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# Advanced video technologies to support collaborative learning in school education and beyond\*

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**Abstract.** The aim of the paper is to characterize two new advanced video technology software systems developed for uses in collaborative learning (DIVER<sup>1</sup> and HyperVideo<sup>2</sup>), and how they extend the paradigms of video use in classrooms today. The rationale for and characteristics of these tools are described, and early experiences with their use are characterized.

**Keywords:** Cognitive tools, advanced video technologies in school education, teacher education, collaborative knowledge construction

## INTRODUCTION

In school-based education, video is often used to enrich regular lessons and as supplement to teacher lectures and explanations in front of a class. In this case, video is a presentation medium used to display information to illustrate and dynamically visualize knowledge to foster a better understanding. Although the results concerning the effectiveness of using videos as presentations are inconsistent, empirical findings on learning with video media consistently show that audiovisual presentation formats facilitate the comprehension and transfer of knowledge, especially in those domains where dynamic processes and concrete objects or complex systems need to be observable for a proper understanding of the topic (for overview, see Wetzel, Radtke & Stern, 1994; Park & Hopkins, 1993).

A second way of utilizing video in school education consists of depicting concrete real-world problems or cases that then are related to more abstract knowledge and problem solving skills. This is illustrated, for example, by the famous “Jasper Woodbury Series”, a set of interactive videos developed by the Cognition and Technology Group at Vanderbilt University in the late 1980’s and 1990’s for complex mathematics problem solving (Cognition and Technology Group at Vanderbilt University, 1997). In this case, video is an *interactive medium* both presenting data and situating knowledge for the purpose of “anchored instruction” (Barron et al., 1998; CTGV, 1997). Here, students are not only supposed to watch and listen to the stories of the protagonist (Jasper Woodbury), but also to work actively and collaboratively with the interactive videos in class. Interestingly, it could be shown in an experiment that those groups of students who were asked by their teacher a) to pose their own subordinate questions while working with the video and b) to self-dependently find the relevant information to answer these questions in a video episode outperformed other groups of students who just viewed the video episode and received general text-based information on problem solving (unrelated to the

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<sup>1</sup> DIVER™, WebDIVER™, Dive™ and “Guided Noticing”™ are trademarks of Stanford University for DIVER software and affiliated services with patents pending. The DIVER project work has been supported by grants from the National Science Foundation (#0216334, #0234456, #0326497) and the Hewlett Foundation. The DIVER team contributing to these efforts includes Roy Pea (Director), Michael Mills, Joe Rosen, Kenneth Dauber, and graduate students Robb Lindgren, Paula Wellings, Sarah Lewis and Lori Takeuchi.

<sup>2</sup> The HyperVideo system was developed at the Computer Graphics Center in Darmstadt, Germany in cooperation with the Knowledge Media Research Center in Tuebingen, Germany.

video). Thus, if a teacher's guidance related directly to the Jasper story and included active cognitive processing of the information displayed in the videos, students learned better to solve mathematical problems than when they just viewed a video episode and received general training in problem solving in parallel (Van Haneghan, Barron, Young, Williams, Vye & Bransford, 1992). To conclude, students guided to actively explore video information can build dynamic mental models of situations (associated with their individual prior knowledge) and relate these to the higher order cognitive skills of collaborative complex problem solving (Kozma, 1994).

A third well-established way of introducing video into school education is performing "video projects" as a specific kind of *media project* (Baake, 1999). Such video projects rely on an idea sometimes described as "learning by design" (LBD, Reimann & Zumbach, 2001) or "project-based learning" (Baake, 1999; Bereiter, 2002). In this paradigm, video is used as a *design medium* whereby students engage in active video production as a motivating and authentic collaborative task. In other words: video is not only used to present information or situate a problem to be solved (like in the "Jasper Woodbury Series"), but creating video artefacts *is* the problem to be solved.

As an example, students are sometimes asked by their teacher to shoot a video clip as their homework. When the lessons are about "advertisement," students may produce a video showing a TV-ad. To accomplish this, students have to structure their knowledge and present their understanding of TV-ads, and they need certain cognitive and social skills to accomplish this activity successfully. In particular, they have to learn a) how TV-ads are produced and how they are persuasive (understanding of lesson content), b) how to use a video camera and how to edit videos (technical routines), c) how to visualize a theme or certain emotions, how to use film techniques in order to persuade people (rhetorical skills), and d) how to negotiate different ideas within a team, and how to collaborate and coordinate the process of video production (social skills). More generally speaking, video production might not only be considered valuable for its own sake (and in design areas or the arts), but as engaging important mental and social processes (in those who accomplish the tasks) that eventually help to develop both the acquisition of interdisciplinary (meta-) cognitive and social skills and a deep elaboration of the topic at hand (Carver, Lehrer, Connell & Erickson, 1993; Scardamalia, in press). We elaborate on this idea below. Research literature in this area consistently emphasizes these potentials of design projects as an instructional method promising to serve several important educational goals at once: the goal of *training skills*, the goal of *building dynamic social relations* and of *building knowledge* (see Oser & Patry's 1990, 1994 taxonomy). The goals of training skills, building dynamic social relations and collaboratively building knowledge become increasingly important in our modern society where more and more individuals have to cope with complex topics, teamwork and large amounts of information every day (Roschelle et al., 2000)—and where media competencies and digital literacy can almost be regarded as "survival skills" (Baake, 1999; Eshet-Alkalai, 2004). Accordingly, collaborative multimedia design projects using the services of emerging computer technologies have become particularly popular in school education – despite the fact they might be rather costly and require new forms of professional development for teachers to support such student work. Examples include contextualized multimedia editing (e.g. Beichner, 1994; Pea, 1991; Scardamalia, in press), interactive game design (e.g., Kafai & Ching, 2001; Rieber, 1995) and hypermedia design (e.g., Bereiter, 2002; Carver et al., 1993; Erickson & Lehrer, 1998; Stahl, 2001). These examples all have in common that they intentionally involve additional creative activities for structuring information in non-linear ways and integrating dynamic visual media with texts. It is expected that here, the potential benefits for student designers are augmented by the specific cognitive skills of "meta-representational" and "meta-relational" thinking (Carver et al., 1992). This leads us to a fourth way of using video in school education that we have been investigating and that we conjecture will be important for both formal and informal learning activities: the use of advanced digital video technology in support of collaborative knowledge building processes.

## **DIGITAL VIDEO TECHNOLOGY AND GROUP KNOWLEDGE PROCESSES**

Introducing video into school education in the future could consist of introducing advanced digital video technologies that will broaden the spectrum of use paradigms described above. Our two groups—in Germany and the United States—have been working in parallel on exemplars of a paradigm that is already a part of our everyday lives, but which has been minimally appropriated yet in K-12 education. Advanced digital video has brought about new conventions of filmic expression in many areas—whether in the arts, at home or in the workplace. For example, in entertainment we use DVD movies that are partitioned into chapters or scenes (including extra scenes that were not shown in the original movie) and which can be randomly accessed by the viewer. Moreover, in workplaces, advanced digital video technology is not only a means of communication via video conference. It is also used for video analyses (e.g., in the area of professional sports, or teacher education). And it is used for collaborative work in life sciences as was illustrated by Sutter (2002) describing the case of two groups of medicine experts from two distant hospitals in Sweden: Here, surgeons, radiologists and cardiologists from two networked groups discussed coronary diagnoses of patients (who had been examined only in one of the hospitals) by means of special X-ray videotapes of patients' coronary and a video display

pointer allowing participants to point to visual details and to add comments to the video information either verbally or by direct pointing.

To conclude, the use of video today might well include the selection of single scenes or objects from existing video information and even the direct integration of video scenes with e-communication tools. The number of workplaces that are making use of advanced video being used in different ways is steadily increasing. Thus, we are confronted with a situation where we need to establish new components of visual literacy (Messaris, 1994) and digital literacy that relate to such work scenarios. Literacy concepts cannot be restricted to static and text-based media anymore, but have to integrate the understanding, analysis and active use of non-linear and audiovisual media as well including the use of digital video technology (Pea, 1991; Pea & Gomez, 1992; Stahl, Zahn, Schwan & Finke, submitted). To this end, advanced digital video technologies may become part of our educational systems. The question is then: How can such technologies be implemented in schools and in educational and learning processes broadly? To approach these questions, we will consider existing advanced educational digital video systems that were developed on the basis of cognitive and socio-cognitive psychological and pedagogical considerations.

### Learning to observe - Learning to analyze.

The DIVER system was developed by the Stanford Center for Innovations in Learning. DIVER is based on the notion of a user “diving” into videos, i.e., creating new points of view onto a source video and commenting on these by writing short text passages or codes (Pea, Mills, Rosen, Dauber & Effelsberg, 2004). DIVER makes it possible to readily create an infinite variety of new digital video clips from any video record. A user of DIVER software “dives” into a video record by controlling—with a mouse, joystick, or other input device—a virtual camera that can zoom and pan through space and time within an overview window of the source video. The virtual camera can take a snapshot of a still image clip, or dynamically record a video “path” through the video to create a dive™ (which we also call a DIVER worksheet, see figure 1 below). A dive is made up of a collection of re-orderable “panels”, each of which contains a small key video frame that represents a clip, and a text field that can contain an annotation, code, or other interpretation. Diving on video performs an important action for establishing common ground that is characterized as “guided noticing” (Pea, in press). The use of the virtual camera for the framing of a focus within a complex and dynamic visual array directs the viewer’s attention to notice what it is that is thus circumscribed, and the point-of-view authoring thus guides the viewer to that noticing act. In this way, DIVER can be used as a tool to promote the development of “professional vision” in learning within disciplinary domains (Goodwin, 1994).

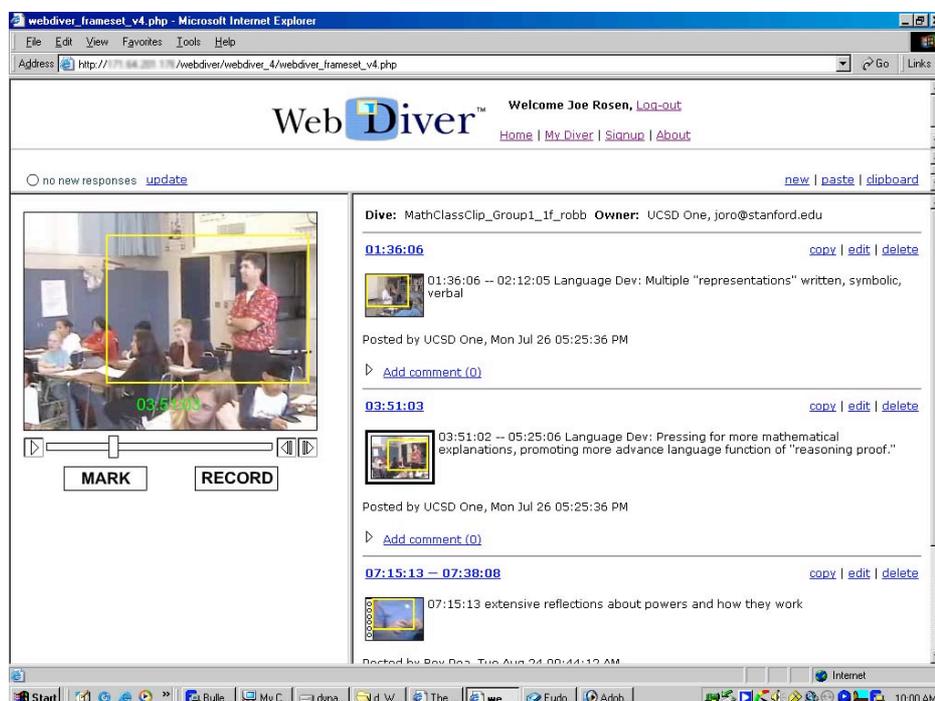


Figure 1: DIVER worksheet

Originally, DIVER’s primary focus was for supporting research activities in the learning sciences (such as interaction analysis: Jordan & Henderson, 1995), and in teacher education, where video analyses play a major role for understanding one’s own behavior and reflecting on it in relation to the behavior of others. DIVER has

also been designed to enable the active exploration of panoramic video data—where one or more digital video cameras and associated mirrors are used to capture 360-degree horizontal imagery. In this case as well, the user may select visual information by virtually ‘pointing to it’ in the much larger spatio-temporal data structure of the video, for the purposes of collaborative reflection and analysis. The final product then is a collection of separate short video segments with annotations that represent the user’s point of view on the video.

There are two different ways users work with video using the DIVER approach. In the first, after creating a dive using the desktop DIVER application, the user can upload it onto WebDIVER, a website for interactive browsing, searching, and display of video clips and collaborative commentary on dives. In an alternative version of the WebDIVER system, one can dive on streaming video files that are made accessible through a web server over the Internet, without either requiring the downloading of a DIVER desktop application or the media files upon which the user dives. Using WebDIVER in either of these ways, a dive can be shared over the Internet among teachers, student-to-student, teacher-to-students, or in other scenarios with colleagues and become the focus of knowledge building, argumentative, tutorial, assessment or general communicative exchanges.

On a more generic level, however, the system might be described as providing a cognitive tool that enables “pointing to video” and thus helping to develop skills of observation and noticing details and enhancing the probability that in the collaborative processes, the focus of attention and negotiating of meaning between participants in a conversation will build upon a common ground. With DIVER it becomes obvious that advanced technology may not only amplify existing kinds of activities and communication, but that it might augment our spectrum of activities and initiate entirely new forms of learning (Pea, 1985; Beichner, 1994).

The DIVER system distinctively enables what its creators call “point of view” authoring of tours of existing video materials in a way that supports sharing, collaboration, and knowledge building around a common ground of reference (Pea, in press; also see Goldman-Segal, 1998 and Stevens et al., 2002 for related prior work). This form of communication with video is important for tapping the powerful potentials of video-enhanced learning.

### **Learning to integrate text and video - Learning to design non-linear information structures.**

The web-based HyperVideo system for collaborative learning was developed at the Computer Graphics Center/Darmstadt in cooperation with the Knowledge Media Research Center/Tübingen. It is based on the idea of “annotating movies,” i.e. selecting video segments from a source video and having spatio-temporal hyperlinks added to video by multiple users. The overall design approach encompasses several steps: (1) information is mainly presented by video, (2) knowledge can be collaboratively expanded by means of both dynamic links and written e-communication, and (3) the process of knowledge building is reflected in a resulting hypervideo structure we denote as a ‘dynamic information space’ of a collaborating group (*DIS*, Zahn & Finke, 2003; Chambel, Zahn & Finke, 2004). Users of the HyperVideo system can create their own dynamic sensitive regions (“hotspots”) within video materials and add multiple links to these sensitive regions. Links can consist of data files uploaded from a local computer, as well as URLs. The links (or the associated information elements, respectively) can then be discussed by means of an integrated e-communication tool. Thus, both randomly accessing information provided by others and adding one’s own new information and knowledge becomes possible with the HyperVideo system.

The system is based on client/server architecture. The DIS containing the content of the hypervideo is stored entirely at the server side preventing the users for any form of data inconsistency. The web-based graphical user interface (see figure 2 below) allows the adaptation due to different GUI layouts and consists basically of a special video player that visually displays the spatio-temporal hyperlinks within the video frame and offers functionalities in order to create new video annotations. The cross platform video player itself is written in JAVA using the Java Media Framework for the purpose of manipulative video rendering. New created video annotations are immediately transferred from the client to the server in order to be instantly shareable by the community. The system concept

On a generic level, the HyperVideo system can be described as a cognitive tool enabling the linking of video information thus helping to learn to establish non-linear information structures and to focus attention and discussion in collaborative learning on associated concepts or related external representations of knowledge (e.g., a visible object and a text, or visible object and a formula). The system was first developed for unspecified situations of CSCL. The basic idea was that structuring hypervideos by dynamic links can serve to promote both learning to integrate different information elements and to develop non-linear knowledge structures by collaboratively designing information and discussing links.

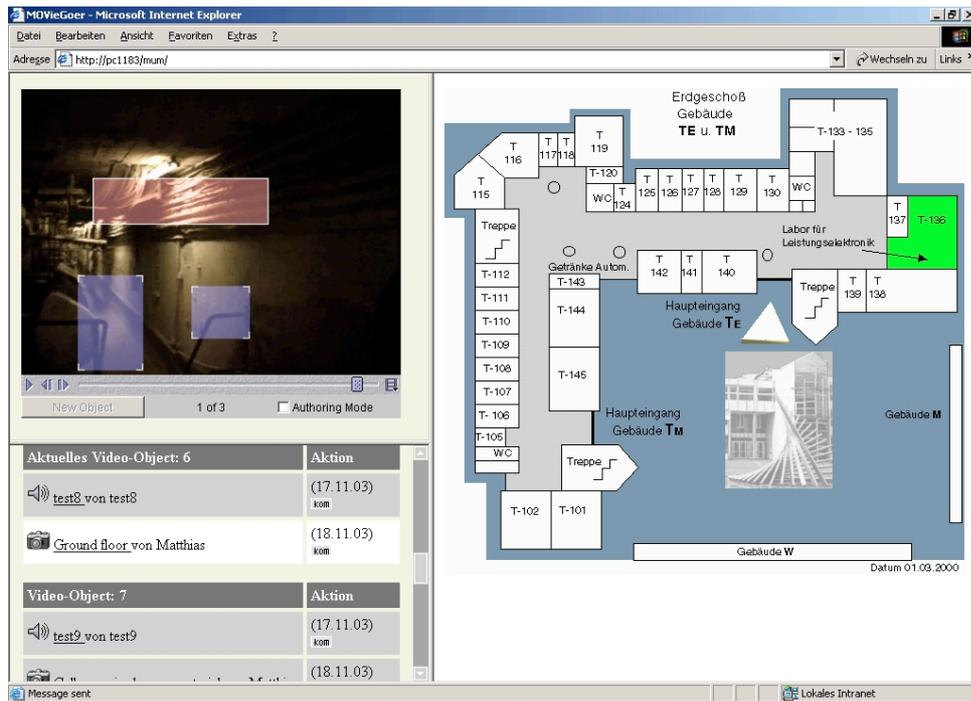


Figure 2: Graphical user interface of HyperVideo

Hypervideo authoring has been discussed repeatedly as an opportunity for performing collaborative hypervideo design projects in educational contexts (Chambel, Zahn & Finke, 2004; Zahn, Schwan & Barquero, 2002). Additionally, the new technology was evaluated and further developed during three psychology courses at the University of Muenster/Germany. These courses were planned according to an instructional program based on courses of hypertext writing, developed by Stahl and Bromme (2004) on the basis of models on text writing (e.g., Bereiter & Scardamalia, 1987). The course concept aims at utilizing central features of hypervideo design as constraints that foster knowledge transformation in learners (Stahl, Zahn, Schwan & Finke, submitted; Stahl, Zahn & Finke, submitted). The concept also aims at controlling basic influencing factors that were identified earlier by Stahl (2001) in the context of hypertext design tasks at school. These factors are of essential importance for our present purposes, as will be described in the following section.

## ADVANCED DIGITAL VIDEO SYSTEMS AS 'RHETORICAL PROBLEM SPACES' IN COLLABORATIVE SITUATIONS

Applying the Bereiter & Scardamalias (1987) model of knowledge transformation to the process of learning by hypertext design, Stahl and Bromme (2004) assume that the peculiarities of hypertext may influence the process of learning in very specific ways: 1) Hypertexts are non-linear media, so hypertext design processes do not only include linear writing processes, but also the selection and creation of small "nodes" and the representation of concept relations by links and an overall structure (integration). Also multiple ways of "reading" the hypertext must be considered (e.g., multiple audience perspectives). This should lead learners to a very deep elaboration of content. 2) Hypertext design problems (due to their complex nature) are solved in cooperation and collaboration with others, so the production process has to be coordinated in a group. This should lead to collaborative knowledge building and knowledge exchange. 3) Hypertext design has just begun to emerge, so that even among professionals different 'metaphors' (= genre knowledge and mental models of the medium) can be applied. To be able to work and learn, students have to consciously develop and negotiate upon a joint idea of 'what a hypertext is' as a first step of their coordinated work. Finding an appropriate metaphor should lead to developing discourse knowledge, on the one hand, and further joint elaborations of the content, on the other hand. These assumptions are also substantiated by empirical results: The reflection of different audience perspectives has been found superior to not doing so. The thorough evaluation of links representing semantic relations between nodes has been found to lead to a deeper elaboration than not using such activities. And finally, a space metaphor showed to guide knowledge transformation processes better than a book metaphor of hypertext (Stahl & Bromme, 2004). Similar assumptions might be made for hypervideo design processes, too, as was suggested by Stahl, Zahn & Finke (submitted).

As was described in the previous section, we view advanced digital video technologies as cognitive tools according to a perspective of distributed intelligence (Pea 1993, 2004). Merging this view with the works on hypertext design fostering knowledge transformation processes (Stahl & Bromme, 2004), we might generally perceive advanced digital video technologies as *establishing new rhetorical problem spaces with their own rhetorical rules*. These rhetorical problem spaces can well be understood in the sense of Bereiter and Scardamalia (1987) who assumed two problem spaces as important for text writing: the content problem space and the rhetoric problem space. However, because in the present context we have to deal with digital video, rhetoric problem spaces are understood as (audio-)visual ones instead of being merely based on text. Consequently, the rhetorical rules of our new rhetorical problem spaces can be extended by visual codes and the editing styles of different film genres (filmic codes of *mise en scène* and montage, see Metz, 1974; Salomon, 1979). In sum, the rhetorical rules relating to hypervideo - as to our opinion - include rules relating to different text genres, to the visual codes and styles of static pictures/graphical displays, as well as to the dynamic visual codes of film and animations.

## **COLLABORATIVE ACTIVITIES INVOLVING ADVANCED VIDEO TECHNOLOGIES**

We are now exploring in pilot studies a variety of ways that collaboration can be advanced in learning using advanced video technologies such as the two systems we have described. In WebDIVER, learners can collaboratively analyze video records from archival sources (e.g., science videos, social studies content), or from video they have themselves collected (e.g., of fieldtrips, art museums, classrooms, or playground activities). Using the HyperVideo system, learners as well as teachers can collaboratively create hypervideo documents (e.g. in university courses, as mentioned above) on the basis of existing or of self-shot videos. Learners can generate links connecting related information, they can add information of any kind to a source video (e.g. an instructional video) and they can discuss their contributions with others. In both the German and Stanford software systems, collaborative video work can take place either face to face in a computer-intensive school setting or after-school club, or over computer networks, involving distant locations, either synchronously or asynchronously. In both systems, learning scientists can also collaboratively engage with video, to interpret and analyze educational interactions or other behaviors of interest to their studies.

In preliminary work with the WebDIVER collaborative video analysis framework, we have found utility in the following scenarios: (1) pre-service secondary teachers in Stanford's school of education, creating dives of ten-minute unedited videorecordings of their own teaching, which they analyze with respect to the rubrics which their faculty mentors use to evaluate their work; (2) learning science doctoral students collaboratively analyzing teaching videorecords according to different disciplinary perspectives (anthropology, linguistics, sociology, developmental psychology, educational psychology, cognitive science) and then working to combine them to deepen the quality of interaction analyses; (3) distributed researchers working to analyze video data from user studies, in this case, of preschool children interacting with a touch-screen video-based storytelling system we call KiddieDIVER, and providing a collective set of recommendations via a dive on these data that was shared with the software engineer over the web for review and implementations of software improvements based on insights from the collaborative video analysis activity; (4) faculty use in preparing dives on videos of secondary educational practices that are used in lectures to exemplify and explore theoretical concepts from the research literature used in their courses (e.g., cognitive apprenticeship, scaffolding, academic language); and (5) a film studies professor working with his students to compare several different film versions of the Shakespeare Play Henry V. We make several points on the last scenario to exemplify the transformative nature of such activities with respect to common pedagogical methods. In each of these scenarios, as in the German hypervideo experiences, we are finding that collaborative diving requires working in new rhetorical spaces, in cooperation and coordination with others. For example, WebDIVER users creating collaborative analyses wish to sustain a private-public boundary even for synchronously-developed collaborative dives, and to have control over when their respective contributions are made reviewable by their collaborators in the common web space in which they are working.

Film students spend considerable time studying major filmmakers, film genres such as *film noir* or *new wave cinema*, the grammar of cinematography (Metz, 1974) including shot segmentation, camera movements such as panning and tilting, and transition effects such as cut and fade, as well as narrative techniques such as montage and flashbacks, and the animated special effects that have defined recent film developments. DIVER provides a new tool for the faculty member and film student to develop the web of perceptive knowledge that ties together the history of films, filmmakers, film methods and techniques and film criticism. In a film studies course now underway using DIVER at Stanford, graduate students in film are studying the relationship between the actor and the written work: How is the medium used to tell the story? For example, students are looking at two clips, the 1989 film adaptation of Henry V directed and played by Kenneth Branagh, and the 1944 film version of the same Shakespeare play directed and played by Laurence Olivier. The same scene and words will be analyzed: Henry V's "Crispin's Day" speech. Previously the film studies professor provided a related assignment to students—describing in an essay what was different about each actor's interpretation—but by

having them write about the movie scenes from memory. With WebDIVER, film students are able to point to specific space-time regions of the film in real-time examples from each movie, and to justify their analysis with video-based argumentation using the scenes from the movies being compared. This exercise will take place outside of the classroom, as a homework assignment. Each student is given their own protected workspace, and they access the films and the WebDIVER analysis tool on-line via a web browser. Students will then present their analysis in class, also using WebDIVER. The students will have a chance to comment on each other's work, both orally in class and again later on-line by adding messages and comments to the web-based Dive worksheets. Although this same assignment has been used in film class before, this will be the first time a) students will be able to point directly to the scenes they're analyzing and referencing; and b) an informal learning discussion (via web page collaborative commentary) will continue outside of the classroom presentations. In WebDIVER, students can also literally navigate the movie by way of the actor's/script's utterances (i.e. click on an utterance and go directly to the corresponding scene in the movie). The utterances also scroll along with the movie. The professor anticipates a nuance and depth to analysis that he has not experienced using his previous approach to instruction and assessment.

Pilot studies involving the HyperVideo system include an experimental comparison of how (and where) authors with different prior knowledge would suggest placing hyperlinks in biology videos (Zahn, Schwan & Barquero, 2002). The results of this study revealed that authors of different knowledge backgrounds (content-experts, media-experts) developed similar ideas of a hypervideo structure, which were mainly based on formal features of the source video (such as, for example, terms included in the audio track). Results also showed – and this is more interesting in our context – that the linking decisions of expert-authors were quite congruent with those of novice users, indicating that even users with low prior knowledge were capable to make meaningful linking decisions. This provides a minimum basis for applying hypervideo design tasks at school. Field studies extending this basis also conducted as already mentioned above: in three courses at the psychology department of the University of Muenster/Germany students designed hypervideos on topics such as ‘techniques of presentation and moderation’ in the first course [n = 16] and ‘the study of psychology in the University of Muenster’ in the second course [n = 10]. These courses were evaluated extremely positive by the students (Stahl, Zahn & Finke, submitted).

Our current work includes a school project, where hypervideo design will be applied in German secondary schools to support media education in German native language lessons (“Deutschunterricht”). The topic will be TV-advertising. We plan to study the collaborative analysis of TV-ads based on the DIVER system and the collaborative hyperlinking of TV-ads based on the HyperVideo system. Altogether, we will conduct two large experiments in a learning lab. Our interest is to investigate the interactions of DIVER and HyperVideo as two generic types of digital video technology with a) individual cognition (i.e. mental models of “hypervideo” in learners) and b) teacher’s instructions (i.e. the support of group discussion by teachers) and the influences of these interactions on group knowledge processes. This future-orientation leads us to the last section of this paper.

## **CONCLUSION AND FUTURE WORK**

In writing about modern music, writing, art and science, Umberto Eco (1989) notes that “‘open’ works, insofar as they are in movement, are characterized by the invitation to make the work together with the author and that (2) on a wider level (as a subgenus in the species ‘work in movement’) there exist works, which though organically completed, are ‘open’ to a continuous generation of internal relations that the addressee must uncover and select in his act of perceiving the totality of incoming stimuli.”

To the extent that DIVER and HyperVideo use can make video and movies and other rich media 'open' to HyperVideo linking and to Diving—interpretation and extensible use with guided noticing, DIVER path movie-making making and annotation—there is without question an active role for the reader, who becomes an author in bringing the work of the video or other medium to a more completed state in his or her interpretations of it. DIVER also provides a tool for evidence-based argumentation, in which one uses what one notices in the medium to make a case around it, and thus extends the work in significant ways with the act of authoring the dive.

For the constructivist educator or more generally for those who want a more active voice in media uses for communication and knowledge production, these two systems exemplify a video use paradigm for education that moves away from today’s broadcast-centric and asymmetric uses of video to the communicative empowerment of the video user, who can easily craft point-of-view movies within movies with commentaries and hyperlinks to share with others. We view this fundamental shift from consumption to authorship of video points-of-view as a vital transformation in the use of the video medium for advancing learning and education.

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