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Making Sure What You See is What You Get: Digital Video Technology and the Preparation of Teachers of Elementary Science

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Abstract

Advances in digital video technology create opportunities for more detailed qualitative analyses of actual teaching practice in science and other subject areas. User-friendly digital cameras and highly developed, flexible video-analysis software programs have made the tasks of video capture, editing, transcription, and subsequent data analysis more convenient, accurate, and reliable than ever before. Although such technological developments offer a myriad of opportunities for advancements in research and training, especially in the area of preservice science teacher education, a number of technical challenges and unforeseen difficulties may arise when relying on video-based methodologies. If unanticipated, these challenges can compromise the overall integrity of research data and detract from training effectiveness. The purpose of this paper is to identify the challenges and opportunities specific to incorporating video technology into the research on preservice science teacher education within the context of relevant literature. Lessons learned from an ongoing longitudinal study of preservice elementary science teachers are discussed, including practical guidelines for use of digital video for research and professional development.

The application of digital video technology (DVT) and the use of computer software programs provide opportunities for innovation within the domain of inquiry in science teacher preparation and can greatly enhance the research methodology concerned with preservice teacher instruction. Video has been used extensively in the past to study the interactions between teachers and students, allowing researchers to examine critically real-time classroom behaviors repeatedly and providing teachers with a valuable resource for an objective self-evaluation (e.g. Plowman & Stephen, 2008; Yerrick, Ross, & Molebash, 2005).

The body of research using video technology includes innovations for enhancing teacher preparation (Dymond & Bentz, 2006), expanding prospective science teachers' views of science (Yerrick, 2002), examining cognitive and decision making processes (Rich & Hannafin, 2008), and fostering reflection and critical analysis among preservice teachers (van Zee & Roberts, 2001; Yerrick et al., 2005).

In addition to using video as a means to improve teacher preparation and to inform the professional development of teachers, researchers are relying more heavily on emerging digital technology as a methodological tool to assure that more accurate and reliable data is gathered and analyzed more systematically. However, incorporating digital video technology into both preservice training and research is not without a number of challenges. Whenever video is used, potential pitfalls and unanticipated technical difficulties can arise that detract from the effectiveness of preservice education and can pose serious threats to conducting valid and reliable research.

The information presented in this paper emerged from extensive use of digital video technology during an ongoing NSF-funded research project examining the factors at work in learning to teach inquiry science at the elementary level. Digital video was used to capture and analyze over 200 videotaped science lessons of participating preservice and in-service teachers in four broad areas of interest: classroom discourse, accurate use of science content and process, and elements of inquiry lessons. These experiences with equipment, collection and management of data, project implementation procedures, videographer training, video storage and duplication, and use of an advanced coding software (i.e., StudioCodeTM), have resulted in many lessons learned about working with digital video technology as a primary data source.

The purpose of this paper is to identify the challenges and discuss the opportunities of incorporating DVT into the research on preservice science teacher education. The importance of DVT as a research tool, the contributions and specific features and benefits of the software packages now available, and future directions for DVT applications will also be discussed. The goal is to provide researchers and preservice teacher instructors with practical considerations and technical guidelines so they may avoid commonly encountered difficulties and to ensure that emerging digital technologies are appropriately applied to achieve the most accurate results.

First, examples from the relevant literature on the use of digital video for preservice teacher preparation and research are presented as background. The characteristics of digital video are briefly described, as well as the advantages of using digital video software for research, including customization, accuracy, and text integration. Next, lessons learned and guidelines are shared for the planning and implementation of research using DVT. Finally, conclusions and implications for research and practice are offered.

Digital Video Technology in Teacher Preparation and Research

Digital Video as a Tool for Reflection

Studies concerning the influence of technology on teacher development suggest that video use can significantly facilitate reforms in science education by enabling preservice teachers to sharpen their skills of observation and reflect on important contextual factors that influence the teaching and learning process (Wang & Hartley, 2003). Yerrick et al. (2005) recognized that "engaging preservice teachers in a process of recognizing children's ideas and examining preservice teachers' personal belief systems during their reflection on practice is a promising area of research for understanding how to make change among tomorrow's teachers" (p. 352).

Digital video also may serve as an effective approach that invites preservice teachers to engage in deeper levels of thinking about their science teaching and sharpen their abilities to analyze and recognize instances of effective teaching. For example, in an exploratory mixed-methods, multicase study using digital video, Calandra, Gurvitch, and Lund (2008) analyzed the digital video vignettes of seven teacher candidates. Digital video facilitated the systematic evaluation of specific teaching behaviors and proved to be an effective tool in guiding preservice teachers through a deeper reflective process on the technical aspect of their teaching.

Additionally, using a group comparison design, Beck, King, and Marshall (2002) randomly assigned 62 preservice teachers to either a technology-supported observational group or a traditional classroom placement observation group. When compared to controls, the preservice teachers in the condition using digital video-supported observation were significantly more effective in their ability to observe, recognize, and analyze effective teaching.

The opportunity to view footage from an experienced teacher's lesson can also compensate for inexperience and provide desired instructional models for vicarious learning. For example, Dymond and Bentz (2006) reported on the development of a digital video archive used to enhance the preparation of special education teachers. Such a library provided a range of effective instructional strategies being implemented with children exhibiting various disabilities.

When incorporated into teacher preparation, the digital video library offers a readily accessible archive of exemplary classroom practices that can be identified, analyzed, and critiqued by preservice trainees and their faculty instructors. Similar practices have been incorporated into research investigating teachers' interpretation of classroom interactions. For example, Sherin and van Es (2005) described two studies demonstrating how sharing videos from various lessons among in-service and preservice teachers and analyzing video using support tools can significantly influence teacher reflections and interpretations. Using a video analysis support tool, mathematics and science teachers became more attuned to classroom events, paying greater attention to *what* was occurring and *how* they interpreted such instructional interactions. Digital video applications such as these provide preservice science methods students and instructors with the opportunity to study and learn from lessons conducted across a range of classroom settings, levels of teacher experience, and children of varying abilities.

The use of digital video also can be beneficial for the preparation of preservice science instructors, particularly when combined with digital software technologies. For example, digital video software technologies such as SMIL and TransTool™ have text-added features for adding captions, transcribed quotations, and written critiques, which can be easily integrated and linked to specific events within every video (Kumar & Miller, 2005).

Using such features, students can now view and reflect on their lessons using prompts from their instructors that guide them to consider their teaching choices in certain critical areas (e.g., "Discuss how you dealt with student questions and misconceptions. Use some specific examples from the tape.").

Web-based tools for self-analysis, such as VAT, are now available and provide access from multiple locations from which preservice teachers can upload and annotate video clips, which in turn can be imported to more sophisticated data analysis programs (Rich & Hannafin, 2008). Web and hypermedia technologies such as these also allow university instructors and supervisors access to the same video sequence and a convenient means for offering supplementary critiques and supervision to novice teacher's commentary and reflections.

Transforming teacher beliefs and acquiring appropriate science content knowledge are additional areas of concern within the realm of preservice science teacher preparation. Incorporating newly available video technologies into the classroom during preservice teacher training may help in addressing these challenges. Digital video allows both researchers and teacher candidates to identify and resolve any inaccuracies in lesson content or erroneous preconceptions about science that unintentionally convey ideas that could negatively impact what children learn. Such misconceptions could also be identified in the early stages of novice teachers' development and resolved before becoming firmly embedded within their body of science content knowledge.

Furthermore, numerous digital technology innovations are beginning to emerge that allow instructors to integrate the data obtained during field supervision with university-based instruction. In this way the link between classroom methods training and field supervision can be strengthened through supplemental use of video for joint review and conferencing among university faculty, field supervisors, cooperating teachers, and preservice students. This integration has many observational advantages for teachers in preparation.

Observational learning for novice teachers is enhanced with various instructional examples that include immediate feedback and repetition, demonstrations of best practices, highlights of effective techniques, examples of theory in action, modeling efficacy, and attending to often overlooked but important elements of instruction (e.g., Bulgar, 2007; Dymond & Bentz, 2006; Yerrick et al., 2005). Additionally, the resulting footage from many different lessons in the field can now be consolidated into one instructional presentation and integrated into the methods courses.

Although performance reflection through a video medium has proven to be an integral component to teacher development, preservice preparation is not the only area in which educational video technology can be successfully employed. When DVT is incorporated into educational research as a methodological tool, investigators can gain valuable insights into children's understanding of science material, as well as the teacher's science content knowledge and personal beliefs about science instruction. The following section describes how DVT has been used for research concerning the preparation of preservice science teachers.

Digital Video Editing in Research

Advances in editing software have also greatly enhanced research methodology in the realm of teacher preparation (Rich & Hannafin, 2008), especially in science education. The term editing in this context refers to examining footage taken from an entire lesson and cutting smaller excerpts from the original to compile a condensed version that emphasizes areas of interest to the viewer. For example, in Yerrick et al (2005) video editing was used by methods students to compile a 5-minute vignette from 90 minutes of footage that contained interviews with elementary students revealing their misconceptions of various science concepts and their explanations for holding these views. The methods students were then asked to prepare a lesson based on this acquired insight into the children's beliefs about science.

The findings suggested that involvement in the editing of the video footage provided the science methods students with a deeper insight into the children's understanding of scientific concepts and enabled them to identify areas within their lessons that needed to be redesigned to accommodate students' diverse learning styles.

As a final stage in Yerrick's study, the teachers were asked to videotape their own lesson and edit the 1-hour sequence into a final presentation that best represented what they learned during the course. Yerrick et al. reported that "The impact of digital video editing on preservice teachers' beliefs includes shifts in 1) reflections regarding children's thinking, 2) planning and instruction informed by reflection, and 3) notions of teacher expertise and requisite knowledge" (p. 351). When preservice teachers participate in the editing of their own captured lesson, the quality of reflection and insight increase dramatically over those merely engaging in passive evaluation and reflection:

> Having teachers edit videos of their child interviews, plan their lessons according to their analysis, plan their instruction with the intent to change children's misconceptions, and edit their own videos helped them make connections with their own values, beliefs, and desires to improve that arguably may not have been attainable by other means. (p. 365)

This type of study illustrates how the integration of video capture and editing facilitates changes in teacher beliefs and fosters a significant transformation from the initial preoccupation with their individual performances and simple presentation of scientific content. The ease and expediency of this kind of action research allows for information derived from research analyses to be communicated to methods instructors and preservice students in a timelier manner than was possible with earlier technology.

Digital video technology has the potential to become a successful tool in preparing teachers because of the ease and simplicity with which researchers now can analyze the video excerpts for instances of high-quality teaching, edit them to display these instances in isolation, and transfer them to a universal medium for instruction and training. Use of video as a tool for instruction may be more effective when instances of high-quality teaching are identified and presented as models.

Furthermore, access to specific exemplars that represent the most research-supported models of science teaching creates a common ground for collaboration between research and practice that leads to state-of-the-art preservice teacher education. With time and cost efficiency, digital video technology affords numerous opportunities for researchers and practitioners jointly to review and select material for inclusion in training curricula and to evaluate their effectiveness.

Characteristics of Digital Video

The primary concerns with using any video format for research and training include image and audio quality, reproduction value, storage, navigation, and editing. Researchers and training instructors could be overwhelmed with several challenges:

- Maintaining the initial quality of the image and audio during recording;
- Ensuring the reproduction quality of successive generations of copies made from an original;
- Dealing with cumbersome navigational capabilities;

- Coping with the expense and inconvenience of inefficient editing techniques; and
- Having a sufficient amount of storage available for primary and backup copies of data.

In the past, attempts to address any of these concerns when using analog format meant sacrificing a significant level of quality. However, recent advances in digital video technologies offer options for overcoming many of these challenges with little to no change in overall quality. Although the benefits of using digital media is known to those with experience using DVT, a brief overview of the advantages may be helpful for researchers who are unaware of its capabilities or who may be apprehensive about incorporating video into research because of frustrations arising from past experiences with analog media (see appendix).

Advantages of Using Digital Video for Research

Among the most impressive contributions to research in teacher preparation are the advances in video editing and coding software packages that have been designed specifically for film analysis and subsequent statistical analyses. One consistent advantage of including video data in any research has been that it provided a convenient method for conducting subsequent objective evaluations and accurate data coding after the initial data collection. Once video is captured, the footage can then be accessed repeatedly for multiple observations and analysis. This feature significantly minimizes and in some cases eliminates errors due to selective memory and retrospective recall.

Traditional in vivo observational classroom studies relying on simultaneous real-time coding and anecdotal recording are susceptible to a number of threats to validity and reliability. The latest digital video hardware and software overcome most of these previous pitfalls, reducing observer error and increasing overall objectivity. Software and computer programs that once were considered in the realm of fantasy have now become a reality for researchers in ways that link qualitative and quantitative data, expanding previously text- or narrative-based data to include objective audio and video options (Weitzman, 2000).

Customization

For research applications it is important to select a software package that allows researchers to customize observational systems through the creation of coding templates and formats. Software programs that offer advanced features such as point and click for counting or recording behaviors, dropdown menus, and active windows allow researchers more observational options at their fingertips and freedom beyond the constraints of traditional qualitative research relying on paper and pencil methods (Weitzman, 2000). An observational code input window is presented in Figure 1 and shows eight categories of variables that were created for onscreen observation and point and click coding. Ideally, such programs enable researchers to devise observational systems that are more directly linked to an underlying theoretical or conceptual framework.

Many video software programs offer onscreen timelines and displays of the entire duration of the footage in hours, minutes, and seconds. Some programs include timeline features that also can provide distinct visual markers that represent discrete behaviors and multiple variables corresponding to separate instances of coded events. After a thorough review of available digital video capture and code programs, our project selected StudioCode™ as the most comprehensive and customizable software tool for analysis and study of elementary classroom based inquiry science lessons.

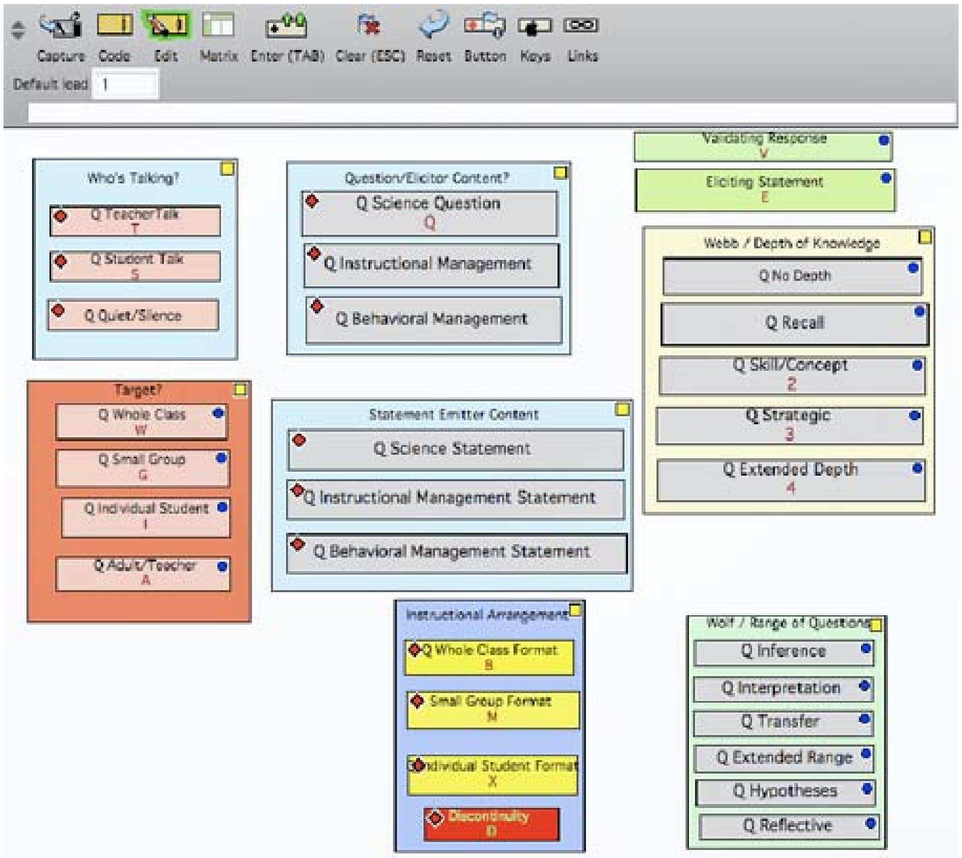

Figure 1. *Code input window using STUDIOCODE.*

StudioCode is one of the most sophisticated software programs of its kind, because it offers versatile onscreen configuration, allowing researchers to simultaneously observe the science lesson video and apply codes using an active customized code input window, while creating an onscreen timeline displaying coded and labeled variables as they are assigned (see Figure 2). With these recently developed software features researchers can create customized systems that isolate any behavior of interest within the entire video, and then assign descriptive labels to the coded instances. Marking and isolating event segments makes them easily located for later review and labeling for sorting and indexing. Advanced features facilitate automatic collation of several different variables under consideration into categories that conform to the chosen theoretical framework.

Maneuverability

Another invaluable benefit to using digital media software is its ease of maneuverability. The ease with which digital files can be managed and manipulated makes it possible to achieve a more thorough and indepth observational analysis of the events originally captured on video. Digital video software is versatile, and with just a simple click or keystroke command researchers can immediately view specific video segments or scenes, including start time, end time, and duration of any instance under review.

Figure 2. *On screen configuration of StudioCode*

These software features are invaluable to observational research. For example, with simple mouse clicks multiple segments of video can be cued for viewing. Such software easily permits video scenes located in different segments of the original footage to be quickly opened onscreen and compared side by side in separate viewing windows. Similarly, multiple examples of a single variable or behavioral instance can be aggregated and viewed sequentially as part of an uninterrupted collection of scenes. These are significant improvements over previous methods of managing and editing analog media in which this type of complex video manipulation and maneuverability would not have been possible.

Accuracy

A potential source of observational error in educational classroom research has been the lag time between viewing a target behavior or event and its accurate recording or notation. In this situation, the researcher must be both observer and recorder. Often these two tasks are required repeatedly and simultaneously, which can present unmanageable demands on attention and technical skill, leading to inaccuracies in both observation and recording. With digital video and the appropriate software, researchers can overcome these challenges and reduce error. Software programs with convenient start and stop functions ensure that behaviors and variables of importance are not overlooked or skipped inadvertently. Video can be paused and coding or recording of information can be entered accurately.

Previously, with analog format, videotapes also could be stopped and played back, but the observations or coding would typically be done using paper and pencil forms. This process was time consuming, inefficient, and complicated. With digital video format, more-sophisticated software programs allow coding to be entered into an onscreen continuous timeline that is time stamped and linked to specific frames of the video. Software driven timelines also provide features for labeling coded variables and sorting them for later analysis. Higher levels of interobserver agreement and observational reliability can be established and maintained through the use of this kind of software, resulting in greater overall accuracy and measurement precision.

Text and Image Integration

Another important aspect to consider is whether or not digital software can combine innovative coding techniques and editing tools with an integrated transcription feature. Transcription is a critically important process for preparing and analyzing data that is greatly facilitated by the use of digital video and software systems. Researchers can use transcription navigation markers to find specific areas of a timeline they want transcribed. Most digital transcription features allow users to highlight a specific verbal behavior or interaction for transcription. The program will play the highlighted instance in a repeating loop until the dialog is transcribed completely and time stamped for future access. The process of integrating a video segment with text transcription provides precise synchronization of the material that facilitates future in-depth study and offers numerous options for further investigations (Kumar & Miller, 2005).

Compatibility and Conversion

Compatibility refers to the ability of coding and editing software program to interface with hardware components and other software programs. The most useful software programs allow for data to be easily exported into more universal applications, such as word processing and spreadsheet programs, where the information can be translated into formats more suitable for dissemination, instruction, and presentation. A critically important initial planning consideration regarding compatibility involves the selection of software that is compatible with specific computer operating systems, as well as with all necessary video equipment such as camera, audio recorders, and storage devices. Additionally, video collected for research purposes eventually may need to be converted into various digital formats. Therefore, additional software may be needed to assist with file conversion in order to resolve any incompatibility issues encountered.

Challenges and Lessons Learned

Along with the many benefits of using DVT as a research tool, a number of noteworthy challenges may manifest themselves. Many of these have been identified in the literature, as reported in *Guidelines for Video Research in Education* (Derry, 2007). This section discusses a number of lessons learned based on our extensive experiences with an ongoing longitudinal research study of preservice teachers learning to use inquiry-based science methods in the elementary classroom.

Many of the obstacles encountered were not easily anticipated during the planning stages of the project, because they resulted from continuously developing video technologies, product improvements, and upgrades. Most challenges were resolved through the acquisition of supplementary software and hardware, by investing in equipment upgrades, or by approaching the issues with a better understanding of equipment capabilities and limitations.

Incorporating DVT into any research design requires a significant amount of planning to ensure a smooth integration. Among the primary concerns involved in the planning of a research project using digital video technology include (a) integrating DVT into the overall research design and methodology, (b) anticipating technical issues that accompany the use of DVT, and (c) developing effective and efficient procedures for conducting valid and reliable digital video-based research. Several important guidelines for use of digital video technology are offered in each of these three areas.

Integrating DVT into Research Design and Methodology

Theoretical grounding. Choosing to incorporate DVT into a research design is merely a means to an end and cannot be assumed to serve as a substitute for sound theory and research methods. The use of DVT applications has little or no value unless guided by a theory or conceptual framework from which the video data can be understood and interpreted (Erickson, 2006). Thus, an appropriate theoretical base or conceptual model should become the framework from which specific methodology can be developed. Such a framework helps focus on the key variables necessary to address the research questions and encourages the selection of variables to be integrated into the video coding scheme.

Since 1 hour of video in an elementary science lesson can contain a seemingly infinite number of variables, it is critical to establish clear and precise operational definitions of the specific behaviors and most relevant interactions or processes under investigation. For example, inquiry science serves as a conceptual framework for our project, and it focuses our work on the extent to which science lessons are inquiry based, both in terms of science content, instructional design, and verbal questioning behaviors and interactions. More specifically, we examine video lessons of preservice science teachers and observe for instances of science content accuracy/inaccuracy, prediction and hypothesis testing, and number, rate, and frequency of science questions promoting deep thinking. Digital video affords both macro- and micro-level viewpoints from which to analyze these variables and study how they develop and change over time, as preservice teachers progress along the professional development continuum.

Moreover, digital video technology that is properly integrated into an overall research design can facilitate the processes of empirical investigation but cannot function independently in terms of data analysis. As Weitzman (2000) emphasized, “Software can provide tools to help you analyze qualitative data but it cannot do the analysis for you” (p. 805). The researcher remains ultimately responsible to match the methods and procedures of a study with the appropriate equipment, software, and available technologies that will provide the best fit with data analysis methods in order to yield results that address the central questions and purposes of the research.

Ethical issues. Additional planning considerations must be given to ethical issues that arise when using video in research with human subjects (Kearney, 2006; Schuck & Kearney, 2006). Classroom research involving not only preservice students and cooperating teachers but also children requires informed consent. Research utilizing recorded images of adult and child subjects is a sensitive matter requiring not only the permission of the teacher participants of the study, but the full and informed consent of parents of the children who may appear in the video. Best practices also include obtaining assent from children before they are included in classroom filming. Children without parental consent or without assent can be positioned off camera during the lesson or involved in an alternative science activity elsewhere.

Another consideration must be given to the possible uses of the video material beyond the initial research. For example, in our project, when we identify scenes of effective inquiry science teaching that include elements of high-quality instruction and teacher dialog, we may wish to edit and compile them into presentations for educational purposes. Participants should be informed of such uses in advance of giving their informed consent. In addition to these informed consent procedures, additional plans and considerations must be made to ensure full compliance with existing institutional review boards and participating school district policies, as well as recognized standards of relevant professional organizations (e.g., American Educational Research Association, American Psychological Association, etc.).

Anticipating Technical Issues

Beyond research design and methodology planning, another area of critical importance is resolving the possible technical issues that may arise when using DVT for research methods (Derry, 2007). Complications often occur when attempting to integrate different digital video components, computer operating systems, and software packages, which cannot always be anticipated during the planning stages. Four major areas should be carefully investigated before beginning a research project with digital video.

High-quality equipment. Depending on the level of funding available, purchasing high-quality digital video cameras with built-in hard drives eliminates the use of intermediary sources of video transfer from analog sources to digital formats, saving time, money, and space. Recommended hard drive cameras with 30 to 60 gigabytes of capacity can record and store up to approximately 7 hours of video. This estimate of storage time can be influenced by a number of extraneous factors, such as lighting, amount of action, and desired image quality level.

Unlike cameras requiring videotape cartridges or mini digital videocassettes, hard drive cameras have greater storage capacity, eliminating gaps due to cartridge changing and allowing for uninterrupted recording of an entire classroom science lesson. Cameras that record to high capacity storage cards are another noteworthy alternative to using those that require tapes or discs. These formats are preferable because the recording will be created in a digital format, making it is easier for researchers to transfer and import the science lesson video into the necessary coding software for use on laptop or desktop computers.

If the available camera equipment uses digital analog tape formats (DAT) or older video formats (VHS), or even more current mini digital cassettes, then the recorded video must be transferred in real time and converted into a compatible file format in order to be used with any computer software program. This process is time consuming and typically requires as much time or more than the duration of the initial video recording. Further time may be needed for conversion of the video into different formats for possible use with other applications, such as burning digital videodisc media or importing into PowerPoint presentations. Planning ahead to use digital hard drive camera equipment will significantly reduce transfer time and minimize the need for subsequent file conversion. Since digital files remain digital, no quality is lost during transfers.

Sound capture. Classroom video research depends not only on high-quality video images, but high-quality sound recording (Derry, 2007). Inaudible video segments can compromise the integrity of the data and render hundreds of hours of classroom video unusable for coding and analysis. Most video cameras on the market today include a built-in microphone. However, this microphone may not ensure the best audio quality and may not be sufficient to capture the specific verbalizations involved in highly interactive experiential science lessons, in which the teacher and the students are moving about the classroom and engaged in enthusiastic discussions. In this case, several options are available for consideration. Small, portable digital video cameras can be easily carried around the classroom to follow the teacher’s every movement. Being in proximity to the teacher brings the microphone into closer range and provides for better audio recording. However, in elementary classrooms, video cameras can be a source of distraction to both the children and the teachers. Using multiple stationary microphones positioned at group tables is another option. This strategy requires more-complicated equipment in terms of recording multiple audio tracks from each group or switching the audio on and off to record from one group to another, depending on the location of the teacher or the action of interest. Additional equipment of this kind also includes more cables and microphones and is time intensive in terms of unpacking and packing for transporting to various classroom sites.

The use of a movable boom microphone is another option, but it also poses distractions and, in addition to a person operating the camera, requires a second research assistant to carry the boom and roam about the classroom. We experimented with several audio options and found the use of a wireless lapel microphone the best option for our research purposes. In this option, the teacher has maximum flexibility, and camera distraction is minimized. In addition, we focused primarily on the verbalization of the teacher, and we were able to obtain high-quality audio of every statement and question spoken during the lesson. With the wireless microphone, the teacher also moves the audio recording throughout the room and helps to record the verbal interactions between teacher and students, as well as between and among the children as the teachers surveys the classroom and checks on group progress.

Storage. Because digital video consumes large amounts of computer hard drive space, storage presents a third area of technical concern for researchers. Depending on individual research requirements, storage concerns should be balanced with the need for video quality, space availability, and budgetary considerations. Researcher should have an estimate of how many hours of video footage will be needed during the course of the study.

For the purposes of our research, many hours of video had to be captured and stored over the course of the multiyear project. The collected videos consisted of two inquiry science lessons from each participant in two separate cohorts of preservice teachers. Additionally, each preservice participant worked with a cooperating teacher who volunteered to have a typical science lesson videotaped as a means of determining any influences the cooperating teacher may have had upon the student's science teaching skill development. The lessons from both cohorts and their cooperating teachers resulted in a total of 204 videotaped elementary classroom science lessons, and approximately the equivalent number of hours needing to be saved and stored.

The approximate storage rate is 10 gigabytes of storage space per 1 hour of video. This rate varies depending upon factors such as amount of movement within the video and compression rate. Therefore, a minimum of 2500 gigabytes of storage was required for the storage of these individual lessons. We estimated needing enough hard drive storage space to accommodate approximately 250 hours of digital video. More movement in the video requires more space for tracking and encoding. Also, the file can be compressed to save space, but a noticeable drop in quality will occur. Researchers must decide in advance where and how they will store the captured digital video files, in order to accurately budget for and purchase the necessary storage equipment.

Two options are to invest in a large capacity server (e.g., RAID – Redundant Array of Inexpensive Drives—which can hold up to 15-20 terabytes) or more portable desktop external hard drives (one to three terabytes). The best option for the research project will depend on a number of factors. For instance, the RAID storage device is ideal and can be configured to provide enormous storage capacity that can be networked for access from multiple users or researchers. The RAID equipment is physically large and not portable, and networking can be complex and require security access protocols.

We elected to use a RAID with a total capacity of 7 TB, along with three additional hard drives (totaling another 2 terabytes) on the transfer computer, for storage and security backup of all research video and computer files. We found that investing in smaller, more-portable devices was more convenient, given a large research staff involved in the coding and evaluation of the videos. Portability and easy accessibility of small desktop external hard drives offered a convenient form of storage needed to accommodate the many various staff schedules. These storage devises are readily available for purchase in a wide range of size and costs.

Planned compatibility. Compatibility between video equipment, computer operating systems, and software packages is a final area of technical concern that can present researchers with multiple problems if not included in advance project planning. Compatibility of file formatting can be an obstacle during many phases of video-based science education research. Unanticipated incompatible file formats can be converted and compressed into alternative formats that are compatible with software and computer operating systems. Because of the wide range of formats available, it is also a good idea to invest in conversion software that has a broader application. However, conversion and compression options are not possible solutions to solving incompatible equipment problems. In situations where the analysis of video data depends on recordings made on various cameras and in alternate formats that were not anticipated at the beginning of the research, a software conversion program capable of handling a broad range of file types is necessary. When these situations arise during research, a software program called Visual Hub™ can be used that allows for the transfer of any video files into a variety of compatible file formats.

Implementation Challenges

Along with research design issues and technical difficulties, several challenges are unique to the implementation of a digital video research plan (Derry, 2007).

Trained videographer. Accurate and consistent data collection using digital video depends on adequate training of individuals operating the camera and recording the variables of primary interest. Researchers may consider two options when gathering video data. First, more controlled and objective methodology will demand trained videographers. Trained videographers are not only familiar with camera operation, but they understand the nature of the research and the variables of greatest interest upon which to focus. This option is costly in terms of funding for additional project staff and training time, but implementation difficulties and threats to validity will be minimized.

As a second option, some projects may elect to ask science teacher participants to provide videotapes recorded by themselves in their own classroom. Advantages include added flexibility in scheduling of the lesson videotaping. In projects with large numbers of participants, fewer demands are placed on researchers to provide a videographer and equipment at a prescribed place and time when the lesson is delivered. Although a more convenient and less expensive alternative, this option may sacrifice control over variable, file compatibility, and image/audio quality. Participant self-taping may be most appropriate for studies that are more anecdotal and do not require adherence to a rigorous research protocol.

In our project, to ensure that videographers understood the importance of capturing the key variables of interest to the study, we found it helpful to devote training time to detailed instruction on what to film, as well as on the use of video equipment and software. Because we studied teacher instruction and verbal behaviors, we required that the camera be continuously focused on the teacher and follow the teacher’s movements throughout the classroom. Such an orientation to the research variables ensured that these behaviors remained the focus throughout the video.

Videographers' logs. Another related concern during the implementation stage of a digital video science education research project under real classroom conditions involves keeping a log of field notes while videotaping (Hall, 2007). For example, science lessons may be interrupted because of fire drills, school announcements, and power failures. Also, loss of battery life, end of tape changes, and related camera malfunctions can lead to interrupted videotaping and result in incomplete data. Some of these problems can be avoided through staff training and preparations.

Since our focus was on teacher verbal behaviors during an entire science lesson, a complete and uninterrupted record be obtained of what was said and what transpired during the lesson was essential to data gathering and subsequent analysis. In order to accurately calculate frequencies and rates per minute of teacher talk and science questioning, video capture must be continuous from lesson start to lesson finish. However, when unanticipated interruptions do occur, detailed field notes documenting the nature and duration of the interruption are essential. If data gathering is interrupted, field notes should document the nature and duration of the interruption and account for any missing data not included on the videotape.

Field notes can describe the setting and classroom context and bring to the attention of the researchers any other extraneous factors or circumstances that affected the lesson but are not apparent on the video. Proper and consistent documentation of these factors should not be left to chance; therefore, researchers and videographers should be trained in such field note taking, and participants should be encouraged to provide any similar relevant information. We found that the use of logs and spreadsheet formats facilitated note taking and could be easily referenced later by researchers and data coders who were not present at the videotaping. Keeping a log of information on each recorded science lesson (e.g., camera number, microphone used, recording speed, format, date and location of the videotaping, and microphone frequency) makes identifying problem equipment and reasons for any difficulties easier.

Equipment preparation. The importance of preparation when managing and using video equipment for research purposes cannot be overemphasized. Preparation for gathering video data of classroom science lessons begins with a sufficient amount of the necessary technical equipment in good working order and readily available when needed (Derry, 2007). All video equipment should be kept in a designated storage area and be labeled with a unique inventory code or number.

Depending on the size and scope of the project, various sets of camera equipment can be sorted into individual carrying cases with a complete supply of batteries, cords, microphones, videotapes, tripods, and accessories. This procedure helps to monitor the location and usage of the equipment and what supplies may need to be replaced for future videotaping. For example, in our project we assigned color-coded equipment bags to individual staff or videographers who were responsible for the scheduled signout and return of camera equipment and supplies. Their responsibilities also included routine checks of proper equipment functioning and ensuring that the necessary supplies and materials were included. Carrying a backup camera and essential accessories like batteries and videotapes, prevented videotaping of lessons with missing data fragments and avoided the need to reschedule science lessons due to equipment malfunction. Planned storage and assignment of equipment also facilitates the scheduling of videotaping at multiple school or classroom locations and prevents camera availability conflicts.

Video retrieval. In addition to cameras and related accessories, preparations also must be made to accommodate the transfer of video science lesson data to multiple forms of external storage. The science lesson videos obtained during our research need to be easily accessed by multiple investigators, so equipment preparations had to include storage of this data on multiple external drives and DVD media for viewing on consumer DVD players. We also planned for conversion of all files to a compatible DVD burning format and make backup hard copies of all videos to prevent the loss of data due to hard-drive malfunction or accidental erasure.

For viewing on DVD players the files must be converted to an importable format compatible with DVD burning software. These examples illustrate the importance of not only having the necessary cameras for videotaping the science lessons, but the value of planning for the successful implementation of several subsequent phases of data transfer and management that also required detailed equipment preparations.

Conclusions and Implications

The incorporation of digital video technology and coding software packages into research focused on improving the quality of science teacher education provides a number of methodological advantages for researchers and numerous benefits for preservice education faculty and students. These methodologies hold significant promise for research investigating the development of effective science teaching pedagogy. They facilitate the transformation of teacher beliefs about science teaching and aid in the acquisition of accurate science content knowledge. Emerging digital video-based methods allow for the valid and reliable capture of discrete instructional behaviors, and they foster reflection on key elements of discourse analysis necessary for effective inquiry instruction. Verbalizations and interactional processes between teacher and students can be studied within the broader classroom context (Plowman & Stephen, 2008), which is especially valuable when examining inquiry-based science instruction.

Digital video recording affords science education faculty members and researchers options for documenting all facets of science instruction from micro skills to macro classroom-level contextual factors. Within the broader context of real classrooms, a finer analysis and a deeper understanding of the instructional transactions associated with effective science teaching and learning can be achieved. The ever-expanding range of video technologies offer particular advantages when employing repeated measures and longitudinal designs that attempt to record and analyze professional skill development over time and across the professional continuum. The archival storage and retrieval advantages can lead to the development of large-scale databases containing exemplars of science education best practices, with the potential for rapid online access by faculty and students for multiple purposes, such as research, training, and course curriculum development.

Preservice science teachers may benefit greatly from the use of video review as a means of reflection, self-evaluation, skill rehearsal and critique, and confidence building (Yerrick et al., 2005). Advances in digital video technologies, software developments, and storage and retrieval conveniences will enable preservice teachers in training to construct more comprehensive and informative Web-based electronic portfolios that encourage continuous performance reviews, progress monitoring, and reflective self-analysis of their development (Rich & Hannafin, 2008). In doing so, digital video technology will help to strengthen both research and practice, and offer a strong link between the two.

Today's rapidly developing digital technologies have made the capture of higher quality classroom video much easier than in the past, and access to faster and more powerful computers have made image manipulation and editing techniques more research friendly. However, the use of digital video research methods is not without significant challenges that, if left unanticipated, can pose serious threats to the validity of any investigation.When incorporating digital video methods into classroom research, anticipating the potential difficulties can help avoid errors and minimize threats to validity. The integrity of the data is always a primary concern, so video and audio quality always must be a priority.

Issues of hardware and software compatibility also must be considered. Technical camera knowledge and pilot filming may eliminate problems such as the video interruptions that result in discontinuities and compromise subsequent data analysis. Many of these challenges can be addressed through advance planning, training of research personnel, and prerequisite technical information gathering. Also, thorough understanding of digital format options is critical to avoid future problems associated with for storage and transfer, external components, and overall quality.

Finally, including digital video into a research protocol is not a panacea for overcoming the complexities of measuring classroom interactions and dynamics (Wang & Hartley 2003). Research methodology that relies solely on video technology can overlook teaching and learning processes that are not directly observable. Researchers always must be alert to the pitfalls of subjectivity and bias that can influence the direction and focus of the video camera lens, as well as the coding and analysis of the data (Schuck & Kearney, 2006). Care should be taken to recognize that the presence of a camera and video recording in classroom environments can cause distractions that lead to reactivity effects, influencing the behaviors and responses of the students and teachers.

Although these challenges warrant constant attention and further consideration, digital video technologies provide numerous advantages and benefits that far outweigh the complexities of their use. The possibilities are virtually limitless for using digital video technology as a research and training tool in the preparation of a new generation of science educators and increasingly will become the method of choice for educational studies in the future.

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Appendix

Advantages of Incorporating Video in Research

***Quality*:**

- Eliminates physical contact between the recording medium and the mechanism of playback eliminating friction and preserving image and the audio quality.

***Reproduction*:**

- Allows data to be quickly replicated completely retaining original video and audio quality.
- Maintains full quality maintained regardless of whether or not the original source is used for duplication, which is convenient when the original source has been archived and immediate access is not available or if the original is lost or destroyed.

***Navigation*:**

- Configured in a nonlinear manner enabling improved navigational capabilities, more efficient use of viewing time, and greater precision in selecting any desired scene
- Avoids excessive wear and tear on equipment mechanisms and maintains the quality of the original video data over time even when specific segments must be viewed repeatedly.

***Editing*:**

- Enables an editing process that is less tedious and more cost efficient.
- Allows for scenes or video clips to be isolated and easily extracted or transferred using standard click, drag, and drop features.
- Provides a range of options for in-depth research study and analysis allowing specific behavioral instances to be compiled for presentation and instructional purposes.
- Facilitates researchers ability to identify specific exemplars, extract scenes with the most relevant information, and join excerpts from multiple sources into multimedia presentation formats such as DVD formats or "stand alone" movies that are easily imported into PowerPoint presentations.

***Storage*:**

- Allows for hundreds of hours of high quality video to be stored in approximately the same physical space as several VHS cassette tapes.
- Removes the need for a significant amount of hard drive space for storage through videodiscs and file compression as alternative means of storage that can address anticipated hard drive storage demands.
- Requires advanced calculation of storage requirements to fit the parameters of the research or the preservice training program.