Science Education Research Using Advanced Recording Technologies

Eric Wiebe
Bethany Smith
North Carolina State University

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Abstract

While A/V technology has gotten increasingly more cost-effective, its deployment in instructional settings has typically not taken best advantage of its capabilities, resulting in low quality data that hampers the analysis process. This paper will outline a two-year process of the design and evolution of recording technology packages for use in a range of science education instructional settings. User needs were explored and analyzed through interviews with educational researchers and curriculum designers. These recording needs were matched with available technologies to create systems comprised of both off-the-shelf components and custom-built solutions. The paper will discuss the matching of research questions with the appropriate scale and type of recording. Standard scenarios developed from past experiences and interviews will be described along with appropriate matches to recording technology. Examples of data collection recording will be given.

Introduction

Just as newly emerging and evolving technologies have changed the way we teach in the classroom, they have also changed the way we can conduct our research on teaching and learning in the science education. The very same audio/visual (A/V) technologies—coupled with new computing and network technologies—that have led to substantial changes in the delivery and management of instruction have also opened new doors as to how educational researchers can conduct their work. While there is tremendous potential for these technologies in educational research, careful consideration needs to be made both in terms of technical specification and use of the equipment and recognition of its influence on research methodology. Innovative methods of educational research magnifies the possibilities for breakthroughs in innovative science learning environments.

Voithofer (2005) presents a useful framework for thinking about how *new media* influences the process of educational research. He notes that all recording technologies—whether it be paper and pencil or a video camera—creates an inscription that is an alteration of the reality it records. While on the surface, new media such as video provides a sense of *immediacy* that attempts to mimic the real world, like all other new media tools it provides for an infinite number of ways of altering the reality it seeks to portray (Bolter & Grusin, 1999).

One approach to recognizing and responding to the ways A/V inscription technologies can influence the research process is to decompose the data collection and analysis into three phases: selection, abstraction and transformation (Jenks, 1995). The research questions should guide both the overall situation in which the data is collected, but also the *granularity* of the collected data. Granularity can refer to both the physical resolution of the data being collected (i.e., can you see and hear at the level of detail necessary to address your research questions) and to ways the initial raw footage of A/V data is later excerpted for further analysis. That is, how are the events that play out over time divided up in such a way to provide robust descriptive episodes that align with the research questions (Goldman-Segall, 1989; Voithofer, 2005). This unit of analysis might be an entire class period, an activity conducted by a small group, or single utterances by students. This analysis of granularity, guided by the research questions, will influence your selection of location, equipment, and data management approaches. In addition, it will guide the analysis techniques used to abstract the original raw data even further.

What follows are the findings from a two year process to match established and emerging A/V technologies with the kinds of research questions our group had been asking in the area of science education. A series of research scenarios were developed to which A/V systems were matched. These systems were configured and analyzed based on: 1) the context of data collection, 2) issues of granularity, and 3) impact on further abstraction and transformation. Through a process of iterative design, the configured systems presented below (and in the full paper) were developed.

Mobile Systems

Whole Class Recording

Whole class recordings are used to investigate a number of types of research questions. Probably the most common are those investigating interactions between the instructor and the whole class. A single class period is the typical unit of analysis for such a classroom recording. However, the class may be structured in such a way as to present natural breakpoints for other units of analysis (e.g., lecture then lab activity).

Usually when you record a class in session, it means you will bring mobile equipment to the classroom where the class is normally taught. Positioning the camera(s) and microphones in the room is dependent on who is considered the most important subject of the recording and the likely influence of the presence of the camera on student/instructor behavior. Resolving auditory detail is often a serious challenge for a whole class recording. In many cases, what is said in the class is of more interest to the researcher than the visual record. Visual resolution for whole classroom recording is usually limited to capturing gross activities and not attempting to resolve inscriptions created by individual students on paper, calculator, computer, etc. The full paper will describe a number of video and audio recording alternatives--ranging from simple to complex--depending on the proposed research questions and level of resolution needed.

Individual/Small Group Recording

Often the research questions of interest involve individual student activity and/or their interaction with other students in a small group. In this case, the goal will be to capture data at a high enough resolution to be able to resolve individual student inscriptions, gestures and facial expressions. Similarly, the audio recording needs to be able to resolve all words and auditory expressions the student's make.

Another challenge with small group data collection is to record computer activity. Alternatives include a camera located "over the shoulder" of the student can capture activity on the computer and recording the computer screen using the internal data stream of the computer. This internal data stream can be captured with "screen grabbing" software or recording devices linked to the monitor output ports of the computer. A variety of recording solutions will be presented in the full paper.

Remote Class Recording

An obvious downside of classroom recording is the need to transport and set up equipment for each recording session. In addition, the presence of the equipment and operators inevitably influences the dynamics of the class. Holding the class in distance education classroom can address some of these issues by having built-in recording equipment and remote operation not requiring operators in the classroom. However, doing these recordings in a K-12 school or community college off campus can create considerable additional work time compared to recording in a classroom on the university campus. Our research group designed and constructed a recording system that addresses some of the disadvantages of field recordings. The full paper will describe the mobile system in more detail.

The Wired Classroom

Because our research group was involved in designing a new research facility this past year, we had the opportunity to "wire" two adjoining classrooms (one equipped for science instruction) with specialized recording equipment. The two classrooms were divided by a movable partition to accommodate up to 50 students in a single space. These specially designed classrooms provided the research group with the ability to record both whole class and small group work at optimal resolution and with a high degree of flexibility. These classrooms made use of many of the previously mentioned technologies and techniques and permanently integrated them into the classrooms.

Discussions with researchers identified as likely users of the classrooms guided the development of the design requirements for the wired classrooms. The resulting design process led to the decision to integrate 12 PTZ cameras and 12 hanging microphones—six in each of the classrooms—into the suspended ceiling tiles. All twelve microphones inputs are sent into a microphone mixer/matrix/DSP specifically designed for video conferencing/distance education activities. The audio outputs are then sent to an A/V matrix that matches audio and video channels and then routed to the hard disk recorders. For a whole class recording, two ceiling cameras in the corners of the room can be matched with a mix of 4-6 microphones in two recorded tracks. For a small group recording, a single microphone is matched with one or two cameras for one or two recorded tracks.

In a control room adjoining the classrooms, recording and control equipment was set up where up to six video/audio streams can be recorded at any one time. Six hard disk recorders are used for recording with analog video and audio input and connected via firewire to a computer for transfer of the digital video (DV) encoded tracks after completion of the recording session. The recording was monitored on an array of video monitors and a pair of speakers selectable to any of the six audio tracks. Cameras are controlled via the IP network from one or more computers in the control room. Alternately, operators can use wireless laptops in the classroom to control the cameras.

This design had a number of advantages. Ceiling mounting provides optimal angle of view for visual recording of inscription activities while cameras farther away from the group can record gestural and facial expressions not caught from directly above. Because the hanging microphones use interchangeable heads with different pick-up patterns, a hypercardioid head with tight, focused pattern can be used directly over a small group while an omnidirectional head can be used for whole class recording. Limiting extraneous noise increases data quality and greatly improves the efficiency and accuracy of transcript generation.

The wired classroom provides a research space that bridges between the largely artificial environment of a research lab while providing a more robust array of data capture options than would be available in a typical classroom. While a research lab allows you to carefully control extraneous variables and wire the space for intensive data collection, it looses the ecological validity of an interactive classroom environment. This wired classroom might be used for research work akin to clinical trials—second stage testing of educational innovations after they have moved out of the research lab but prior to widespread dissemination.

Data sources

Research questions should both drive the selection process for the original A/V recording and the subsequent abstraction and transformation process. The initial recordings can be considered the primary data source and be thought of as the source of maximum granularity. For every derivation, decisions need to be made about appropriate granularity—both selection and resolution. There are often limitations of resources of both time to view/analyze and digital storage space that force choices of lower granularity than the original source.

In addition to secondary data sources derived directly from the primary A/V recording, there may also be alternate data sources collected by other means. For example, computer keystroke data logs may be recorded on the computers students are using. Eye tracking technologies can also be used in tandem with video recordings to provide data on where a student's gaze falls when engaged in an activity. These types of real-time data recordings can, like a second video recording, be time-synced and merged with the another video recording of an event to provide a new way of visualizing how events are unfolding in a learning situation.

In addition to real-time data sources, more summative data sources such as survey data are very often used as a means of providing triangulating data as part of a research study. Both analysis of all of these sources of data and eventual presentation of the results requires careful thinking: How will events that unfold over time on video be abstracted and integrated with summative data sources? What is the appropriate unit of measurement to use in extracting video clips so that they align with the measures aligned with other sources?

Conclusions/Implications

Evolving A/V technologies have opened the door for innovative approaches to collecting, analyzing and managing educational research data. As with all technological innovations, careful consideration has to be made as to how best to apply the technology to achieve the end research goals. In this case, important considerations are: constant reference to the research questions being asked, how the A/V technology influences the nature of the reality of the event being recorded, and the needs and responsibilities of the researchers to the participants in the study. This paper describes a two year process of systems research and design that led to the specification of a number of configurations for the recording and management of A/V data. Since both the technology and our understanding of the needs of the researchers in our group continues to evolve, so to will the system designs. However, this article also reinforces a number of more stable, universal understandings of how educational research should be conducted, regardless of the data collection and analysis technologies being employed.

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