Under Pressure: Using Technology to Promote Deeper Understanding in Environmental Science Topics

Arunan Rabindran
Robert Kooima

Jiexin Lian
Jason Braasch

ABSTRACT

This article proposes a technology-enhanced scientific inquiry project for middle school students (5th – 8th graders) as a means of facilitating children's conceptual understanding. The design attempts to harness students intuitive understandings (which are often counterproductive to learning) in aiming to afford students opportunities to actively construct more scientifically accurate understandings of air pressure as it underlies weather patterns. Students are immersed with and embody the scientific phenomenon, manipulating air pressure configurations and weather patterns in their classroom. Simulations are used within the physical space based on video-based tracking and projection. It is predicted that assessments for scientific understanding (i.e. pre and post concept maps, and far-transfer tasks) will illuminate marked improvements regarding the experimental group's conceptual understandings relative to a control group.

INTRODUCTION AND RATIONALE

Air pressure and its relationship with weather patterns can be quite difficult for students of various ages to understand [6]. Of greatest concern are the conceptual difficulties facing middle school students (5th – 8th graders), particularly because air pressure underlies various weather-related scientific phenomena focused upon in their curricula [3]. Student difficulties often relate to their intuitive understandings about the world around them. For example, many have noted that children intuit pressurized air movement as unidirectional and linear, a conception that often impedes instruction designed to convey the more scientifically accurate relational causality [5, 10, 9]. Moreover, middle school students tend to differentially attend to the concept of air pressure in their explanations of scientific events; that is, they tend to understand air pressure when there are obvious effects [4]. On the other hand, when the effects are less obvious, they believe air pressure is absent rather than in a state of balance within the system as a whole [3, 11, 9, 10]. Though these intuitive conceptions may be adequate to explain day-to-day events, they can often be "at odds" with the accepted scientific conceptions, ultimately inhibiting deeper, more complex understandings [7]. Therefore, it is of interest to clearly delineate the types of preinstructional understandings that students hold, and, more importantly, to offer instructional practices that may instantiate conceptual change towards the accepted scientific understandings.

It may be that students are not being afforded the opportunities to actively make sense of air pressure's role in weather patterns. Passive transmission of information, indicative of teacher-led and textbook-based instruction, may not provide these opportunities. As a result, students may exhibit resistance to updating their representations and may continue to hold on to these weaker intuitive models. Learning these rather difficult concepts and relationships may warrant scientific inquiry-based learning environments. Inquiry-based science learning, as specified by the National Science Education Standards [13] and the Benchmarks for Science Literacy [12], is valued because it has facilitated deeper scientific understandings in a host of different domains and situations. It may be that harnessing students intuitive understandings of the relationships between air pressure and weather may afford students opportunities to reconceptualize their understandings, the result being substantial conceptual change [7]. Therefore, it is our objective to investigate the relative importance of student agency in science learning, with particular attention to the affordances of technologically-enhanced inquiry-based learning environments, specifically targeting the conceptual relationships between air pressure and weather patterns. Implementing this type of instructional interaction may help remediate alternative preinstructional conceptions that students may hold because they are allowed to practice valued scientific reasoning skills (i.e. developing and testing hypotheses) about the target concepts: air pressure-weather relationships. In affording students these opportunities, we predict there will be substantial learning opportunities as their overall knowledge organization will likely begin to align with the more accepted scientific understandings.

PARTICIPATORY SIMULATION

Participatory simulations plunge learners into life-sized, computer-supported simulations, creating new paths to scientific understanding. It also creates a scenario, mediated by a set of underlying rules that enable inquiry and experimentation. [15].In this project, we design a set of participatory simulations to tutor the students towards the relational causality of air pressure. With the help of video projection and video-based tracking, the students are transformed into high-pressure or low pressure air mass in a weather system. The students are given the goal to make it rain in a specified area of the classroom. In the classroom, some position is marked as a "water body" (see Fig.4 and Fig.5). The distribution of students in the classroom simulates pressure systems, imbalance between pressure systems and the development of winds. When winds blow over the water body from high pressure area to low pressure area, they pick up moisture and it rains in the low pressure area. Through participating in the experiments, the students are expected to learn the following: (1) Wind is created between high and low pressure systems, and not when pressure systems are less disparate; (2) The created wind can pick up, accumulate, and displace moisture towards an area of low pressure. Consequently, they learn the fact that air-pressure exhibits a relational causality.

Compared with other approaches, the participatory simulation approach has unique advantages. By this approach, experiments are built on notions of social and tangible computing in physical space, and these new experiments allow students to “dive into” a learning environment and directly engage with the complex system at hand. The students are granted the freedom to co-construct hypotheses and are provided an environment for unlimited hypothesis testing. As a result, their hypotheses can be iteratively evaluated and modified. Manipulating air pressure patterns results in subsequent changes in weather patterns. By physically interacting with each other to solve the shared problem, the participants can significantly benefit from the power of group working and develop deeper understandings of the relationships between air pressure and weather patterns.

Some people may argue that participatory simulation-based experimental design may oversimplify the relationships between air pressure and weather. Although the real mechanism behind air pressure and related weather patterns are much more complicated (e.g., seasonal differences), but a well-designed set of experiments would be able to capture the dominating causal mechanisms and filter out the relatively unessential information. A simplified model can not fully describe the reality, but provides better methods for children to understand the core underlying mechanisms.

STAGES OF INQUIRY

Students participate in three phases of tasks (per each experimental prompt) given in the following order: **1) Pre-Inquiry 2) Experimentation 3) Post-Inquiry**.

In the **pre-inquiry stage**, students construct concept maps and answer items couched in everyday events. These measures provide evidence of the quality and organization of students’ preinstructional understandings of air pressure and weather patterns. Such methods can establish the many ways people intuitively mentally represent concepts and, in turn, document how representations may change over time as a result of our instructional remediation [14]. Regarding the concept mapping task, students will be provided with cards holding generic actions, descriptors, agents and relations (see Figure 1 for an example pre-inquiry student response). Students will be asked to use the cards to show how they understand each concept and will provide think-aloud verbal protocols in explaining their constructed response.

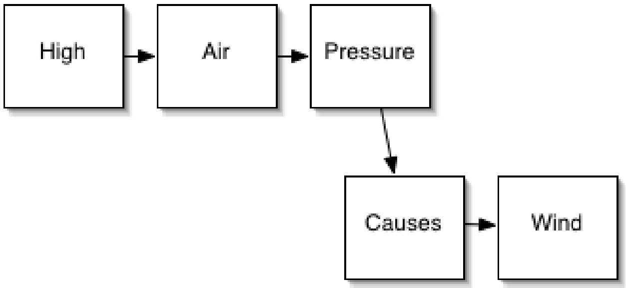

Figure 1. An example pre-inquiry concept map

During the **experimental** stage, students will be given increasingly more complex inquiry prompts. They will be told they are pressurized air masses (divided into some high and some low) and their object is to complete the specified task. There are three sequentially asked questions and they are as follows: “How do you make wind in this room?”, “What can you do to make it rain here?” and “How do you stop the rain that is occurring in the room?” Students might start by exploring the physical space and begin to propose hypotheses and test co-constructed hypotheses. As they start to align into high and low pressure air masses, the simulation will respond regarding the representative weather patterns.

During the **Post-inquiry** stage, students will be randomly split up into several groups to discuss how they understood the focal concepts. After the discussion phase, students independently construct concept maps. Differences in conceptual understanding will be measured in the changes in quality and organization of the constructed responses (i.e. how does each student’s pre and post-inquiry maps differ for each of the 3 tasks?).

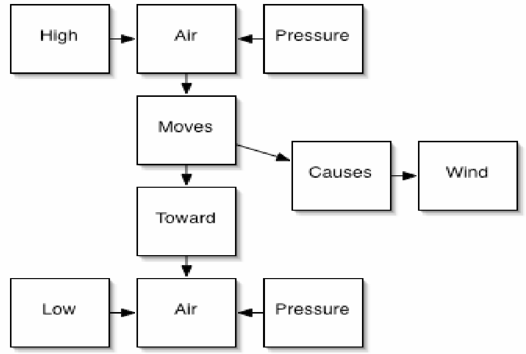

Figure 2. An example post-inquiry concept map.

The two main challenges that are inherent in the design are as follows: 1) What types of prompts will be used if students come to impasse during an experiment? 2) What ways can we establish that students learn better in this kind of a system when compared to a conventional method of learning weather? First, it is altogether likely that students may come to impasse during experiments. Our chosen resolution is to adhere to a neutral prompting scheme in which an instructor intervenes with questions like "What seemed to not work during the experimental phase? At which point did you feel that you were on the right track?" The point of this method of prompting is to provide students with scaffolding that affords opportunities for them to illuminate which configurations did and did not work. In doing so, they are not led in any specific direction, but are rather provided with opportunities to openly discuss what moves might lead to task completion.

The common assessment tools (e.g., concept mapping and far-transfer tasks) provide insights into changes in understanding. Control groups show typical textbook-based learning. The control groups essentially go through an identical process, save for the experimental inquiry phase. The main importance of comparing the experimental and control groups would be to establish the value added by the technology-enhanced inquiry phase in promoting deeper conceptual understanding of air pressure as it underlies weather patterns.

IMPLEMENTATION

The implementation of the interactive air pressure system consists of hardware and software components.

DISPLAY

The hardware platform includes a display system and a participant tracking system. The display uses a single LCD or DLP video projector to project the application onto the room from above. The goal is to apply the weather system to the classroom itself, so no attempt is made to clear space for it. The image of the application falls on the floor, the desks, and even the participants.

In order to maximize the projected area, the projector is mounted on the floor at the center of the room, oriented vertically. The projected image is reflected from the ceiling by a sheet of light-weight mirror Mylar, affixed with tape, Velcro, or thumbtacks. While nearly-perfectly reflective, this Mylar sheet is not expected to function as a perfectly flat mirror. Ripples will distort the reflected image, but this is expected to enhance the analog notion of a weather system, rather than detract from the display.

As an example configuration, we consider a room with a 10-foot ceiling. A projector positioned on the floor and reflecting from the ceiling has a throw distance of 19+ feet. Typical projectors produce an image approximately 10 feet wide at such a distance and require a 5-foot wide area of Mylar. A more useful configuration uses a short-throw lens. The resulting image is up to 20 feet across, though a 10-foot wide area of Mylar is required. See Figure 3.

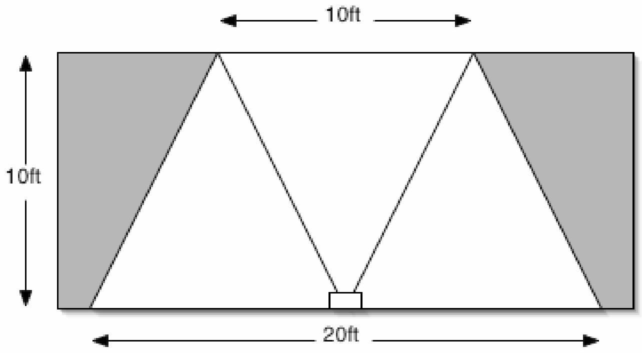

Figure 3. A short-throw installation with 10-foot ceiling.

TRACKING

The Mylar mirror is also exploited for participant tracking using fiducial markers. A digital video camera is mounted coaxially with the display projector. A properly-selected lens allows the field of view of this camera to match that of the projector, so that area of the captured image matches that of the projected image. The room is illuminated using infrared light and the camera is fitted with an IR-pass filter. In this configuration, the camera captures an image of the room from above with the image produced by the projector subtracted. The infrared illumination also allows the system to function in a darkened room, which may be desirable to enhance the visibility of the projector image.

Participants wear fiducial markers to indicate their position and identity as high or low pressure systems. Fiducial markers are simple black-and-white images that are designed to be easily recognized and localized by image processing software (ARToolkit). They can be printed on normal paper and affixed to hats worn by participants. The minimum size of these markers is limited by the resolution of the camera. For a standard 640x480 device, markers approximately 4 inches square should suffice.

Tracking software captures an infrared image of the room and extracts known fiducial markers from it. This is done 10 to 20 times per second. The resulting position and type information is forwarded to the simulation software as input.

SOFTWARE

The application software simulates and displays the interactive weather model. Weather modeling is a very complex field, and truly accurate modeling remains outside the capability of even the most powerful systems. Here, accuracy is not a goal. Instead, we use a simplified system that exhibits the desired properties of air pressure systems, but can be manipulated and solved in real time.

Weather is modeled using a basic two-dimensional vector field. Wind velocity and moisture content values are maintained at each element of the grid. As the participants move, the positions of pressure systems within this grid are updated. Changes in wind velocity are computed using a set of equations describing air flow. High-pressure areas act as sources, and low-pressure areas act as syncs. Bodies of water act as moisture sources, and moisture flows along the vector field. As moisture accumulates, clouds form and rain falls.

This system is solved in real-time using a basic Euler integrator, and the display is updated accordingly. The vector field is displayed using particles superimposed over an image of the environment. Animated points trace paths along the vector field, with velocity proportional to its magnitude. In this way wind speed and direction become apparent. Particle color indicates moisture content. Secondary effects such as cloud formation, rain, and lightning are overlaid atop this particle view. Audible cues including wind and thunder accompany the display.

The following screen captures display the simulation in action. “H” and “L” icons are used here to denote participant locations. In Figure 4, we see wind flowing from a high pressure area, which results from a concentration of “H” participants, to a low pressure area. White and blue particles denote dry and moist air, respectively. It is apparent that air moving over the lake at the center of the room collects and carries moisture in the direction of air flow.

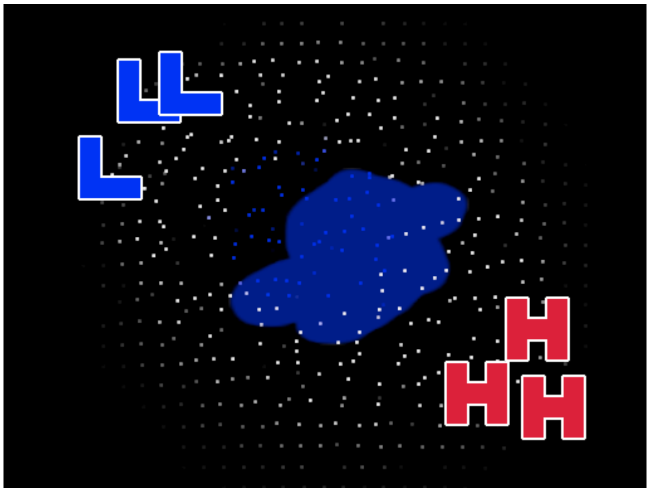

Figure 4: A simulation screen capture showing particle flow.

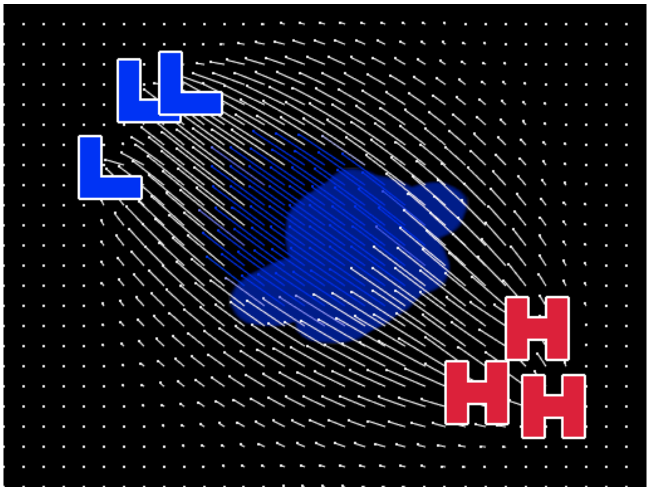

Figure 5: A simulation screen capture showing the vector field.

CONCLUSION

Active construction of knowledge is an integral part of science education. In affording students opportunities to actively co-construct knowledge of otherwise abstract concepts and relationships, results should illuminate this design’s importance in making air pressure and its relationship with weather patterns more realizable. By using scientific assessment tools, it is predicted that middle school students (a group that normally displays ill-understood notions of air pressure and its relationships to weather) will show marked increases in understanding by having participated in the proposed learning environment.

REFERENCES

1. ARToolkit http://www.hitl.washington.edu/artoolkit/
2. Anderson, R.E. Social impacts of computing: Codes of professional ethics. *Social Science Computing Review* 10, 453-469,1992.
3. Basca, B.B., and Grotzer. T.A. (2001) Focusing on the Nature of Causality in a Unit on Pressure: How does it Affect Student Understanding? *Presented at the American Educational Research Association (AERA) Conference*, Seattle, WA, April 10-14, 2001.
4. DeBerg, K.C. Student understanding of the volume, mass, and pressure of air within a sealed syringe in different states of compression. *Journal of Research in Science Teaching*. 32(8), 871-884,1995.
5. Engel Clough, E. & Driver, R. What do students understand about pressure in fluids? *Research in Science & Technological Education*, 3(2), 133-144, 1985.
6. Grotzer, T.A. Transferring Structural Knowledge about the Nature of Causality to Isomorphic and Non-Isomorphic Topics. Paper *presented at the American Educational Research Association (AERA) Conference*, Montreal, Quebec, April, 2005

7. Hunt, E., and Minstrell, J. A cognitive approach to the teaching of physics. In McGilly, K. (ed.), *Classroom Lessons*. Cambridge, MA: MIT Press, pp.51-74, 1994.
8. Klemmer, R.S., Thomsen, M., Phelps-Goodman, E., Lee, R. and Landay, J.A. Where do web sites come from? Capturing, N.O., Jehøj, H., and Mackinlay, J.D. *Fluid Annotations in an Open World*. Proc. Hypertext 2001, ACM Press, 9-18, 2001.
9. Rollnick, M. & Rutherford, M. The use of a conceptual change model and mixed language strategy for remediating misconceptions on air pressure. *International Journal of Science Education*. 15(4), 363-381,1993.
10. Sere, M. A study of some frameworks used by pupils aged 11-13 years in the interpretation of air pressure. *European Journal of Science Education*. 4(3), 299-309,1982.
11. Shepardson, D. & Moje, E. The impact of a science demonstration on children's understandings of air pressure. *Journal of Research in Science Teaching.* 31(3),243-258, 1994.
12. The Benchmarks for Science Literacy, American Association for the Advancement of Science (AAAS) ,1993
13. The National Science Education Standards. National Research Council, 1995
14. Trowbridge, J. E., & Wandersee, J. H. (1996). How do graphics presented during college biology lessons affect students' learning? *Journal of College Science Teaching*, 26 (1), 54,1996.
15. Colella, V. (2000). Participatory Simulations: Building Collaborative Understanding Through Immersive Dynamic Modeling, *The Journal of the learning sciences*, 9(4), 471–500.