improvements in students' knowledge from the beginning to the end of the camp. Individual *t* tests—Statehouse group, $t(5) = 8.82$, $p < .05$; Theater group, $t(4) = 3.32$, $p < .05$, and Solar System group, $t(3) = 5.05$, $p < .05$—suggested that all groups improved in their knowledge over the course of the camp (Barab, Hay, and Barnett, 1999).

Students in the Solar System group consistently demonstrated an improved comprehension of the value of scale models for understanding science, as well as demonstrating an improved appreciation for what is necessary to build a scale model. Additionally, students had a more accurate understanding of the size and distance of the planets, as well as what causes a lunar eclipse to occur and why we do not see them every month. It is important to note that these gains did not result from didactic lectures; rather, the students' increase in knowledge was a result of completing practices within the context of the larger project.

Students were also asked to draw a scale model of the solar system, including correctly indicating relative size, distance, and order of planets. Student work was somewhat surprising in that many of the students, despite coming to understand that they could not show the entire solar system on one screen if they wanted the user to be able to distinguish the planets, drew all planets and the sun on one page.

In all but one case, the drawings incorrectly depicted all planets being shown on a single piece of paper. It appears that students did not have a strong grasp of scale in terms of their paper drawings, despite building a scale model of the solar system on the computer.

In addition to the more quantitative pre- and post-test measures, it is also important to qualitatively examine student projects as another indication of what students learned. Although a seemingly daunting task, all groups designed and constructed a VR project in 5 days. However, the final quality of the projects varied greatly, with some projects having more functionality than others. Focusing specifically on the Solar System group, these learners completed the construction of the sun, planets, and several moons; made the planets orbit around the sun; and included a couple of moons orbiting around their planets. The sophistication of the three-dimensional representations indicated a deep appreciation for the content that the students were modeling.

Students also designed the organizational framework including different level of detail to represent the inner and outer planets, and World Wide Web pages that included information about the planets as well as VRML planet close-ups. This type of work indicated an understanding of the complexities of doing modeling activities. It also, again, demonstrated student understanding of the content being modeled. Learners did have difficulty tying the entire project together. They had most of the pieces developed, but did not synthesize them into the framework they designed. They also had difficulty developing elliptical planetary orbits and in the end substituted the easier one to construct a circular one.

Learning in SAC97

Learning was first evaluated by examining differences in students' understanding of the scientific method before the camp started and after it was completed. Specifically, students were asked what the scientific method was, with all answers being evaluated in terms of those features traditionally depicted in textbooks (hypothesis, results, analysis). Significant differences were found between pretest (M = 1.19, SD = 1.49) and posttest (M = 1.88, SD = 1.36) scores, $t(20) = 2.73$, $p = .011$. Specifically, students recognized the value of developing a hypothesis and the need for developing credible methods that justify the findings as valid. Overall, these results suggest that students' knowledge of the scientific method did increase over the course of the camp. It is important to note that these gains did not result from didactic lectures in the classroom. Rather, the students' understanding arose from engaging in practices alongside, and under the guidance, of the more knowledgeable scientists within the context of practice.

Learning was also evaluated by examining differences between students' application of the scientific method both before the camp started and after it was completed. Students were asked to read and respond to a scenario and then apply the scientific method to the scenario. Significant differences were not found between pretest ($M = 1.24$, $SD = .76$) and posttest ($M = 1.66$, $SD = 1.39$) scores, $t(20) = 1.88$, $p > .05$. These results suggest that the students' ability to apply the scientific method did not increase over the course of the camp.

Although SAC97 did provide an environment in which students studied science, SAC97 had the additional opportunity to support students' appreciation of the fundamentally situated nature of science; that is, the evolution and adaptability of the scientific method when applied within the context of varying situational demands (Knorr-Cetina, 1981; Latour & Woolgar, 1979; Roth & Bowen, 1996). The fact that students did not improve their ability to apply the scientific method, coupled with interview and field note data, suggests that students may not have developed an appreciation of how to adapt the scientific method to novel contexts. This may have resulted from the fact that in SAC97 many of the problems were well defined and it was the scientists, not students, who had the primary responsibility of defining both the problem and methods used in trying to understand the problem. Furthermore, the circumstantial (situated) nature of science was minimized in that directors, teachers, and scientists wanted to provide as much of a tightly controlled experience as possible. Although this emphasis increased the possibility that students experienced applying all of the steps of the scientific method, it may have had the undesirable effect of preventing students from applying their own problem frames and appreciating how one adapts the scientific method to varying conditions.

Learning was also evaluated using the authentic outcome measure of student presentations. Presentations in all groups were complex and scientific. The presentations provided evidence of students' skills in using the presentation software, students' understanding and implementing the scientific process, and students' presentation skills. Presentations included digitized pictures that the students had taken, as well as those already taken by the scientists. They also included self-produced graphs representing analyses of data, and in some cases illustrative drawings of students' work. All presentations were distributed across group members, with each apprentice having a particular set of slides and content for which he or she was responsible.

All student presentations had over a dozen slides, which illuminated the steps they took in completing their scientific investigation. A rubric was designed to analyze the completeness and quality of the students' presentations, especially in relation to the scientific method, including whether they clearly stated the problem, introduced the hypothesis, explained the tools, reviewed the results (utilizing and developed graphs and tables), and discussed the importance of the findings. With 100% rater agreement between the two raters, average scores were 10 out of 11 possible points. In fact, one of the raters who had a Master's degree in Physics continually commented on how impressed he was with the quality and sophistication of the presentations. All groups learned about doing successful scientific presentations, articulating their data clearly and completely, with the most common limitation being the lack of discussion regarding future implications.

Discussion of Learning in FC97 and SAC97

FC97 learners learned about VR, VRML, or Quick Time VR (QTVR); the World Wide Web; and a content area in the construction of virtual worlds. SAC97 learners learned about new areas of science, but most important about the process of real science. The comparison between the two camps can be illustrative. FC97 learning came from what Perkins (1991) called the "setting of the problem" and the development of the practices within a constrained conceptual environment. Their learning came through the practices they developed, specific goals they set, and understandings that were constructed to meet their own project goals. There is a creative and critical aspect to their learning through the construction of new ideas, new ways of doing things, and then trying them out and evaluating them based on goals. Putting learners into these types of environments does not always assure a dynamite end product. As we mentioned, the Solar System group's project fell short of their own, their mentors', and the directors' original goals. However, that does not mean to say there was any less learning occurring. It was clear that there were many important learning outcomes that were met in the Solar System group.

In many ways, SAC97 learners provide a sharp contrast to the FC97 learners. Their learning can not be seen as either creative or critical. The practices they came to understand represented an appropriation from the community, not a creative endeavor. The practices were to be accepted on blind faith based on the scientist's unspoken, but obvious, authority. Their learning of the practices had no critical aspect, it was done to scientist specifications. This was not because of some arbitrary pedagogical notion of the scientist, it was based on history, efficiency, and external demands of the practice. Thus, what students learned did not come from their construction of new ideas, new ways of doing things, and then trying them out and evaluating them based on their goal. Rather it came from the example of the experts, then appropriation from the expert, and was evaluated by the experts based on issues or goals that may have not been fully understood by the student. This may be a factor in why SAC97 learners were not able to apply the scientific method to other contexts in the posttests. Students were not, nor could not be exposed to the problem-setting aspects of science without completely changing the camp by having the scientists "dumb down" their science, because their science requires graduate degrees to understand the issues in the problem setting.

SAC did have a number of advantages: for one, learners were exposed to general scientific issues in the rich context of the community of practice. The practice of data collection is a prime example. There was a rich discussion between subjective measures (coding rat behavior) and objective measures (computer counting the number of times the laser beam in the cage was broken). This discussion is described in countless science textbooks and lectured as a part of countless science courses. The benefit for these learners was that the concept was both introduced, exemplified, and used in the rich context of the community of practice. This connection and embeddedness of what these learners came to understand is the power of SAC97. This connection may have powerful implications for lifelong learning as well. If learners can make and keep this connection with science, they may have a leg up on using that connection throughout their lives in learning science. In contrast, although students at FC97 did get to "own" the entire process, they did not observe the connections and see how experts themselves valued and utilized these same processes.

DISCUSSION

The central goal of this article was to compare and contrast two learning environments, one based on constructionist learning theory and the other based on legitimate peripheral participation or apprenticeship learning. In this section we explore the overall similarities and differences between the two environments, focusing specifically on issues of authenticity, ownership, power, and task structure. We have found that the strengths and weaknesses of these two learning environments cluster around these four constructs in a rather provocative way. These issues were identified based on a combination of theoretically relevant constructs that have been used to distinguish constructivist learning environments from didactic ones, a synthesis of the earlier results section, on reviewers' feedback, and on further examination of those issues discussed in the constructivism and apprenticeship learning literature.

Authenticity

To different degrees and for different reasons, students in both camps were participating in authentic activities using authentic tools. Currently, and partly in response to the more general movement of situated cognition and apprenticeship learning (Brown et al., 1989; Collins et al, 1989), we are witnessing a pedagogical shift toward establishing "authentic" science experiences (Krajcik et al., 1998; Means, 1998; Roth, 1998; Roupp, Gal, Drayton, & Pfister, 1993). Authenticity, however, is a concept that is referred to by many and yet remains poorly defined. In designing a learning environment intended to support authenticity, one has to come to terms with what is meant by authentic and to whom (Shaffer & Resnick, 1999). Therefore, "discussions of authenticity must consider authenticity in terms of the life-world of the student and in terms of a target professional domain" (Barab et al., 2000, p. 40). Here, we define authenticity as the quality of having correspondence to the world of scientists, and suggest that this can be achieved through simulation or participation models for establishing authentic learning environments (Barab & Hay, 2000).

The simulation model is predicated on the assumption that the classroom environment (both in terms of the goals, practices, instruments, and peer relationships) should be made as similar to communities of practice outside of the school as possible.

> This term [simulation] refers to pedagogical design intended to support students in reproducing the "doing science" practices of real-world practitioners, but in the context of classroom and as a part of the culture of schools-a simulated "community of scientists." (Barab & Hay, 2000, p. 12)

In contrast, the participation model of doing science emphasizes engaging students in doing science "at the elbows" of scientists, in their laboratories and at their field sites. The participation model of authenticity is predicated on the assumption that the authenticity of a learning activity is dependent on the extent to which learners participate directly in the ongoing practices of a community (Barab et al., 2000). The important difference between participation models and simulation models is that unlike the highly constrained environments (exacting procedural requirements, qualifications, and goals) of doing science in real-world laboratory situations present in participation models of doing science, in simulation environments (what Senge, 1994, called "practice fields"), students are able to take ownership and engage in all aspects of the problem-solving process.

FC97 students used three-dimensional modeling tools to model the solar system. Their activities were consistent with what astronomers do in trying to understand astronomical phenomena, building models and exploring their dynamics. One of the major factors in giving the goals the air of authenticity was the tools that they used in attaining their goals; that is, they were not "dumbed down" or "kiddy" versions of the real thing. However, students in FC97 were not working with scientists and no scientists were invested in their work. As such, students were doing what scientists do, but in a context created only to support students in their work—what Barab and Hay (2000) described as simulation authenticity. Although the activities may have been authentic in that they were engaged in modeling (practices resulting in the building of a VR world), they were not authentic in that there was an outcome that was meaningful to a real-world community of practice.

SAC learners were doing the science that scientists do, and doing it alongside real scientists—what Barab and Hay (2000) described as participation authenticity. They were investigating scientific issues of import to the community, and there was the expectation that they were helping the scientists. In fact, when one student misunderstood that his work was not useful to the scientist, he became angry and sent an e-mail to the scientist who clarified the misconception. Whereas FC97 took place in a classroom converted for the week, the SAC97 participants were working in the laboratory where real scientists do their work. The fact that students were doing authentic work as part of a community was not integral to the design or success of FC97, based on constructionism, but was a necessary component of the SAC97 environment, which was predicated on apprenticeship learning and legitimate peripheral participation.

Another difference was how the learners viewed success. In SAC97, being a member of the scientists' community was the determiner of success, whereas in FC97 the completion and the quality of their product was the determiner. This distinction needs some unpacking. In SAC97, the actual success of the ongoing inquiry was of little importance to the learners. They were not in a knowledgeable position to make judgments of the success; that would be left up to the eventual reviewer of the eventual manuscript. However, this did not impinge on the learners' enthusiasm, because they trusted the mentor in the direction of overall project and its eventual quality. Their main concern was becoming a member of the community and to effectively act like a scientist. In FC97, the goal was clearly on the product (the solar system, the virtual tour, the play) and their enthusiasm would ebb and flow as they appeared to either be making strides toward success or failing at the completion of the project and their perception of its quality. Consistent across both camps, however, was that there were concrete outcomes that had a clear audience. SAC97 learners viewed their work leading up to the presentation of their research to a "scientific community," and to their families and friends. The FC97 learners viewed their projects as being apart of the camp Web site where potentially anyone on the Internet (relatives, distance friends, etc.) could view their work.

In summary, it is not that learning environments predicated on legitimate peripheral participation are necessarily more authentic than constructionist ones. Authenticity is a more complex issue: one needs to consider the question of "authentic to whom?" There are advantages to both types of learning environments. In terms of the effects of these differences, SAC97 learners clearly had an advantage of better understanding of specific practices of "real science"; however, this was arguably focused on the predictable parts of the scientific endeavor. This included things like subjective and objective data collection techniques of rat behavior, but not the development of initial questions, final conclusion, or the development of new data collection techniques. Authenticity was based in the lab in SAC97 both contextualized and motivated learners through some rather boring techniques. It is conceivable that if these techniques were taught in traditional classrooms, they would not have been well received by these learners. FC97 learners clearly had the advantage of taking a project from initial conceptualization to final completion. In doing so, they developed executive and inventive practices and skills. This included project planning and management, as well as developing a visualization technique to handle the problems of seeing the solar system at different distances. Authenticity was based in an exciting project in FC97 that motivated the learners to develop new skills and produce a product for a clear audience.

Ownership

The ownership was clear in FC97, with students having much latitude in the planning and design of their activities. This is not surprising in that a central tenet underlying Papert's (1991) constructionism is that students will have the freedom to guide the creation of their projects, constructing their own goals, processes, and outcomes. In FC97, for the most part it was their project. However, given the complexity of some of the model building, we see frequent interactions in which the mentor teachers had difficulty giving up the control. Instead, as students modeled the more dynamic and complex aspects of planetary dynamics, the mentors had difficulty letting go and allowing the students to "own" the problem and the solution. A central challenge for constructionists is to determine how to support students in the more challenging areas of their work without stealing ownership.

In contrast, in SAC97, students were stepping into the long tradition and goals of the scientist. To a large extent, the goals, which tools to use, how to use them, and the outcomes were decided for the students. To our surprise, this did not appear to undermine ownership. Instead, students talked to other students about their research, taking much pride in addressing their research question. Scientists, for the most part, had worked to create compelling projects that were both legitimate avenues for their own research yet approachable to middle school students. Scientists appreciated the importance of supporting students in "owning" the problems.

In some sense in science education, ownership and authenticity can be conceived as tensions in that as authenticity increases ownership decreases. This is because as the project or set of activities becomes more authentic to a real-world community, one might imagine that the opportunity for middle school learners to have ownership would diminish. Although this was partly the case, we also found that students in both groups had a sense of ownership, with students taking pride in their work and their completed projects. This is not to say that there is no tension between authenticity and ownership, rather that the increased authenticity of the activities in SAC97 did not appear to undermine students' feelings of ownership over the projects.

Power

In this section, we reflect on the camps in terms of three types of power: student power, instructional power, and community of practice power. First, in terms of student power, the power to define goals, create practices, create outcomes, and set evaluation criterion was given to the campers of FC97. Although there were very real constraints placed by the camp directors on the students, the tools they worked with, and the high-level goals of the camp, these constraints created a "field of play." They did not prescribe exact goals, practices, outcomes, and evaluation criterion. The power to define goals, create practices, create outcomes, and set evaluation criterion was not given to the campers of SAC97. All these elements were determined by the mentor scientist. Said succinctly, students at FC97 could create their learning/doing context, while students at SAC97 had theirs appropriated.

This is probably one of the most fundamental distinctions between LPP and constructionist learning environments. Although this clean distinction did not hold completely across the two camps for their entire camp (remember the solar system mentor being overly "instructive" and the SAC97 campers' "construction" of their PowerPoint presentation), it is a clear distinction between the core activities of the two camps—if not for most of the activities of the two camps. It is also a useful distinction that brings theoretical debate into the focus of real-world specifics.

The question is: What role did power play in the learning environment? There is clear evidence that simple categorization will not work. The lack of power did not correlate with a discernible loss of attention, ownership, group identification, authenticity, acceptance of the goal, persistence to the goal, enthusiasm, or learning on the part of SAC97 campers. We found this more than a bit perplexing and certainly unexpected. For example, the methamphetamine group was told to engage in the rather tedious activity of watching the rat move back and forth in a 2-ft plastic cage for long periods of time, an activity that, in the planning stage, we were worried about being boring for even the most excited and bright student. However, despite having almost no power to define their task and practice, they were as engaged and as on-task as any teacher would have the right to hope for.

We did notice clear differences across both groups when mentors, teachers, or camp directors invoked power in a more directive instructional fashion—instructional power. This power came from the authority of certification (PhD or teacher certification), and through the mentors' position within the university. This can be contrasted with the power of the community and lab that the scientists invoked during SAC97, a type of community power that was not available to FC97 mentors. In contrast, when instructional power was invoked there was a discernible loss of attention, ownership, group identification, authenticity, acceptance of the goal, persistence to the goal, enthusiasm, and, we would speculate, learning—we did not specifically examine learning in those areas where instructionist approaches were used.

Our conclusion is that power is not the core issue; rather, it is the source of the power at issue. When the power came from the community of practice, campers accepted it, but when the power came from the teachers they did not. To put it simply, teachers, through no fault of their own, are in a position that they must say "do it this way because I say so," instead of "do it this way to be a part of the community of practice." And when they said "because I said so," there was discernible loss of connection to important educational dimensions.

In the analysis of power, some of the most important insights come from not just an analysis of what is there, but what is not there. What is not there in SAC97? Friere (1970) argued that what is missing is "the students' creative power to stimulate the credulity" (p. 60). Friere further stated that "knowledge emerges only through invention and re-invention, through the restless, impatient, continuing, hopeful inquiry men pursue in the world, with the world and with each other" (p. 58). Clearly, SAC97 did not foster campers' creative and inventive skills and attitudes. Just as Friere would fear, in SAC97 the goals and means of science were not questioned. This was not the case in FC97, where campers were questioning everyone from mentors to directors to visiting experts. The power role in SAC97 suppressed the creative endeavors and in FC97 it nurtured them.

Task Structure

We characterize the two camps in the terms of normal and inventive. SAC97 was typified by learners appropriating a set of fixed or "normal" practices from the mentor scientists. FC97 was typified by learners using the resources at their disposal to develop and explore inventive ways of doing things. Theirs was a process that was as much fraught with wrong turns and going down blind alleys as making things work, solving a problem, and weighing the options. SAC97 learners had a clean and smooth path created by both the larger community and their mentor scientist. That is not to say SAC97 learners had it easy; in fact, the practices that SAC97 learners engaged in were extremely complex. The point is that they were pre-established and fixed. Successful appropriation of a practice meant immediate success, whereas successful development of a new practice (getting a planet to move) in FC97 simply created the opportunity for success, not its inevitability (does the planet move correctly?).

Similarly, the goals of SAC97 research projects were well defined in their expectations. As in normal science, although the "answers" are not known, both the overall goal (understanding prenatal drug sensitivity) and the specific subgoal (collection and analysis of rat behavior data set) are well defined. In FC97, their goals were much less defined. For example, the Solar System group appeared to actually have fairly well-defined goals, the creation of a virtual solar system. However, this belies the real goal definition. Issues like How many bodies should the model contain?, How accurate should the orbits be?, and so forth turn a seemingly well-defined problem into an ill-defined one. Whereas SAC97 learners' goals were similar in almost all respects (except the actual data) to scores of other research projects the mentor had collected in the past, FC97 learners' goals had to be negotiated within the context of what they could learn how to do, the power of the technology, and the time constraints. This distinction should not be confused with well-defined or ill-defined domains. When comparing the solar system project in FC97 with the projects of SAC97, both domains of science were fairly well defined at the level these learners are engaging in them. The distinction here is the definition of learning environment goal, not the domain.

CONCLUSIONS

The comparing and contrasting of these two learning environments, we argue, is an opportunity to look more generally at the empirical differences between two learning theories that are frequently grouped under the umbrella term of constructivism. In the end, we believe the differences lie in whether the learning environment has a community-centered focus or a learner-centered one. Both environments share authenticity of practices and goals, ownership of the environment by the learners, and a focus on project outcomes rather than tests. Community-centered environments (e.g., SAC97) focus on imparting fixed community practices, and learners are engaged in activities with well-defined goals and subgoals. The definition of success, for the learner, is becoming a community member, and the mentors are invested both in learner development and the quality of the outcome. Learner-centered environments (e.g., FC97) focus on learners' developing emergent skills, where goals are ill defined, where the success is the development of a high-quality product, and where mentors are facilitators, but do not have added investment in the quality of their product.

The search for general empirical characterization of different types of constructivist learning environments cannot be finalized within one comparison between two learning environments. We believe that it can become a catalyst for a new level of discussion on constructivist learning environments—a level where the discussion does not start with an obligatory reference to traditional teaching methods, but rather a way to refine and explore the terrain of what is often nested under the umbrella term of constructivist learning environments.

This terrain will be developed by concluding with a set of common and individual strengths and weaknesses. Both learning environments improved understanding, were authentic to learners and teachers, and had a high degree of ownership (although from different sources). The strengths of FC97 were the opportunity to invent new practices, apply new tools in new ways, and meet new challenges. They were empowered to creatively and critically work through a full range of activities of a project requiring the development of new skills, practices, and knowledge. Mentors were engaged but did not have a vested interest in the outcomes of the project. It was the learners' project. The lack of a history and future of the practices, products, and activity groups formed was a weakness of FC97. There was a distinct lack of efficient progress, a higher level of frustration, and a lack of connection to the community of practice.

In SAC97, the strengths included a clear connection to the community of practice and its related connection of past and future of the practices, the particular project, and the goals of the particular scientific agenda. Learners understood and were relatively skilled at particular techniques of conducting that science. Mentors had a major investment in the product, so there was precise attention to details of reproducing the methods. The major weakness in SAC97 was the lack of inventive, critical, or executive skills and understanding of the scientific endeavor. Campers learned the scientific method, but they did not learn how to use the scientific method in novel contexts.

The discussion that, in the past, often centered on ownership, authenticity, and learning, in the end was not the distinguishing feature nor the strength of these learning environments. In the end, the issues of power, skills and understandings engaged (inventive/critical/executive vs. reproduction), and task structure were the source of much of the distinctions and the relative strengths. We hope to continue to extend these ideas in our future work.

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