The NICE Project: Learning Together in a Virtual World

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Abstract

This paper describes the NICE project, an immersive learning environment for children implemented in the CAVE and related multi-user virtual reality (VR) technologies. The NICE project provides an engaging setting where children construct and cultivate simple virtual ecosystems, collaborate via networks with other remotely-located children, and create stories from their interactions in the real and virtual world.

1 Introduction

The NICE project [10, 11] is an effort to build Narrative-based, Immersive, Constructionist/Collaborative Environments for children. Developed at the Interactive Computing Environments Laboratory and the Electronic Visualization Laboratory of the University of Illinois at Chicago, NICE aims to create a virtual learning environment that is based on current educational theories of contructionism, narrative, and collaboration within a motivating and engaging context.

Designed to work in the CAVE (tm), and related projection-based VR hardware, NICE allows groups of children to learn together both in the same physical location, as well as from remotely located sites. Additionally, a web-based component allows other children to participate from less expensive desktop hardware.

In section 2, we first briefly describe other current work involving VR and education. In sections 3, 4, and 5 we describe the theoretical foundation and the implementation of the NICE project. In section 6 we discuss evaluation, and then finally give our conclusions and plans for future work.

2 VR and Education

Virtual reality environments designed for education typically fall into three categories: networked text-based virtual environments, desktop virtual reality simulations, and immersive virtual environments.

2.1 Text-based Virtual Worlds

Text-based virtual worlds, commonly known as MUDs and MOOs, support real-time interactive use by a large number of users sharing the same virtual world from remotely located computers. The advocates of textual VR cite two educational virtues of text-dependence: the creation of a community context, and the encouragement of reading and writing [3]. Text-based VR has developed a strong connection to narrative and the area of Interactive Fiction, as participants can assume various identities, develop situations cast in story-like formats, and interact with objects and characters [5]. On the other hand, the lack of a specific learning structure and direction may leave many participants floundering without specific goals. The lack of multi-sensory representation may also render MUDs incomplete learning environments in and of themselves, and text-dependence assumes literate children.

2.2 Desktop Virtual Reality

Desktop virtual reality applications on personal computers allow users to walk through simulated environments created via readily available commercial software. Some slightly more expensive systems add peripheral devices to provide a higher degree of interactivity. The VR projects developed using these low-end technologies are limited in size and complexity, and lack immersive and interactive qualities. Typical projects resemble 3D multimedia simulations and may involve the creation of simple models and minimalist worlds, which can be experienced via "walkthroughs" [7].

2.3 Immersive Virtual Environments

Immersive educational environments are being developed using high-end equipment. They are consequently limited to situations with special funding, such as academic and research environments. Most of the projects are developed especially for head-mounted display systems.

A large part of this educational research has been focused on science education, as in the ScienceSpace projects [4]. Other projects such as the Virtual Reality Roving Vehicle, and summer camp programs in VR for students [2] at the Human Interface Technology Laboratory at the University of Washington focus on "world-building" activities, where students create the objects of their own virtual worlds using desktop 3D modeling software. Although this gives the opportunity for students to understand the process involved in creating a virtual setting, the actual immersive experience is limited to a short 4-10 minute visit of the pre-designed virtual worlds.

2.4 The Promise of VR for Education

VR offers promise as a learning tool as it allows access to the unreachable or the unrealizable; it can provide multiple or alternative representations; and it can help make abstractions more concrete [1]. VR is also touted as a medium for interactive, collaborative, and engaged learning. While highly responsive interactive virtual environments can provide immediate feedback and be extremely motivating, they may also foster automaticity, thoughtlessness, and lack of problem solving. Telepresence - the integration of VR and high-speed networking, creates new possibilities for distance learning and the exploration of social behavior amongst remotely located learners sharing the same space. However, as the number of simultaneous users increase, issues of control and the structure of learning will emerge. Virtual environments are also valued as being extremely motivating, especially for students with non-traditional learning styles, but this engagement is due in part to the novelty effect and not necessarily inherent in the design of the learning environment.

The NICE project, which is seeking to explore the potential of this promising tool, is described next.

3 NICE

NICE (Narrative Immersive Constructionist / Collaborative Environments) is an exploratory learning environment developed for use by children between the ages of 6 and 10. It is set on a virtual fantasy island where the fairly large terrain includes a variety of spaces that invite exploration. When the children arrive on the island, they are greeted by the talking signpost - one of the many 'intelligent' guides or 'genies' on the island which directs them to several points of interest. The children can climb down a dormant volcano to access the catacombs beneath the island, look for fish in the sea, or help tend the garden as shown in Figure 1.

In the garden there are several crates of seeds for the children to choose from. When they drop a seed on the ground, the corresponding vegetable begins to grow. The children must make sure the plants are not too close together, and that they get enough water and sunlight. They can water the plants by pulling the raincloud over top of them. When a plant has had enough water, it pops up a little umbrella and the children can pull the cloud away. When the sunlight is too bring the plants put on their sunglasses; when they feel crowded they move restlessly. The children must keep the weeds from crowding out the plants and decide what to do with the flowers which occasionally bloom. They can also shrink down to the size of a mouse to get a closer view of the plants and to explore underneath the soil.

The garden is persistent and continues to evolve, so the kids can come back and check on its progress at a later time. Multiple children can interact with the garden and each other from remote sites. Teachers or parents can participate, either as members of the groups, or disguised as genies. This allows teachers to advise the children in person or to direct parts of the activity from "behind the scenes". They can also determine the pace at which the world evolves; they may choose to see the plants grow very quickly, or, in the case of a school project, extend their growth over the period of a semester.

NICE is an outgrowth of two previous systems: CALVIN and the Graphical StoryWriter. CALVIN [6] is a networked collaborative environment for designing architectural spaces. The Graphical Storywriter [13] is a shared workspace, where young children can develop and create structurally complete stories. Building on elements from these previous works, we have created a prototype learning environment for young users which presents simplified ecological models within a fantasy setting.

This highly graphical, immersive virtual space has pri-

Figure 1: A child (represented by an avatar) planting carrots in the NICE garden

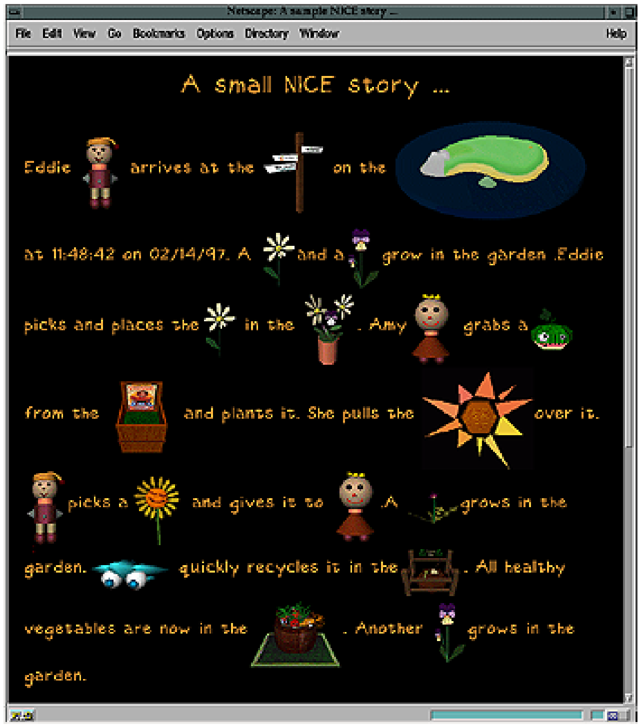
marily been designed for use in the CAVE, a multi-person, room-sized virtual reality system developed at the Electronic Visualization Laboratory of the University of Illinois at Chicago. As the CAVE supports multiple simultaneous physical users, a number of children can participate in the learning activities at the same time. Since the CAVE library can support heterogeneous VR display devices (ImmersaDesk(tm), InfinityWall(tm), BOOM(tm), fish-tank VR systems) children can join in the collaboration from a number of different VR hardware platforms.

NICE focuses on bringing together concepts of constructive group activity and narrative, within the nexus of motivation and exploration. In the following sections we will describe the underlying pedagogical principles as well as the technical aspects of the system.

3.1 Constructionism and Narrative

Constructionism is an approach to learning that has received much attention in the educational technology circles and is being applied to many current educational software projects. It deals with the ways learners assimilate knowledge by engaging in self-directed learning activities which are accomplished through constructive tasks [9]. In NICE, constructive play involves the planting and tending of the garden.

Constructionists believe that learning takes place when engaged in the construction of a personally meaningful artifact, such as a piece of art, a story, or an interactive computerized object [8]. Aside from the garden itself, another product of constructive activity in NICE is the narrative - the stories formed by the kids that participate. The narrative revolves arotnd tending the garden and the reactions or decisions taken while interacting with the genies. Every action in the environment adds to the story that is being continuously formed. The narrative structure captures these interactions in the form of simple sentences such as: “Amy pulls a cloud over the carrot patch and waters it. The tomatoes complain that they are not getting enough water.”



A small NICE story ...

Eddie arrives at the on the at 11:48:42 on 02/14/97. A and a grow in the garden .Eddie picks and places the in the . Amy grabs a from the and plants it. She pulls the over it. picks a and gives it to .A grows in the garden. quickly recycles it in the . All healthy vegetables are now in the . Another grows in the garden.

Figure 2: a small NICE story on the web

This story sequence goes through a simple parser, which replaces some of the words with their iconic representations and publishes it on a web page as shown in Figure 2. This gives the story a picturebook look which the child can print out. The children enjoy this process, especially when they get to take home the written and illustrated version of the narrative in either printed or electronic form.

3.2 Collaboration

Equally important to the construction of one’s knowledge is the experience gained by participation in group activity. Collaboration is emphasized in our framework through the combination of collaborative learning across both virtual as well as physical communities.

The network component of NICE allows multiple networked participants to interact simultaneously with the same virtual environment and each other. These participants may be children, or teachers, or computer controlled agents. Multiple distributed NICE applications running on separate VR systems are connected via the central garden server which guarantees consistency within the shared virtual environment.

Each tracked participant's presence in the virtual space is established using an avatar with separate head, body, and hand as shown in Figure 3. As each person's head and hand are tracked, this allows the environment to transmit gestures between the participants such as the nodding of the user's head, or the waving of the user's hand to the other participants. As the child waves her hand in the real world, her avatar waves its hand in the virtual world. These avatars have sufficiently detailed representations so the participants can communicate notions of relative position to one another with phrases such as "it is behind you" or "turn to your left." Ambient microphones at each site allow the users to talk to each other. When a child speaks, their avatar's mouth moves to help differentiate which character is speaking.

Collaboration in NICE also includes the interaction between the kids and the genies which populate the virtual environment. The genies operate as interface and feedback mechanisms, disguised as helpful character guides in the virtual world. They provide a way to replace menus and other traditional interface techniques with a more transparent and effective method for use by young children. Many times, when developing and testing the system, we use the Wizard-of-Oz prototyping technique where actual people, disguised as genies, simulate agent behaviour. The children may be unaware of which characters in the environment are controlled by the computer and which by a human operator.

Collaboration also involves the social interaction among children located in the same physical space. Theories that emphasize the importance of social interaction in cognitive growth [14] suggest that successful collaborative learning involves more than the final creation of a learning product. Learning that is contextualized in a social setting may involve verbal interaction, collective decision making, conflict resolutions, peer teaching, and other group learning situations characteristic of a classroom setting. With the use of VR technology that supports multiple users in the same physical space, as well as appropriate interaction techniques, a number of kids can participate in the learning activity at the same time, without having to take turns or wear heavy and intrusive hardware devices.

Figure 3: Jim (the avatar) and Eddie working together in the garden

NICE's networking component allows clients other than virtual reality interfaces to participate. For example, a recorder client can be connected to the network that records all of the movements and interactions in the virtual environment. This allows the session to be replayed later during evaluation studies. Monitoring clients can be connected to monitor the state of the NICE island and the state of the network. Web-based clients can also connect and cooperate with the VR clients. We will elaborate more on this in the next section.

4 NICE on the web

Allowing web-based clients access to this immersive virtual environment has several advantages for both the users and the researchers in NICE.

Virtual reality hardware is expensive, and is far from being integrated into the modern classroom; NICE uses a Silicon Graphics Onyx with two Infinite Reality Engines for its graphics. While the number of museum VR installations is growing, the time that a child can spend in an immersive virtual environment is still very limited. The web-based component allows children to extend their interaction with the virtual world beyond the limited time they can spend in the virtual environment itself. We have previously described how the 'story' of the child's experiences on the island can be published on the web, but the web also allows the children to interact with the virtual world.

The web is also used to monitor the current state of the

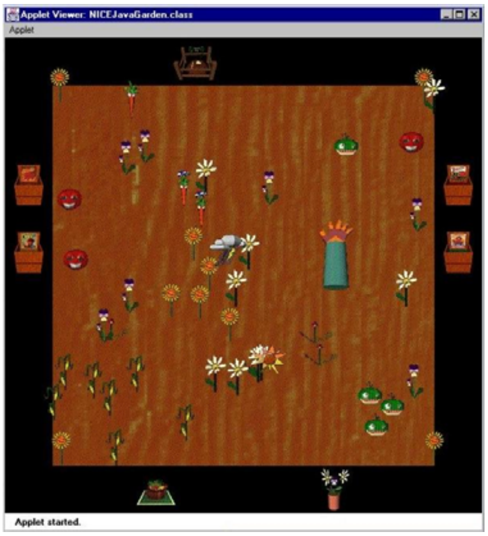
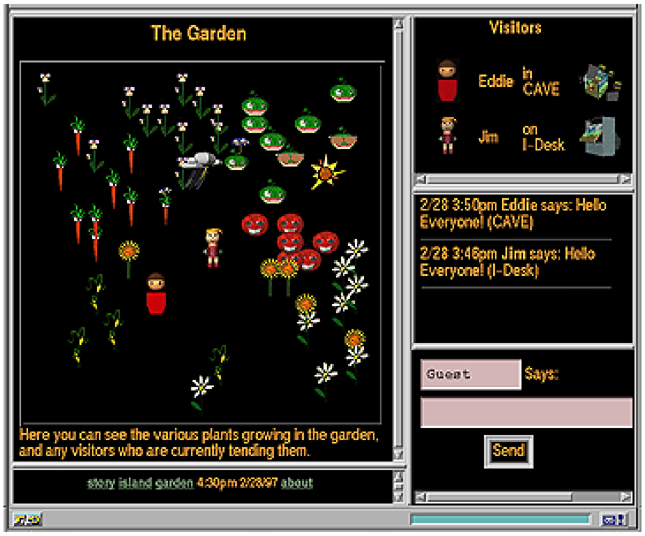


Figure 4: Interacting with the garden through a java applet on the web



Here you can see the various plants growing in the garden, and any visitors who are currently tending them.

2/28 3:50pm Eddie says: Hello Everyone! (CAVE)

2/28 3:46pm Jim says: Hello Everyone! (I-Desk)

Figure 5: Monitoring the garden from the NICE web page

garden, and control various environmental parameters in the environment. The web also makes a convenient way to distribute updated models for the environment to remote sites.

4.1 Collaborating in the Garden

Students without access to a VR system like the CAVE or Immersadesk, can still participate in the collaboration through a web browser. Using a Java applet (figure 4), children interacting with a two-dimensional version of NICE on the Internet can simultaneously share and manipulate the same virtual space as the children in the CAVE. The users of the 2D environment use a 'traditional' mouse and icon interface to interact with the garden, but have the same ability to pick and plant as the VR users do. These desktop users see the virtual reality users as 2D icons on their screen, while the VR users see the desktop users as 3D avatars in the space.

The web-based users can converse with the other virtual and remote participants and coordinate their actions by typing in the provided chat window - a feature which resembles text-based virtual environments. We are currently moving towards streaming audio from the virtual world to the web-based clients to improve communication with the web-based clients.

4.2 Monitoring the Garden

The NICE web page shown in Figure 5 keeps track of the current state of the persistent virtual environment including who is currently visiting the island, and the current state of the garden. This allows the users and developers to monitor the state of the virtual environment from a desktop computer with a web-browser and an internet connection. The web is also used to monitor the state of the network connections, keeping track of more detailed information than is given to the casual users, allowing us to further refine our networking protocols.

4.3 Controlling Garden Parameters

Visual languages have been shown to be ideal programming languages for children because they can map abstract concepts to pictorial elements that they are more familiar with [12]. We envision a visual language where the growth model for the garden and the behaviour of the animal genies may be programmed by manipulating iconic representations of data and operators, provide immediate feedback, and can be learned quickly by the kids.

The parameters in the garden server controlling the growth of the plants and vegetables on the island can be manipulated through this kind of interface. Our current prototype is a two-dimensional interface where the child, by clicking and dragging icons to control the ecological model, can observe immediate feedback and effect in the three-dimensional VR environment.

4.4 Downloading Models

All of the models used in NICE are VRML models stored on the NICE web server, allowing us to leverage the existing distributed server resources of the web. Each VR user keeps a local cache of these models. When the environment is first launched, the web server is checked for any newer models, and if any are found they can be immediately downloaded, allowing the VR interface to automatically upgrade itself.

Similarly, each user can create their own VRML avatar and make this avatar accessible from their local web page. When they join in to the collaboration, this avatar is automatically downloaded to the other users. This way each user is not constrained by the pre-existing avatar models but can create a very personal avatar to represent themselves.

5 NICE Networking

NICE's networking architecture was based on experiences with several previous collaborative immersive environments. The networking protocols selected were tailored towards the characteristics of VR data, and the ability to easily enter and leave the environment from anywhere on the internet.

The number of participants is limited only by bandwidth and latency of the network. In practice we have had as many as 16 simultaneous participants spread over 3 continents (North America, Europe, and Asia). Multiple distributed NICE applications running on separate VR systems are connected via the central garden server to guarantee consistency across all the separate environments. The NICE garden is persistent, as the garden server is constantly running and will attempt to reestablish lost connections in the event of failure. This allows users to casually join in the collaboration whenever they wish. The garden continues to evolve even if no users are present: the plants continue to grow; animals may try to eat the vegetables; and weeds slowly take over the garden crowding out the other plants.

NICE uses a combination of reliable and unreliable protocols. For the information from the garden server which controls plant growth, picking, and planting, a reliable TCP/IP connection is used. For the avatar position and orientation data, multicast and / or UDP is used. Multicast is preferred when the collaboration is within a subnet, but it is inconvenient to have to set up multicast tunnels for casual long distance collaboration. So, a router is continually in operation which broadcasts packets between multicast and UDP connections. Multiple routers can be chained between distant remote sites allowing some clients to communicate via multicast while others use UDP to share the same information. Figure 6 shows a typical set of connections in NICE.

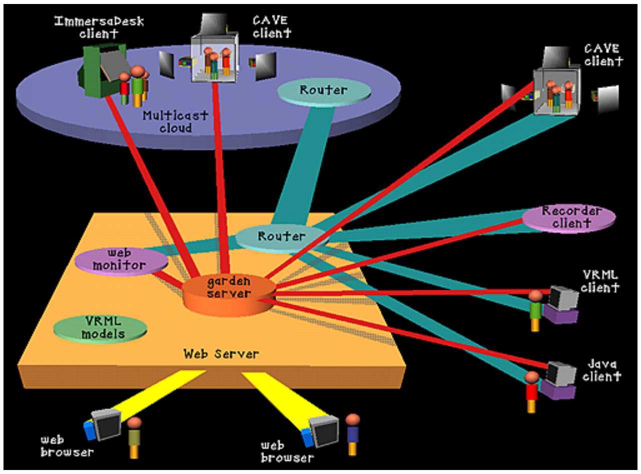


Figure 6: Typical NICE networking connections - all of the interactive users are directly connected via TCP/IP to the garden server running on the NICE web server. A CAVE, a Java client and a VRML client are connected directly to the router on the web server through UDP. A CAVE and an Immersadesk which share a common multicast subnet are also participating in the collaboration through a local router. The session is being automatically recorded, and two users with web browsers are watching.

The garden server and a UDP router reside on the NICE public web site. This allows any CAVE or web browser to join into NICE from anywhere on the internet. NICE has performed robustly in transcontinental collaborations at SIGGRAPH '96, Supercomputing '96, SIGGRAPH '97, and to Japan and the Netherlands at Supercomputing '97.

As we want to allow connections to the Java interface even for users with 28.8K baud modems, a certain amount of filtering is necessary to allow those users to interact in real-time with the VR users. Filtering is performed at the router on the packets containing tracker information since this is the most abundant data and loss of small amounts of this data will not greatly affect the consistency of the world.

6 User Studies

It is important to investigate the educational efficacy of VR in specific learning situations and broader learning domains, and to develop new rubrics of educational efficacy that compare it to other approaches. In practice, however, the assessment of VR technology has been focused primarily on its usefulness for training rather than its efficacy for supporting learning in domains with a high conceptual and social content.

The education world would argue that using paper and pencil, in the form of standardized tests, is not an effective way to evaluate a virtual learning experience. As VR is a dynamic learning tool, evaluation should be tightly coupled with the actual learning process. Following the authentic assessment model, learning in constructivist learning environments is directly related to its evaluation. Moreover, considering the immature nature of the field at this time, it is important to apply multiple measures of learning and performance.

6.1 Methodology

In the Spring of 1997, we observed a total of fifty two children, 6-10 years of age, while interacting with each other and the virtual environment. Before their VR experience, the children completed a set of pre-test questions as well as concept maps, aimed at testing their ability to implement what they plan and orient themselves in the virtual world. Two groups of children at two physically separate virtual reality systems were studied each time. Each group included 4 children, one of which was chosen as the leader or coordinator of the task. The two groups collaborated remotely, represented by the avatar of their leader, to create and maintain a garden similar to the one they planned out before entering the virtual world. In addition to the two avatars sharing the same virtual space, an adult acting as teacher was disguised as another avatar and participated from a third VR system. The teacher-avatar served multiple purposes: to guide the children on their task, to facilitate their discourse while in the environment, and to be part of the learning process while observing and evaluating it. In this way, learning and assessment took place simultaneously during the virtual activity. Each session lasted for an average of 40 minutes and was followed by interview questions, drawings, and an essay completed by the children. Some observations from this study are given next. These studies are discussed in greater detail in

6.2 Observed Results

A variety of techniques were employed for gathering data, both embedded in the computer and external. The observed results were collected by converging the multiple pieces of data gathered through observation, interviews, and questionnaires, and were grouped according to an evaluation framework which was designed to take into consideration the unique aspects of the medium. This framework included guidelines for the study of the results with respect to their technical, orientational, affective, cognitive, and pedagogical aspects.

Although the technical and physical issues concerning the use of this new technology by children were not the primary focus of these studies, several general observations were made. The children had little difficulty learning how to use the interface technology and displayed minimal instances of physical fatigue. They did, however, feel limited by the technology in terms of their ability to orient themselves and these technical limitations hindered both usability and learning.

It is generally argued that the affective factor, encompassing interaction and engagement, is one of the most important advantages virtual reality has to offer to education. Indeed, during these studies all children were extremely motivated and continued to be engaged throughout multiple sessions and after hours of participation. Most importantly, however, we observed that the children's engagement was not limited only to increased motivation. The amount of interactivity and engagement directly influenced the outcomes related to the effectiveness of the learning process. Learning was directly tied to the children's level of engagement: the ones actively involved were more engaged and motivated to complete a task and consequently understood the model employed by the NICE garden. The leaders, the ones controlling for the most part the interaction, retained the most out of the experience, while the children that were less engaged did not understand the concepts as well. While the above suggest that 2nd graders can work effectively in VR, it is much harder to conclude whether anything conceptual was 'learned' during this experience. Pre-study questions and interviews showed 12 percent of the students had a good understanding of environmental concepts, while 35 percent did in the post-study. Of the 35 percent, 75 percent were leaders of their various groups. Our studies are now focusing more on this cognitive area

Additionally, our observations indicate that the use of teachers as avatars in the environment was pedagogically effective especially with regards to collaboration. The teacher, participating as another character in the world, acted as mentor "from behind the curtains" and helped keep the children on task. Nevertheless, the teacher was in some instances still perceived as an adult and had to spend time attempting to keep order -not unlike a real classroom.

These studies provide only preliminary observations in the area of virtual reality learning. They may serve, however, as a base for further exploration in the area of virtual reality evaluation and address issues in the design of virtual learning environments.

7 Conclusions and Future Work

Although the cost and size of the CAVE, or even smaller VR technologies, prohibits their use in today's classroom, efforts are made to conduct studies at classrooms with portable VR systems. As the technology continuously decreases in cost and increases in power, more museums and cultural centers are beginning to acquire multi-user VR systems which allow for many children to participate in the experience at the same time.

While we continue our studies, we are using experience gained from the previous studies to improve the virtual environment. In the area of interfaces, we are refining the interface by developing more natural modes of interaction that improve the direct manipulation of the environment. In the area of the garden itself we are working on a scalable growth model where younger children would see a simpler model, while older children would see a more complex (and realistic) model. In the area of collaborative learning we are investigating issues of self representation, non-verbal communication, and the use of VR as a way to enforce role differentiation.

NICE has also served as a valuable technological and educational prototype environment for several other collaborative educational worlds we are currently creating.

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