Learner Articulation in an Immersive Visualization Environment

Joan M. Mazur
University of Kentucky Center for Visualization and Virtual Environments
100 Quality Street, Lexington, KY 40503
jmazur@uky.edu

Cindy H. Lio
University of Kentucky College of Education
Department of Curriculum & Instruction
335 Dickey Hall, Lexington, KY 40506
Chlio2@uky.edu

ABSTRACT
Learner articulation, described variously in the literature on cognition and instruction as self-explanation or self-directed generative summarization, contributes to new learning through the process of combining ideas in the course of expressing them. In this observational study, we examined movement, gesture and verbal explanation as 14 undergraduate engineering students explored in an immersive visualization display to understand concepts in basic fluid dynamics. Data from user videos, interviews, and a 3-D graphical tracking tool were analyzed. Approach, observational, and perspectival 'moves' were in evidence to support articulation. Students' dietic, iconic and metaphoric gestures combined with their verbalizations to achieve generative articulations regarding the content. Accuracy of articulations and system features remains an open question.

Author Keywords
Immersive visualization, immersive learning, HCI, and learner articulation.

ACM Classification Keywords
H.5 [Information interfaces and presentation (e.g., HCI)]: Miscellaneous; H.5.2 [User Interfaces]: Evaluation/Methodology.

INTRODUCTION
Students' understanding of concepts in fluid dynamics can be impoverished because available content representations, even graphical 3-D representations such as those provided by commercial software like FieldView, may not be dynamic or rich enough to support novel perspectives that are available in a physically immersive setting. Thus, undergraduate students in a Basic Fluid Dynamics course at the University of Kentucky were observed using a new, physically immersive visualization display—The Metaverse--to explore concepts related to fluid flow. We were particularly interested in learner articulation as it might be supported by the immersive display system. The term learner articulation is "derived from — the act of giving utterance...to force a cohesive explanation and —the action…of jointing or interrelating of concepts and relationships" [1]. Quite literally, then, articulation involves, on one level, putting one's ideas into words. On another more metaphoric level, articulation suggests fitting together ideas into integrated wholes and meaning making. Learner articulation, described variously in the literature on cognition and instruction as self-explanation or self-directed generative summarization, contributes to new learning through the process of combining ideas in the course of expressing them [2]. We believe that this idea of "learner articulation" is an intriguing and potentially highly useful one as we begin to examine the human-computer interaction in environments designed for supporting learning in the form of exploration, inquiry and the achievement of new understandings. We also see that an examination of movement and verbal explanation–what Koschmann and LeBaron term — "the conversation of gesture" has not been fully exploited as a method for showing how users interact with a system to construct meaningful understanding. While the research on learner articulation has often involved collaboration, the students in this study were not collaborating with another student to develop their articulations. Rather, in the more metaphoric HCI sense, these subjects were 'conversing' with the display, manipulating and changing the views through their body movements and gestures and thereby reporting 'running models' – explaining in the moment [3] their insights and questions regarding the fluid dynamics content.

THE METAVERSE IMMERSIVE ENVIRONMENT
Despite impressive hardware advances, the primary modes of computer-based communication and collaboration remain largely unchanged. Users still interface with computer systems via the conventional keyboard, mouse, and monitor/windowing system and communicate with one another using 20+ year old mechanisms such as electronic mail and newsgroups. Even new and exciting capabilities, such as (multiparty) video-conferencing and real-time navigation of 3-D models, have had a limited effect because they are constrained to the conventional keyboard/monitor interface and are often subject to inadequate network support/bandwidth resulting in disappointing interactions (blurry pictures, annoying pauses and skips, sluggish

response, postage-stamp size video, etc.). Other emerging technologies that break free from the conventional interface, such as ‘virtual reality’ systems, ‘augmented reality’ systems, and ‘immersive“ systems’ (e.g., CAVEs) are typically special-purpose environments designed according to rigid (i.e., inflexible) specifications. They are difficult to install, calibrate, and maintain, and are too expensive, large, or complex to be used by the typical computer users working in an office, classroom, lab, or at home. The Metaverse is a synthesized world that combines computer-generated elements and real-world elements, allowing them to co-exist thereby breaking the physical barriers of time and space that would normally constrain them. To fully participate in this meta-world, users must access it through an interface (called the Metaverse Display Portal) that is 1) visually immersive, 2) interactive, and 3) collaborative.

THE CORE LABORATORY DISPLAY

Thus far, evaluation activities have taken place in the Collaboratively Rendered Environments (CoRE) display. The CoRE is a multiprojector, multi-PC display system that automatically calibrates the position of cameras and projectors, corrects for projector overlap and renders a seamless display on arbitrary surfaces. The display tracks users’ motion within the environment and reacts to users’ head motion by modifying the rendered content appropriately. In contrast to fixed, high-end immersive displays, or head-mounted displays, the Metaverse project, as well as a number of similar research programs promise to provide users with an immersive, nonrestrictive environment for relatively little cost and with little modification of infrastructure.

DATA COLLECTION CHALLENGES

New methods for data collection are suggested by the unique spatial and temporal aspects of the Metaverse environment. For example, we needed a tool to support situated evaluation techniques that were used to describe interactions, applications, and issues supported by the multiple points of view (researcher, designers, multiple backgrounds of users etc.). A transaction recorder, referred to as the Meta-situational Tracker (MST), was developed to record physical and temporal user data that will supplement the use of more traditional methodologies such as interviews, observations, and survey data.

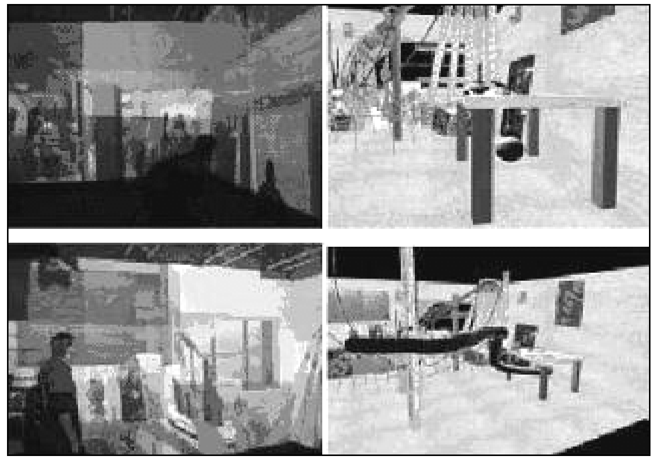

Figure 1. User’s motion visualized as a trajectory of viewpoints over time. Example of the Meta-situational tracker in use (top left). User explores the 3-D environment beneath a virtual table (top right). User’s position (bottom left) is recorded and presented as a sphere in the scene (bottom right).

The Meta-situational tracker, shown in Figure 1, provides a controllable visual display of a user’s location within the display environment either in real-time or in ‘playback’ mode by loading a previously recorded session. Researchers can view the environment being visualized by a user, the user’s position within the environment, and the statistical information about the visualization session (frame rate, average user velocity, etc.). The tool is interactive with a GUI controller (Figure 2) that allows researchers to rotate the scene as well as control the playback of previously recorded sessions. The transaction recorder outputs categories of data: 1) Feature extraction - what aspects of the environment are used and how? 2) Feature evaluation - what did the record show resulted from the action? 3) Evidence accumulation in an aggregate of time spent performing certain actions and the frequencies of those actions.

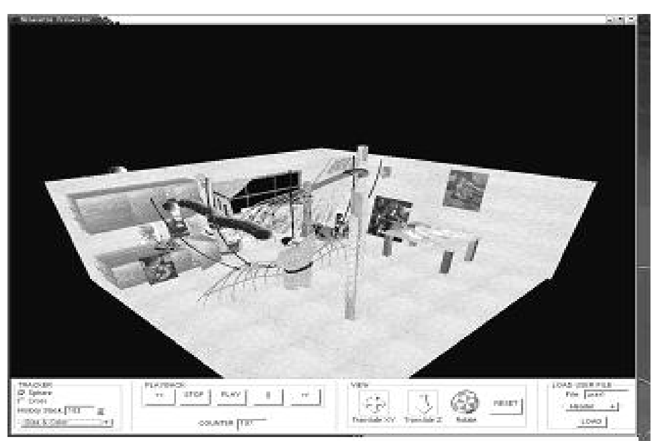

Figure 2. The MST GUI for researcher access and analyses.

DATA COLLECTION IN ME330 BASIC FLUID DYNAMICS: FALL2003

The initial data collection for the Metaverse Project with actual students was conducted in Fall 2003. Undergraduate engineering students' use of the immersive environment focused on the course content of ME330, Basic Fluid Dynamics. ME330 met three times weekly and the professor conducted a 'recitation' session, during which he reviewed and took questions from students whose schedules permitted participation in this extra session. Of the 25 students in this Fall's group, 11 were not able to attend the recitation due to scheduling conflicts. Given the time/content constraints of the regular class schedule, the recitation students were the voluntary participants in the Fall data collection.

Content rendered for the immersive display was an animated "Poor Man's Navier-Stokes" equation developed by the professor. Prior to freely using and exploring the display, the 14 students (13 males/1 female) were shown a brief digital video of the instructor using the display as an advance organizer. Students were videotaped and the MST engaged. Immediately following their use, students were interviewed using their own taped exploration session in the display as a prompt. Students also completed an immersion questionnaire (IPQ) and discussed their understanding of the content representation.

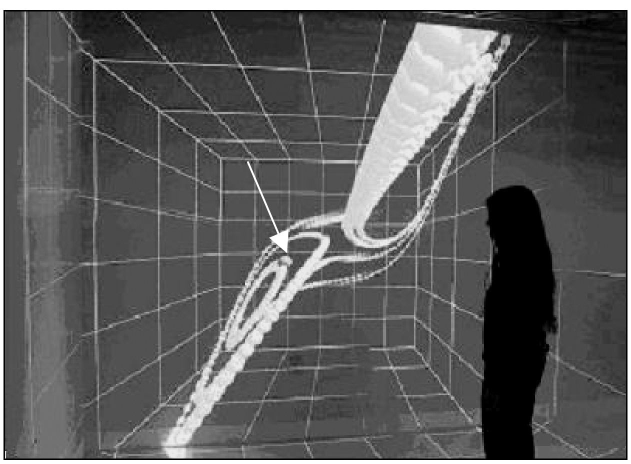

Figure 3. Student observes the chaotic behavior of the "Poor Man's Navier-Stokes" equation model. Arrow pointing at a red ball represents the latest version of the trajectory as it moves in time.

The basic concept of Poor-Man's Navier Stokes representation could be expressed with a real-world example of a drop of cream in a cup of coffee. As one stirs the coffee, a chaotic yet predictable flow ensues. The red ball, as indicated by the inserted arrow in Figure 3, shows the leading edge of the drop of cream swirling in the cup while the green trails, shown as white trajectories, show the path of the erotic turbulent fluid flow over time.

Data Analysis

The two authors viewed the student videos independently for evidence of students' use of dietic (pointing) [4], iconic (representational) [5] or metaphoric gestures [6]. As physical body movement can affect the views of the immersive environment, we also performed a descriptive analytic review of users' actions within the display to seek for general patterns of whole body movement (as opposed to gestures alone). Individual student's combined use of movements, gestures and verbalizations were compiled as 'episodes' of 'articulation' of particular concepts or principles related to the temporal movement of a fluid packet in space (as represented in the immersive display).

Findings

Orientation and Navigation

Students in this group displayed three basic holistic 'moves' within the immersive display. The first type of move was an *approach* move. This action, an initial orientation of the student to and within the immersive display, was characterized by either a reticent or an aggressive approach. Only two (2/14) students were reticent and one of them was the only female participant in our sample. The others, however, moved forward into the display and reported they were not hindered by the novelty. We were surprised at the second distinctive move, which we termed an *observational* move. As the fluid packet in the animated display swirled in a figure 8 trajectory (Figure 3), it was possible for the user to block the RF controller disk, essentially stood still to watch and examine the behavior of a particular region in the equation model. Nine students employed this strategy (9/14). The third type of move observed was a *perspectival* move. In this action, a student would move strategically to get 'around' or 'under' the abstract visual representation to view. This move is completely unique to working in an immersive display, and one quite literally cannot get 'under' a 3-D representation in a non-immersive setting. The difference between these two moves is interesting. In the *observational* move, the student was stationary. In the *perspectival* move, the student moved fully and used body positions and gestures to achieve the desired view of the equation. Only two students could not negotiate this type of move (even when prompted), however, the amount of time spent in achieving a particular view or remaining within it, varied greatly (from 3 – 25 seconds per episode).

Gesture, Verbalization and Learner Articulation

Adopting procedures outlined by Koschmann and LeBaron [2], the enumeration of gesture types (dietic, iconic and metaphoric) was recorded for each student. Verbalizations of content were related to gestures through a process of transcribing the videotapes and interviews, and matching the gestures with the verbal explanations, in particular, 'episodes' that contained obvious articulation of concepts or principles of the Navier-Stokes equation. We selected two episodes of content explanation for each student, designating ones that were either most salient to the displayed representation or were proportionally longer than other episodes for that student (thinking that 'running models' take some elaboration time). Our preliminary analyses have shown some suggestive patterns.

Dietic gestures were used to denote non-process elements of the fluid dynamics flow represented by the Navier-Stokes equation. For example, students would point to a red ball leading the animation strands and say, "that's drop of cream in the cup." Or "those lines are the cream swirling around". Dietic gestures were also used for query. One student pointed at the black space in the representation and said "What's *that?*" Iconic gestures were used primarily to articulate processes that students inferred from the immersive representation. For example, several students used an iconic gesture of a figure eight to represent that chaotic nature of the flow as they were within the center of that very immersive figure 8 representation. One person repeatedly used iconic gestures to refer to the 'random' flow (a misconception, the flow is chaotic, but not random). Finally, metaphoric gestures were used rarely. Only two students (2/14), both males, were observed using metaphoric gestures. Their transcripts indicate they were articulating highly abstract elements of the representation (packet flow) and were using a spiraling motion of their hands to articulate the oscillations over time and through space. The use of metaphoric gestures by these students reflects findings similar to those reported in the literature [6].

CONCLUSION

The work presented in this paper brings these newly described insights in learner articulation to the HCI arena. We believe that future studies of user feedback and explanation as learner articulation will spur HCI researchers to conduct fine-grained analyses of the physical and cognitive articulations of the 'running models' as users learn to interact with immersive visualization systems and the content provided within them.

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