AudioExplorer: Multiple Linked Representations for Convergence

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ABSTRACT

The problem of convergence is an important one for designing collaborative-learning environments. Ideally, learning environments allow novices to work together to achieve convergence of correct understanding, without constant support from experts. In order to achieve this, software designers need to investigate properties of the environment that support convergence. One of these properties is multiple linked representations (MLRs). In this paper, I describe AudioExplorer, a learning environment where students, working in pairs, explore the physics of music. AudioExplorer is remarkable in its use of many linked representations; thus, it is a good environment to research the role of MLRs in the convergence process.

Keywords

Representation, software design, convergence, audio, inquiry-based learning

CONVERGENCE AND MULTIPLE LINKED REPRESENTATIONS

Jeremy Roschelle proposes that the "crux of collaboration is the problem of convergence (Roschelle, 1996)." Can two (or more) people working together reach convergence of understanding? Furthermore, is that convergent understanding closer to real understanding than the members of the group could have reached without collaborating? Roschelle shows that students (working in pairs) can achieve convergent conceptual change, using the Envisioning Machine (EM) software. EM is a direct-manipulation graphical simulation of particle dynamics (velocity and acceleration of a particle). Students are asked to manipulate position, velocity, and acceleration of a particle to match the motion of a simulated ball. Though students did not converge on everything that scientists know about velocity and acceleration, they did manage to work together to achieve better understanding. Since a typical classroom environment contains few experts (for the most part, one teacher) and many novices (students), creating learning environments where collaboration among novices is productive becomes necessary. So, what features of a learning environment support the convergence process?

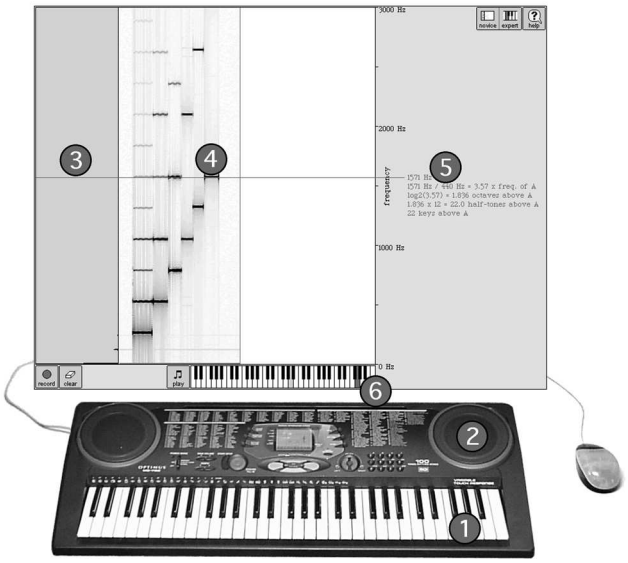
MLRs can support the convergence process. In many scientific fields (such as mathematics and chemistry), phenomena can be looked at from different perspectives. For instance, in mathematics, a two variable relation can be looked at as an equation, graph, or table (Kaput, 1989). In chemistry, a chemical reaction can be looked at as the physical chemicals, the underlying reaction equations, the results of spectroscopy, etc. (Kozma et al., 2000). The power of multiple representations is that they emphasize different aspects of the same system. To understand each representation and how they are linked together is to understand the domain more completely than any one individual representation.

Both Kaput and Kozma assert that connecting multiple representations in a learning environment should be helpful for student understanding. This is based on the theory that students should be able to move between different representation and that each can inform the other. In chemistry, Kozma finds that experts move easily and often between different representations, while novices tend to get fixated on one representation (Kozma, 2001). Offering clear linkages between the representations should be a way to scaffold novices to go between them. As for convergence, MLRs offer the opportunity of different ways of exploring the same domain. Since the evidence displayed by the environment is multiple (more than a single representation), there is a greater chance that useful convergence dialogue will occur.

AUDIOEXPLORER

AudioExplorer is a computer environment to explore the physics of sound by examining the frequency domain. The frequency domain is a transformation of the sound signal into its frequency components. Since our ear perceives frequencies, examining the frequency domain is a useful way to understand the properties of music. The system consists of a music keyboard giving sound input into the computer (Figure 1); the AudioExplorer software displays the signal on the screen, which can then be analyzed by the students.

AudioExplorer is a tool for inquiry-based learning. The environment gives the users the opportunity to explore the subject (audio and music) and thereby discover the principles of the subject rather than passively learn about them. Thus, learning is active and students are encouraged to construct their own meaning.



First, the student strikes a key on the music keyboard (point **1**). This produces a sound (point **2**). That sound is converted by FFT (Fast Fourier Transform algorithm) to an instantaneous frequency response notation (point **3**), where sonic energy is indicated by length of the line. The frequency response is recorded over time (point **4**), energy being indicated by darkness. Then, the student can use the analysis line to find out the frequency of the harmonics (point **5**); the students can drag the analysis line up and down by dragging on the spectrum graph to measure the exact frequencies. The calculations that the software shows (at point **5**) convert that frequency to the matching key and highlight it on the display's keyboard (point **6**). In the example in Figure 1, the fundamental harmonic is the key that was stuck originally by the student (point **1**). Thus, the multiple representations come full circle.

Figure 1: AudioExplorer usage set-up with numbers indicating representations

Each representation has different features that allow the users to look at the sound phenomena from different perspectives. So, each representation has different affordances that allow the user to better examine the domain. Each representation suppresses some aspects of the domain and emphasizes others, thereby supporting different forms of approaching the material. Perhaps most importantly, the linking of these representations creates "a whole that is more than the sum of its parts (Kaput, 1989)."

EVALUATION

In the extended on-line version of this paper, a formative evaluation of AudioExplorer is detailed. Students (working in pairs) were able to use AudioExplorer to engage the subject. They moved easily between the multiple representations and were able to understand the links between them. MLRs supported the convergence process. Significant learning was achieved with two learners and a supportive learning environment.

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