Multimedia Journal Articles: Promises, Pitfalls and Recommendations

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Abstract: Advances in technology now make it possible to augment the format of traditional journal articles with integrated multimedia features that include sound, video, dynamic images and interactivity. The purpose of this report is to explore some of the issues involved in taking such a step. The theoretical rationale for how interactive multimedia journal (IMMJ) articles can support the reader's comprehension processes is present, based on earlier research on the effects of using various media to accompany text and narration. We discuss some of the limitations and problems in the use of the IMMJ format, based on our initial experiences with a prototype used to communicate a complex multimedia-based instructional intervention. We conclude with recommendations for how to use this format most effectively, avoid common pitfalls, and develop initial tests of its impact on audiences.

Introduction

Advances in technology now make it possible to augment the format of traditional journal articles with multimedia features that include sound, video, dynamic images and interactivity. The purpose of this report is to explore some of the issues involved in taking such a step. In particular, we will explore a new form of scientific reporting – the *integrated multimedia journal* article (IMMJ). IMMJs are electronic articles which present text, figures, tables, sound, colour images, and dynamic images (eg, movie clips) in an integrated format. These media are considered *integrated* because their fusion is intentionally applied to support the comprehension processes of the reader, and not merely for the sake of combining media (Cognition and Technology Group at Vanderbilt, 1993). It is now possible to construct such articles using standard word-processing applications.

The IMMJ, through its use of text, sound, and dynamic graphics, supports the comprehension processes of the reader of an article reporting on an instructional intervention and its impact. Indeed, as researchers have heeded the call for the scientific study of instructional interventions that occur in the authentically rich environments of classrooms, the limitations of purely text-based reports have become clear. Researchers and practitioners, seeking to replicate interventions or to understand what a classroom intervention was actually like in order to make informed evaluations, are often left relying on the descriptive talents of the author. The broader bandwidth of the IMMJ format, as compared to a traditional text-based medium, is capable of enhancing scientific reporting and training efforts.

As a basis for this discussion, we first describe a prototype IMMJ article we have developed to communicate a complex instructional intervention. The theoretical rationale for how IMMJs can support the reader's comprehension processes is then presented, based on earlier research on the effects of using various media to accompany text and narration. We then discuss some of the limitations and problems in the use of the IMMJ format. We conclude with recommendations for how to avoid these problems, use this format most effectively, and develop initial tests of its impact on audiences.

A prototype integrated multimedia journal article

We have recently developed a prototype integrated multimedia article for the reporting of scientific investigations into the learning of middle school mathematics. Our discussion is informed by the construction of this IMMJ article. The electronic article (Nathan *et al*, 1994) reports on a multimedia intervention and assessment that taught six 5th grade classes the elementary statistics concepts of business mathematics – specifically, how to produce a business plan for a school fundraising activity by calculating expenses and estimating revenue. The IMMJ article is based on an earlier article developed in the traditional format (Barron *et al*, 1994) which reported on this classroom intervention and assessment. The particulars of the study and its findings are presented there.

In constructing the IMMJ version from the original article, several sections were converted from text to video and sound: verbal descriptions of the intervention materials which appeared in the original text version were replaced with video footage from the multimedia intervention; lengthy quotes from student interviews

were also replaced with the corresponding video clips from the original interviews; and, in one case, a static picture of a dynamic process (showing the time it takes to fill a pool and its relation to the rate of water flow) was replaced with the dynamic simulation that had been used as a teaching aid in the classrooms.

In contrast to their cousins – multimedia and hypermedia platforms – little is required from the reader of our prototype IMMJ in terms of navigation ability that is not already common to the text-based reading process, because our example electronic document maintains the linear 'article' model of a scientific report. The reader moves through the article in a linear manner, making large or small moves, forward and backward, with the familiar scroll-bar technology common to many current applications and operating systems (Figure 1).

When the reader encounters a dynamic QuickTime™ image,[1] it appears as a colour or black and white figure, about 3 inches in width and 2.5 inches in height, with a 'filmstrip' icon in the lower left-hand corner. Clicking on the image with the rolling mouse cursor brings up a 'control bar' with the familiar play, forward, reverse, and pause icons common to tape recorders and VCRs. When a video clip ends, it changes the figure back to the original still image showing the first frame of the clip. Instructions describing these control operations to the reader appeared at the beginning of the IMMJ article (and are reproduced in Figure 2).

The prototype article contained a total of nine video clips and one narration (audio-only clip) which accompanied a still image of a data graph presented to the students for their analysis.

The prototype provided a concrete illustration of the capabilities associated with the broader bandwidth afforded by the IMMJ format. The IMMJ is capable of providing exemplars of a wide range of instructional materials including those that are video and computer-

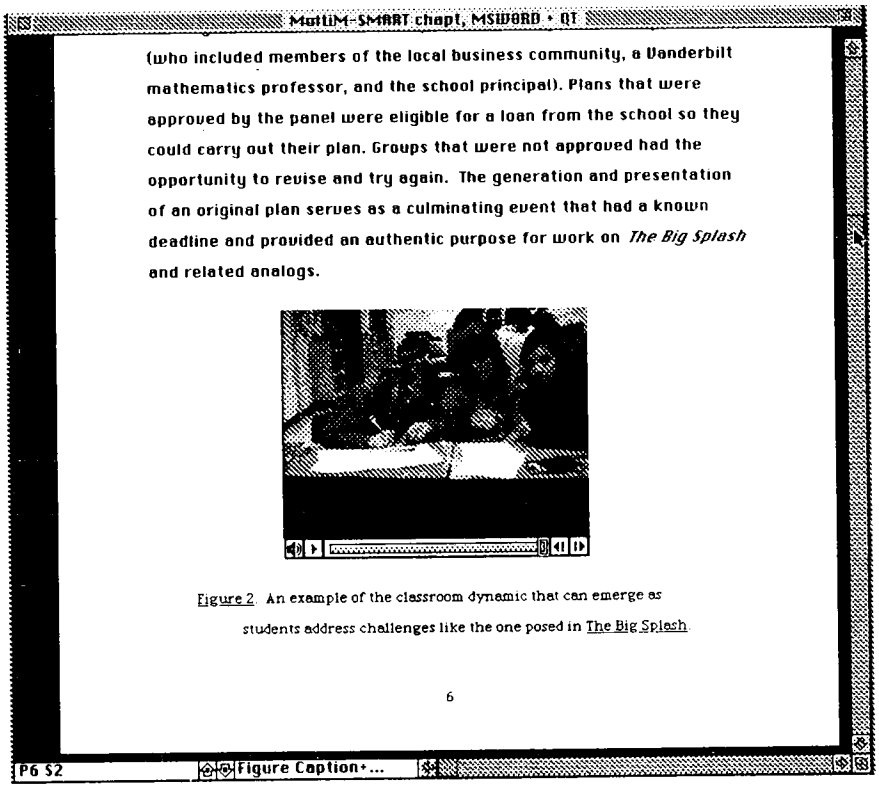

Figure 1. *A portion of a page from a multimedia article. The dynamic figure (video clip) shown includes a 'film-strip' icon that, when selected, produces a control bar for the reader to play or pause the video and adjust the volume. Sliders on the side allow the reader to move through the entire article, forward and backward in either small (line-by-line) or large (page-by-page) steps*

[1] QuickTime™ is a standardized way of storing a variety of dynamic media types such as movies and sound bites. QuickTime™ is a trademark of Apple Computer, Inc.

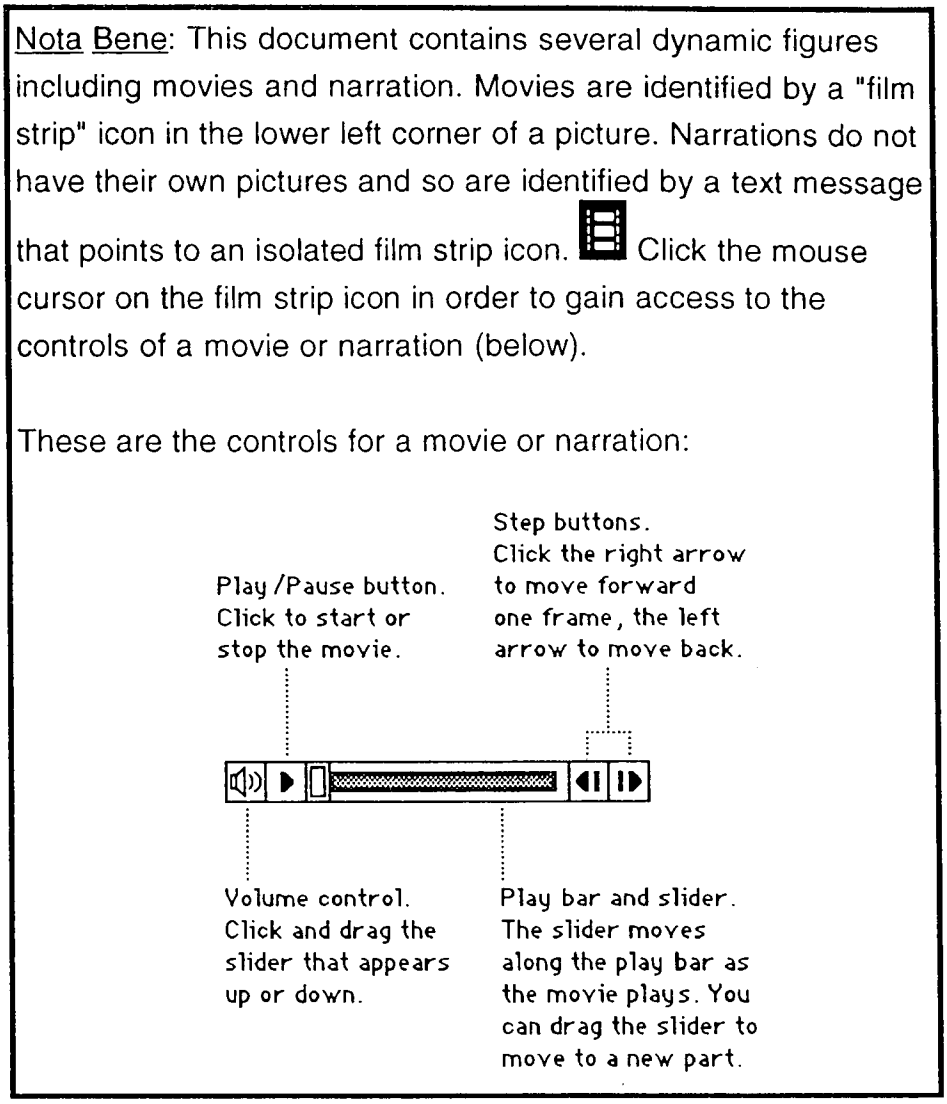

Figure 2. *Instructions to the multimedia journal article reader (from Nathan* et al, *1994)*

based. It also can convey how these materials are delivered to the classroom, and what their impact is on the classroom and the teacher in a visually and auditorially rich medium. However, it is also limited. It is clearly not a panacea for the replication and evaluation issues that arise in educational research. For example, it is no substitute for professional development workshops or for the learning process that each educator and researcher must face with implementations of innovative classroom practices (eg, Brown, 1992).

On the other hand, the theoretical framework presented in the next section suggest that the IMMJ can support readers in the development of more accurate mental models of instructional interventions, and provide valuable video-based anchors to support readers who may be unfamiliar with common technical language and jargon. This form of support can greatly enhance training efforts that are designed to disseminate innovative interventions, as well as the reporting activities that are central to educational research activities.

The promises of multimedia articles

Research from a variety of sources indicates that static and dynamic illustrations can provide support for mental model construction during reading and listening.

Given the theoretical rationale for improved understanding of the situations depicted in IMMJ articles, we can posit several areas of promise for this medium.

Support for mental model construction

In our experience, readers of articles describing instructional interventions often develop a poor understanding of the intervention when given only a verbal description, or a verbal description with occasional static illustrations (Cognition and Technology Group at Vanderbilt, 1994). Similarly, very lengthy descriptions of the behaviour of people are often less helpful than video enhanced descriptions (Rock and Bransford, 1992). When confronted with such descriptions, readers often seem to *assimilate* the described work to known instructional approaches. They say, for example, 'We do multimedia work just like that in our laboratory.' It is very difficult for the reader to understand how similar an intervention is to their own work and where the substantive differences lie until the reader actively engages in the instructional activities. When the new intervention is effectively communicated to the interested observer, *accommodation* rather than assimilation occurs.

Appropriately constructed illustrations, both static and dynamic, are believed to help the readers' and listeners' memory and comprehension processes by facilitating appropriate uses of assimilation and accommodation through the development of more accurate mental models of the situation described in a passage or lecture (eg, van Dijk and Kintsch, 1983). Mental models are cognitive structures that organize knowledge in ways that support knowledge use and the acquisition of new information (see the 'situation model' construct proposed by van Dijk and Kintsch, 1983). Mental models are often considered to be image-like, because they capture holistic qualities among components in a situation, such as their spatial or causal relationships.

Mental model construction, sense-making, elaboration, comprehension monitoring, and other higher-order processes that can occur during reading (and listening) are very demanding on the reader's (listener's) limited working memory resources (Daneman and Carpenter, 1980). Illustrations support the reader to the degree that they decrease the reader's working memory load by providing redundancy, by providing new information, and by helping to organize complex information that may be unusual or highly detailed (Hegarty and Just, 1989; Lodge, 1990). This frees up resources for use in mental model construction. Illustrations also help directly in mental model construction because they provide concrete images for the mental model (Hegarty and Just, 1989; Sharp *et al*, 1992). Mental animations can similarly help the reader, but the mental animation is quite limited and its large processing demands can interfere with verbal memory and lead to a large number of re-readings (Hegarty and Just, 1989).

Because these mental representations mediate the reader's subsequent cognitive activities that are based on the text information and its associated concepts, the accuracy of one's mental models – their consistency with the original information and with the world – strongly determines the level of performance on a variety of tasks, including problem-solving, retention, elaboration, and later learning (eg, van Dijk and Kintsch, 1983). For example, Sharp and her colleagues (1994) found that multimedia support for reading comprehension can help readers (viewers) make valuable inferences that are not provided explicitly by either the video imagery or the text. Multimedia-based support for inference-making during algebra story problem-solving has also been demonstrated, with a direct effect on performance (Nathan, 1991).

Communicating affect

Affect is something that teachers view as extremely important (Goleman, 1994) yet has been one of the hardest things for people to measure and present in a static format. Visuals that show affective responses of students and subjects can help readers to appreciate the human impact of various learning opportunities or experimental manipulations. For example, short clips (before-and-afters) that depict students who initially knew almost no basic mathematical facts and then became fluent in their use via a computer training program is effectively communicated through the video medium. The visual clips add a dimension to the interpretation of the numerical data that simply can not be captured by numbers themselves. This is evident in the experimental findings on the impact of video on judgment-making (Delclos *et al*, 1987; Rock and Bransford, 1992).

Support for noticing

Educational research must be effectively communicated to the greater research community, so that findings may be understood and incorporated into the larger, emerging theoretical framework of learning and instruction, and so that successful methods of instruction and assessment may be replicated and disseminated. The ability to explore visual cases provided by authors can help one develop the pattern recognition skills necessary to notice relevant features in new situations (Bransford, Franks, Vye and Sherwood, 1989). For example, Michael and her colleagues (1993)

showed how instruction in language therapy that made use of video-based instructional materials was more effective in communicating theoretical principles, and facilitating the application of these principles to their clinical practice than for those who received the traditional format of instruction. With traditional instruction, students may successfully answer questions about language theory, but be unable to identify when or how to implement the theory, see how the theory relates to communication development, or how the relevant information can be applied to actually affect a patient's language development.

Support for new audiences

A significant promise of IMMJ articles is that, through the use of video-based anchors, they may increase the breadth of the audiences who can understand such articles and participate in the resulting discussion. At present, most journal articles use a lot of technical language and jargon – often as a necessity in order to be concise and precise. By combining text with video, it should be possible to make the basic points of articles more comprehensible to a wider variety of people – including teachers, administrators, parents, and community members – by anchoring unfamiliar technical terms to video depictions of the language use (eg, Sherwood, Kinzer, Hasselbring and Bransford, 1987). Selected video depictions of the classroom intervention can provide a diverse group with a common frame of reference. In this way, IMMJs may prove to be more inclusionary, promoting participation in the discussion of approaches and results with all of the relevant communities that may be involved in the thought process that accompanies any large-scale change in educational practices.

Pitfalls

In the previous section we discussed several areas of promise for IMMJs. At the same time, our experiences and discussions to date have raised some important issues that temper these expectations. These include the proper use of video-based data, developing unrealistic expectations for its impact, and difficulties of assessing the benefits of multimedia-based reports.

Limitations of video-based data collection

Video and audio-based data collection, as with other data-collection activities, are highly selective processes. Videographers often must make difficult decisions regarding which behaviours they will record and which they will neglect. For example, a videographer who elects to follow teachers throughout a class activity to record their teaching approach (including how they make contact with their students, model the intended behaviours, and field questions) cannot also record the interest level and behaviours of the students or the nature of student interactions. Similarly, if a particular student or student group is selected as the focus of attention during data collection, then interactions with other students may be lost. Audio selectivity is also an issue. Often to capture clear audio, it may be necessary to use a unidirectional microphone which filters out sounds that are outside the narrow pick-up pattern. The resulting picture of the classroom is necessarily biased. If the chosen group is not reflective of the class in general, the bias is even more extreme. This limitation means that presentation of chosen excerpts can be highly misleading. Also, to improve the clarity and brevity of presentation, a great deal of editing may take place. This can result in the omission of certain events, and may distort their context or re-arrange their chronological order.

Unlike traditional quantitative data such as reaction times, there is a strong tendency with video-based data for people to feel that 'seeing is believing.' Biased choices in data presentation consequently can dramatically and convincingly distort the reality of the classroom. It is important that any data video-based, verbal, or otherwise, be presented in a global context so the reader can see the range of behaviours and typical behaviours, in addition to any illustrative examples (Chi, 1992).

Overconfidence in the medium

Although carefully constructed multimedia-based scientific reports can support readers' comprehension and replication activities, even integrated multimedia articles are likely to be insufficient, in general, to foster the mental model construction exhibited by experts in an area of instructional development. We do not feel that this medium can be used as a replacement for professional development. Potential users of IMMJs need to be aware that they can ask too much, and have unrealistic expectations of what the format can actually do. We hold this view for two reasons. First, the educational practitioner has to acquire and think through a great deal of information, and often needs to generalize beyond the information presented, in order to adapt a programme to a particular classroom environment and set of pedagogical goals (Cognition and Technology Group at Vanderbilt, 1994). The second is due to the nature of the learning process itself. We expand on each of these reasons below.

The complexity of educational practice

Teaching is a complex cognitive skill that draws on a store of content knowledge specific to the domain, as well as pedagogical and metacognitive knowledge and strategies for conveying information and monitoring the impact of instruction (eg, Leinhardt and Greeno, 1986). The process of instruction is far too complex to specify

in advance. Teachers are continually thinking, making decisions, and reflecting on those decisions (Clark and Peterson, 1986). Teaching is best thought of as a problem-solving task where contingency based planning (Suchman, 1987) plays a major role (Leinhardt and Greeno, 1986).

In this light, it is not practical to expect teachers to adopt and execute novel instructional interventions on the basis of reading an article or manual – no matter how thorough or engaging that article may be. Although prior research strongly suggests that the IMMJ is likely to improve the ability of journals effectively to communicate what went on in a classroom and thereby enhance understanding of an intervention to the point of replicability, the prospective investigator needs to engage in training activities that foster professional development. These activities help teachers to acquire specific strategies for particular circumstances. In addition, the teacher-as-learner needs to acquire more than a specific set of strategies that have proved successful for other teachers. Development of a theoretical understanding for a new set of instructional practices is needed so teachers can generate novel strategies and transfer their knowledge to new situations (Brown and Campione, 1994).

The learning process

The second reason that we do not think IMMJs are guaranteed to be sufficient to support the adoption of new, complex instructional approaches has to do with the learning process itself. Typically the emphasis in training is either on teaching principles or specific strategies through telling or reading. Teachers of a new approach must also be supported in the process of *conditionalizing* their knowledge; that is, learning to recognize the conditions for which various principles and strategies are relevant and effective. Learners new to the principles which underlie an instructional intervention do not necessarily notice what they need to notice in order to apply it (eg, Randolph and Evertson, 1992). Consequently, they cannot retain and learn all that they need to know about the new programme.

An effective technique to help in perceptual learning is the use of 'contrast set' where different teaching practices, for example, or client-reported symptoms can be juxtaposed to help the prospective learner of a new method to identify the important features (eg, Bransford, Franks, Vye and Sherwood, 1989). The use of contrast sets provides a powerful, and perhaps necessary, way to help learners develop the expertise necessary to notice the features that experts identify as relevant (Bransford *et al*, 1989; Garner, 1974). Expert-moderated discussion of these contrasting cases among the learners has been shown to create the necessary understanding to support acquisition of successful teaching practices (Barron and Goldman, 1994).

Getting too fancy

Another area of potential difficulty in IMMJ use is that people often will use the features of a new technological medium just because it is available, rather than because it is relevant or necessary. There is a danger in this because the inappropriate use of video, sound, and interactivity can actually detract from the content that one is trying to convey, and hinder reading comprehension. An example of this type of behaviour comes from the early days of word processing applications that supplied a wide range of character fonts. Many presenters, seeing the enormous possibilities to enhance their talks, would produce slides that contained a myriad of styles, sizes, and shapes – each trying to out-shout the other. The result was a brief period when many researchers' presentations were nearly incomprehensible. A similar danger may occur with IMMJs, resulting in a poorer rather than a greater communicative ability of the reporting format.

Confidentiality and security of video-based data

Our preliminary work with the prototype IMMJ article has also uncovered important ethical issues regarding the use of this technology for sharing video-based data. Authors of these articles, in their efforts to report on their experimental interventions will want to present the most convincing evidence available, that shows that their intervention has had a profound and beneficial impact. One of the most effective means of doing this is the 'before-and-after' technique. The presentation of pre-intervention data that depicts subjects' negative behaviours and performances in a vivid form, however, compromises the relationship of the experimenter and subject. Students can no longer be anonymous because we can see them. Even if the investigator thinks the student is being shown in a positive light, someone else may interpret it differently. Obviously, the investigator must first obtain the proper clearances from adult guardians of students, teachers, and in some cases the students themselves if video-based data are to be used and shared with the larger community. But we need to be aware of the pitfalls that can also occur. For example, a teacher may agree to be taped, and make a slip of the tongue that is corrected the next day (but not during the taping). Showing such behaviours out of context damages the reputation of valued professionals who are, after all, offering their classroom to support research activities.

Recommendations

Our experiences with the development of multimedia materials and learning environments lead us to propose the following ways to avoid some of the most damaging issues surrounding IMMJ use.

Establish clear standards for reporting

Standards must be developed to ensure the scientific integrity of the reported work, the confidentiality of subjects, and the report's readability. People's tendencies to use the most advanced technologies available to present their work regardless of the appropriateness of the format should be avoided. In particular, we want to avoid the equivalent of multimedia 'marketing tapes' that are all glitz and no substance. Any future guidelines for IMMJ articles must insist that all the major features of traditional journal articles are included, particularly, the theory based introduction, clear presentation of experimental methodology and results, and a theoretical discussion of how the data support the major conclusions of the article (APA, 1994).

There is also a concern about navigation difficulties within multimedia environments, and its negative impact on readability and later comprehension (eg, Gray, 1990). We have found that use of a linear format that parallels traditional article structure provides the reader with the guidance needed to navigate effectively within the article with no apparent compromise to readability or usability. While we do not think that IMMJs are fundamentally limited to the linear format, or that it is inherently the best structure, we do feel that the article structure should always be as simple as possible. Only when a new functionality shows itself to be truly desirable and adds substantially to the clarity of the article should it be added. In the future, we hope to utilize principles for the reliable design of hypermedia environments that support other forms of navigation with no resulting degradation of the reader's discourse comprehension.

Along with standards for the organization of articles, there is a need for clear standards regarding the presentation of data. Two issues come to mind: the integrity of the data being reported, and ensuring the confidence of experimental subjects.

The integrity of video data can be ensured by providing annotations to the data that describe the conditions of filming (eg, chosen angle, unit of focus), and describe any editing activities (either in-camera or in the studio) that alter the succession of events, or give the illusion of compressing or altering the time at the recorded events. A concern that has been raised is the 're-purposing' of published video data for other uses that may in fact be at odds with the author's intentions or with the agreed convention of data reporting. A third party may copy video-based data that show the beneficial use of a student-centred instructional intervention, and by taking it out of context, use it to show how 'chaotic' innovative instruction has become. One possibility to ensure that the sequence of video data presented is accurate and unchanged by anyone after publication is to embed within the video material encrypted digital time stamps that describe the placement of a frame (eg, marking a frame as number 1100 of 4100 frames, collected from 14 November, 1994, 10:20:00 am to 10:22:16 am). Viewers may then examine the time stamping to see if the data are presented as it was originally intended. In addition, once digitized, the multimedia materials can be posted through the internet to a company that provides 'digital notarization' services. By using recently developed algorithms that establish positive identification of time and date of digital file creation, intellectual ownership and data preservation can be established for all of the video-based materials that may be used in an IMMJ article.

The assurance of confidentiality of subjects in video-based data is a complex issue; we do not have the ideal solution (ie, one that will satisfy parents, schools, researchers, and human subjects review boards). But video-based data is quickly becoming a vital part of research in the learning sciences. Collection and analysis of these data is important for the research community to move forward on its empirical evaluations of experimental hypotheses. At the same time, care must be taken with respect to presentation in public forums. We take the position that it is best to be safe rather than compromise the relationship between human subjects and experimental researchers. Generally, we find that very brief images that capture the global nature of the classroom intervention are generally safe to show because they do not centre on any one person, do not reveal any particular behaviours that can be considered negatively, and still provide the reader of an IMMJ with a good feel for the execution of an instructional intervention. Video-based data of individual subjects in such a widely disseminable forum as an IMMJ, however, can be compromising to the persons depicted. Thus, we recommend that IMMJ authors do not show footage of individual teachers and students until better standards can be agreed upon for the anonymity of video-based data.

Experimental assessment of the format

As we develop IMMJs with the intention of supporting readers' comprehension processes, we need to consider the kinds of mental models we want readers to construct. An important research issue is to document the mental models that are formed by experts in the field as they read scientific reports for the purposes of understanding and replication (Cognition and Technology Group at Vanderbilt, 1993). This provides us with a measurable criterion of success against which the understanding and replication activities of novices can be compared. Refinements to the article can then be made and tested with the goal of approaching the expert's level of comprehension.

Other kinds of comparisons involve mental models developed from traditional text-based media and those resulting from matched articles in the IMMJ format, across diverse sets of audiences. Individual differences in reading strategies and prior knowledge are important considerations that must be examined in any such assessments of this technology. Our goals in these assessments should include determining what within the IMMJ version is helpful and, further, what might be added to make them even more helpful.

Finally, we must be aware of the difficulties in substantiating any of the benefits that may exist from using multimedia-based forms of reporting. Assessment of reading comprehension is a difficult task that must take many factors into account, such as the reader's goals for reading and his prior knowledge (van Dijk and Kintsch, 1983). Most methods of comprehension assessment focus only on the collection and analysis of verbal/linguistic measures. However, some of the most profound effects, such as developing a better sense of the activities that may have occurred in a class, or the spatial aspects of an intervention, while still knowledge-based, may not readily show up in linguistic measures (eg, Michael *et al*, 1993). If linguistic assessments do not capture the changes that result from the added visual or interactive experiences conveyed by the IMMJ format, then it will appear as though there is no benefit to using the technology. Because of this, the assessment of understanding must include tasks that are free from the reported biases of verbally accessible information. One approach is to consider recognition/classification tasks where the reader can respond with a choice, rather than a verbal response. For example, the reader can respond 'new' or 'old' (ie, familiar) to graphical depictions of the experimental set up that describes the spatial layout of the experimental classroom as described in both the text and IMMJ versions of an article's 'Methods' section. Clearly, this issue must be addressed and forms of assessment expanded if we are fully to evaluate the merits of this approach.

Conclusions

The technology is currently available to develop research articles that are augmented with sound and dynamic images (including video and interactive graphics). Our initial prototype of such an integrated multimedia journal article and theoretical consideration of how these articles can enhance mental model development through the appropriate use of audio and video, suggest that this is a valuable technological innovation for the science community. However, this technology cannot address all of the problems that researchers have in reporting their experimental work and findings. To ensure that the practices of an innovative instructional approach are disseminated reliably, the IMMJ is best used as a component in a larger training project whereby experts can direct the learners' attention to the instructional practices critical to its execution. Several recommendations are put forward that are likely to assist authors and readers to use and evaluate this new reporting format. Ultimately, the true worth of this form of reporting will be based on its ability to support communication and collaborative sense-making in the research community that is not readily available through the use of traditional articles that use only text and static diagrams.

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