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Design Methods for Educational Media to Communicate

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Design Methods for Educational Media to Communicate

When We Cannot Predict What Will Work, Find What Will Not Work

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Introduction

In the last decade, innovations in mathematics and science education have been accomplished through convergences between fields such as artificial intelligence, cognitive science, and teaching methods. Increasing accessibility through visualizations, often with computationally enhanced tools for science students, lead to changes in curricula and pedagogical transformations of the culture and practice in the classroom. Communication of these innovations is still largely through text-based journals that focus on theoretical issues. This is in contrast to the known communication variables required to change the adoption rates of such innovations. One part of the solution for disseminating these new measures is to turn to case study methods constructed from situated video-recordings. Using video cases helps ground teachers’ understanding of learning theories in the actual clinical details of a change in classroom procedures.

This chapter reports on the design research and testing of a case-based video resource that uses DVD technology and is intended to serve as a teachers’ resource that can support the diffusion of innovations in mathematics education and their adoption. This DVD exemplar is the commercially available companion to the Children’s Math Worlds mathematics curricula for students from kindergarten through grade five. DVD technology was selected for this companion resource because it uses broadcast, television-image-quality resolution to present classroom detail, and because, as a technology, it has become ubiquitous in many homes and most classrooms. Although benchmark testing showed that several promising affordances and construction methods of this resource failed to function with the target audience, these failures are often unreported. However, they were extremely formative and predictive of the changes needed throughout the development of this medium. Therefore, this chapter argues for the reporting of malfunctioning features as a significant component of all empirical and design methodologies. Although the research methods used do not offer the means to predict final market adoptions, they do identify significant, ineffective, media constructions. Certainly, if these features were to remain in this project’s “workshop-in-a-box” format, they surely would predict poor performance of the DVD in the real marketplace.

The Children’s Math Worlds Project

Many voices have been calling for significant improvements in mathematics education, especially for students from impoverished backgrounds. The Children’s Math Worlds project (CMW; Fuson, 2003) developed ways to build on students’ understandings. For over a decade, researchers at the CMW project have worked intensively with classroom
teachers to study how children think in mathematical situations. During this time, these researchers and teachers have devised informal and formal learning activities based on how children think and have generated ambitious, world-class curricula that can support high levels of mathematical understanding by all students. These curricula were formulated in classrooms in diverse urban and suburban communities in five states and involved 200 teachers and 4,000 students in kindergarten through grade five.

One important goal of the CMW curricula is the creation of a classroom culture of conversation and activities that will enable children to understand the use of formal mathematical notation and methods. Over the course of the project, various kinds of conceptual supports were developed to help students link their informal ways of thinking to formal mathematics. In 1993, the research team began to work in English-speaking and Spanish-speaking urban classrooms; then, research was extended to suburban classrooms. Year after year, all the curricula and training were revised based on what the CMW researchers learned in classrooms and from teachers. This design process was empirically based and iterative. In general, lessons about what worked and what did not work for teachers and students were reflected in the next iteration.

To communicate the complex details of the CMW curricula and promote their adoption, a six-hour video resource, a sort of workshop-in-a-box, was created. DVD technology was selected both for image resolution and image size and also to build on the widespread adoption of this technology in the home. The design of this DVD was grounded in principles from learning theory and the literature on case construction. The research method used an iterative design that tested both the effectiveness of various designs and, specifically, the opportunities offered by DVD-based technology in each of the multiple versions developed over a four-year period. One of the objectives was to produce a workshop-in-a-box that is widely effective in the marketplace. Interestingly, the practical nature of the design process resulted in a final design that varied significantly from the initial, theoretically-formulated designs. The new DVD technology did not function as theorized in the grant application. For example, because DVD technology offers multiple audio and video channels, several audio tracks to provide teachers’ commentaries on their classes and an audio channel to provide expert commentary on the classroom pedagogy were incorporated. Several video channels allowed the teachers to switch between views of the classroom and the new media grammars of construction, which were included to focus attention. Media grammars include all of the normal forms of changes in the film frame and the editing that we know how to read in TV and mainstream film. These included the dissolve (a transition between the picture of one place to another place to indicate a change in location or time) and the dip (a transition to all white or black or to a brief title sequence to indicate that the program is moving onto the next topic).

As a practical matter, designing effective media for mathematics education is likely to result in disconnects between theory and practice. These gaps are rarely the focus of researchers nor are they reported in journal articles; however, they can illuminate methodology and suggest areas of research in which the predictive components of various theoretical formulations can be tested. Although usability issues may account for some problems with any facet of technology, a general concern of design based on learning theory is that there is an assumption that most design variables that support effective use have common predictive value. This chapter hopes to make a contribution by detailing those features of design that are not equally effective in media for mathematics education. Therefore, the research focus turns now to early benchmarks for discovering these ineffective design features.

The realization that design and knowledge do not have a continuous landscape but,
rather, are multidimensional and have a separate epistemological basis is an essential
twentieth-century philosophical understanding made clear by Ludwig Wittgenstein.
Wittgenstein explored the highly complex, multidimensional character of knowledge in
his *Philosophical Investigations* (2001). Some readers may misunderstand the complex
epistemological contribution made in this book and its implications for psychology and
learning theory. The persuasiveness of the summary metaphor of knowledge as a land-
scape may be partially to blame. One can misunderstand this statement to mean that
knowledge is like a simple landscape. This chapter describes the author’s journey in
creating the commercial version of a new media form on DVD with sufficient empirical
benchmark testing to ensure that, at a minimum, the components and technology that
had malfunctioned were removed, even though there is considerable literature about
their promising benefits.

Developing an Educational Research Visualization for
Mathematics Innovations

The final DVD has three major parts: the first one is explanatory; the second one is
devoted to the main classroom components that demonstrate the major engines of the
CMW innovations; and the third one contains on-camera interviews with teachers
about these classroom components.

Demonstrating complex systems is the focus of the field of scientific visualizations
where modeling systems serve both to predict and to integrate research and theory.
Complex societal problems have required science to respond with complex models
that provide both explanations and predictions. Today, in most scientific efforts, new
models contain accurate and predictive visualizations that inform both the community
of researchers and the community of practitioners. In the same manner, the classroom
video cases and the other features of this new DVD resource provide not raw data but
an authentic representation. Thus, one way this media form can be approached is as
the educational version of a scientific visualization—in other words, an educational
research visualization (ERV).

The DVD needed to present complex details of real-world situations through word
problems in the curricula and those generated by students. The students were in grades
one through five and came from four public schools that used the CMW curricula.
Three of the schools were located in high-poverty, urban areas; the fourth was a sub-
urban school that contained immigrants from many countries. The selected examples
represented teachers and students who were at various points along the path to a
collaborative classroom where the students demonstrated high levels of explanations
about mathematical thinking.

The CMW project developed some inexpensive manipulatives to help students make
more sense of the content. Later in the project, large, dry-erase MathBoards™ with
conceptual supports were created to enable students to make mathematical drawings,
or “proof pictures,” which they can share with the rest of the class. These mathematical
drawings are central to the project. As a visualization of knowledge, they enable stu-
dents to integrate their mathematical understanding with formal solution methods and
notations, thus providing a bridge from concrete to more abstract thinking. After some
time, students no longer make drawings, but they can still use mental visual images
from their drawings to explain and make sense of their formal numerical methods.

These important aspects of the project that enabled students to find meaning in their
mathematical experiences are shown and discussed in the main segments of the DVD.
For example, a typical CMW curriculum always began with a new mathematics topic,
with students making their own mathematical drawings. Then, it introduced the kinds of drawings that have been powerful in classroom research. For multidigit numbers, these are drawings of hundreds, tens, and ones. For word problems, there are mathematical tools that show the structure of the real-world situation described in the word problem. For multidigit multiplication, there are area models of rectangles. For fractions, length models using unit fractions are shown.

Some of these methods or algorithms for solutions are unfamiliar to teachers. During focus groups teachers reported the need for more domain knowledge, so almost an hour of new mathematics knowledge was added. Interviews with the CMW teachers were filmed at the end of each school day, but it was not until later in the development of the ERV that it was found that, by making these interviews available on the DVD, they would be highly persuasive in explaining how the CMW innovations could be adopted and used in the classroom. So, again, a new section of the DVD was created, containing both long, largely unedited versions of the interviews and shorter, single-point, summary segments. Providing both short and long versions of these interviews reinforces the attempt to represent authentically what was discovered in the classrooms.

The CMW research shows clearly that more “accessible algorithms” are available than the more complex methods commonly taught. In fact, these accessible algorithms can be used with any curriculum, as can the mathematical drawings used by CMW students and shown in the classroom segments on the DVD. Also, we believe that the best way of communicating these accessible methods is through the complete clinical detail that can only be provided in high-resolution video.

The Look and Feel of Educational Research Visualization

Given the limitations of written descriptions of live media, the reader will understand that only an overview of the DVD is provided here. However, the following figures represent the feel of the final ERV and will give the reader a sense of this new form.

The still from the video reproduced in Figure 17.1 is from one of the main segments and shows several features of the curriculum (which includes students using graphical visualization methods) and the DVD-based, educational research visualization. Ethnographic film-makers working in the classrooms were able to film close up by using two video cameras and two, high-resolution, still cameras to follow specific students’ work and questions as well as teacher–student interactions. Segments of the DVD demonstrate the pedagogy and mathematics and how these new algorithms are used effectively by students. What the reader can take from the images in Figures 17.1 and 17.2 is a perception of how the ERV essentially created “existence proofs” for teachers. In many grades, with many students and teachers, this ERV shows how these more accessible mathematics algorithms, developed by Fuson (2003), are used easily by a broad range of students to solve and explain mathematical problems.

When sections of mathematics domain knowledge were added to the DVD, simple computer graphic animations of the mathematical solutions were combined with the classroom footage (this builds on a film form created by the ethnographic film-maker Timothy Asch; Asch & Chagnon, 1975). Figure 17.2 is an example of the simple graphics style used in the explanatory sections of the ERV on the DVD. The new algorithm shown in Figure 17.2 is called the “new groups below” method; the CMW research had shown that these accessible algorithms improved students’ work. Although each new accessible algorithm represents a significant research result that needs to be diffused, each one also needs to be presented to teachers in the context of situated pedagogy supporting students in talking about mathematics, which is another significant component of
the CMW innovation. An example of the explanation section in the DVD is given below. In it, the mathematical processes are animated while the steps are narrated and the advantages are explained to students of placing the new ten on the equals line, rather than putting it above the tens column.

The animation gives complete explanations of the use of this accessible algorithm called “new groups below.” In Figure 17.2, two-digit numbers (58 + 36 =) are being added together. However, the extra ten created in adding 6 and 8 is placed on the equals line, rather than above the tens column, as in the typical algorithm. Fuson’s research (2003) has shown that such transformations in the graphical visualization of the problem and the mathematics representation combine to make the solutions easier for students. The new ten is more visible to students on the equals line. Also, graphical proof drawings, as seen in the student’s work in Figure 17.1, are obvious examples of the principle of making meaning through scientific visualizations, which informed the Children’s Math Worlds research.

To continue with the explanation of the student’s solution using this method, Figure 17.1 shows how eight ones are combined with two more ones from the six to make one additional ten. Four ones are left; thus, four is the answer in the ones column to the problem of 8 plus 6. The additional ten is written graphically by students on the equals line, rather than above the tens column, as is more familiar. In the final segments, only simple graphics, such as a circle, as seen in Figure 17.1, are used to highlight for viewers and teachers that the additional ten has been placed on the equals line.
Components of Educational Research Visualization

The main segments of the ERV were edited to provide focused presentations of the significant research results at each grade level. Additional, largely unedited, video segments of longer duration were constructed so that audiences would have a less processed and more natural set of representations from real classrooms that conveyed the students’ and teachers’ mathematical conversations. Brief and in-depth interviews with the CMW teachers were included too. The completed ERV contains:

1. Segments of mathematics domain explanations in which graphics are used to animate the students’ work; while the narration by Fuson (2003) provides the details for understanding the mechanisms of representation that create a more accessible algorithm.
2. Long and largely unedited segments from each grade level, in which the students’ use of these new algorithms is presented as it happened in the classroom.
3. Interviews with teachers that focus on some of the main features of the CMW innovations. These interviews are presented both in a shorter edited form and at length, so that the ERV user can select the amount of detail desired. Teachers explaining how they developed these innovative curricula in their classrooms are highly effective communicators of the details of the variables that improve the prospects for adoption of the new curricula.

Testing late in the project confirmed that teachers respond well to information communicated to them through interviews with the CMW teachers; therefore, such
interviews were included as an additional, 40-minute component of the final ERV. The total DVD package can be almost six hours long because of the large recording capabilities of a single, 9-gigabyte DVD. In 2006, the new, 30 and 50-gigabyte DVD systems became available; so shown in standard definition rather than for HDTV, up to 50 hours of standard definition video could be recorded on a single disc.

To summarize the scientific and design issues of validation and redesign, many features could not be tested during the design phase, so final scientific validation has to await release and distribution of the commercial product. Market testing is needed for a complete empirical validation of this ERV medium. Until such market results are added to the research results, effectiveness cannot be claimed. Although the features were maximized and benchmarked to ensure their functional use, the expectation is that, as a package, all of the segments will coalesce into an effective visualization that will be useful for a large, clinical-style innovation. This video form will be used differently by different audiences. However, the question remains whether the sum of such a large database of highly constructed segments combined with explanations and longer, less-edited segments will be persuasive in changing the current classroom behavior in mathematics pedagogy of those considering adoption of the CMW curricula. The benchmark testing was formative in its goals, rather than attempting to support theoretical constructions primarily. In other words, the ERV has formative empirical validation from benchmark testing of its offerings by users in the real-world market.

Standard Methods Versus Design Engineering Methods

Earlier papers (McCormick et al., 1987; Zaritsky, 2006; Zaritsky et al., 2003) discussed the emerging importance of using video cases in education and teacher preparation and summarized the difficulty of being able to generalize formative design principles from one project to another. Focus groups containing teachers, mathematics educators, and college professors tested each version of this ERV. In 2003, some results demonstrated that certain constructions and learning opportunities seemed to malfunction, were used ineffectively, or were not used. Although this should not have come as a surprise because such designs cannot be developed from untested theory, what was especially surprising was that these malfunctions did not fall along any distinct theoretical lines such as case length, the use of close ups, or application of the new mathematical algorithms. Instead, the malfunctions ranged from complaints that some of the teachers filmed were too attractive, confusion about how to use the additional audio channels, and unfamiliarity with the new mathematics of the CMW algorithms demonstrated in the classroom video. Thus, a primary finding is that the design of a visualization method for education needs formative benchmark testing across the range of its educational opportunities and media constructions with innovative media grammars and DVD navigational forms.

The sister field of design engineering also reports that, in the early stages, one should expect to find many malfunctioning components or even malfunctions of whole designs. One implication is that projects designing similar, video, case-based materials may need a greater focus on empirical methods in order to determine the malfunctioning elements. Rapid, design-based benchmarking provided a successful set of methods that the ERV project borrowed from the sister field of design engineering (Ulrich & Eppinger, 2000). Flowers (Zaritsky et al., 2003) of the design engineering program at the Massachusetts Institute of Technology, has written that design-based creations must rely on a willingness to learn and change paths, with each phase being based on the recognition of malfunctioning goals or construction methods:
Effective design is, of course, not a random process; however, it does change direction, sometimes dramatically. Throughout the process, when a path is recognized as non-optimal (e.g., using data drawn from prototyping, focus groups, benchmarking, and market research), a different path is considered and chosen. Further, though stages of the design may be treated independently, the combined effort must amount to more than the sum of its parts and result in a robust solution. (Zaritsky et al., 2003: 32)

In the ERV project, focus groups and individual testing with oral recordings made by the users were the methods employed to gather data for the benchmark tests. This process of formative benchmarking differs from a statistical form of laboratory research in many ways; for example, the number of subjects differs, the discovery of patterns of malfunctions differs, and the understanding of the mechanisms of broken components varies with the clarity of the reports. The ERV project’s goal was not the discovery of how the human brain functions when using multimedia but the limited goal of developing a design that would work in the real world to diffuse and support the adoption of the CMW curricula in tens of thousands of classrooms. Therefore, the validation methods used were largely formative and far from comprehensive; thus, they do not support accepted general principles. However, benchmark testing throughout the project’s cycles did ensure that such formative methods were effective in validating the goals in advance of obtaining the results of actual, market-based data.

The original grant from the National Science Foundation for this project was for researching the use of new technologies, such as multiple video and audio channels on DVD platforms. After three years’ work, it was found that too many channels created undue complexity and, thus, were likely to be a problem for many teachers when a commercial version was published. The reader who buys or rents DVDs will know that these channels are features common to theatrical DVD releases; consequently, there are market forces at work supporting their use. However, it is hoped that two years of DVD use of multiple channels will not produce the same complexity for most teachers. Because early testing resulted in the discovery of several problems, features such as the navigation tool had to be redesigned, resulting in the size of the final DVD package nearly doubling in order to provide a complete presentation of the mathematical knowledge required by teachers. Focus groups and individuals reported that required components were missing.

During the development stage, the number of reports required to convince the researchers of the presence of nonfunctioning components changed, but, for the most part, the nonfunctional components could be identified from the first five or ten accounts. When individual reports were similar in their descriptions of broken features and broken mechanisms, redesign began. When a significant new component of domain knowledge was created late in the project, only the mathematics knowledge segments were tested by a small number of the project’s staff and mathematics education experts. Such formative testing is the recommended method in a design engineering project. However, a research method such as a randomized controlled trial, which would force significant quantitative results, would not have produced more scientific results than these formative methods.

A somewhat easier way to state the project designers’ research goals is to suggest a simple thought experiment. For example, given a radically new bicycle design project, how many subjects need to fall off the bicycle before another design approach is considered? In the later phases of the ERV project, fewer reports of malfunctions were needed to prompt a redesign. In an earlier article written with Professor Flowers and
others (Zaritsky et al., 2003), iterative design and phase-appropriate testing as they are used in the field of design engineering were summarized in this way:

The value and relevance of qualitative or quantitative methods in product design vary as a function of the design stage. When designers “solidify” designs, they do so only in accordance with proven merit using the appropriate metrics for data collected by the appropriate method at the appropriate stage within a context with known (or assumed) limited resources.

(p. 33)

Standard statistical forms were less appropriate approaches during the formative stage of the ERV project. Instead, the model of iterative design, as detailed in design experiments (Collins, 2004; Kelly, 2006), was used as a research foundation and method. Design experiments are essentially formative efforts, often research conducted in classrooms, in which the team continues to improve the research innovations, the curriculum, the science tools, or the cognitive approaches of the learners by means of iterations of the research design. Journal reports contribute narrative and other ethnographic details that provide warrants for the innovation’s claims and support the foundational theory. In the ERV project, through iterative phases, it became clear that the ERV media needed to be redesigned to eliminate malfunctions. The ERV project also needed to ask intended audiences what they found was missing and what was needed for the DVD to function on its own. As noted above, it was more appropriate for this iterative design project to use formative benchmarking methods, rather than standard, statistically validated, empirical methods.

**Education Needs Empirical Results on Video Case Construction**

The literature on case-based video has yet to develop criteria for the construction of appropriate video cases and for appropriate clinical skills for the recording teams. The literature does not suggest methods for determining the appropriate length of cases for various goals; it does not explain the views needed for the cameras; and it does not offer solutions when a project requires close-ups of the work of students. These are the reasons we have been explicit in describing our recording methods. The case literature has yet to specify testing methods that will ensure sound construction with effective repetition of individual case examples in order to build up a family of examples that stretches across students and classrooms. Although numerous theories and research projects informed the construction of the ERV project, in practice, the theories were only generally useful or suggestive. “Generally useful” is far less useful than “prescriptive,” for example, in describing how text-based cases should be constructed (Shulman, 1992). I do not disagree with these goals for text-based cases, but they are far more diffuse and less specific than what is needed to guide the construction of video-based cases.

The research and writings in educational psychology informing case-based projects include the theory of cognitive flexibility, which attempts to explain how individual cases, when added together, provide an understanding of the family of features that are required in order to comprehend science. In general, this theory says that, in messy domains, one needs to present a large population of cases so that learners can determine the common features of the family. In this manner, learners will be enlightened by the deeper nature of the processes demonstrated by the features that form the family. In designing this project, a large database of video cases of the CMW innovation was
included, rather than only a few specific cases. Although cognitive flexibility theory (Spiro et al., 1987, 1988) was helpful as a guiding notion for building a large database of cases in the ERV, it provided little or no guidance or specifications for individual cases. For example, how many and what type of video-recordings constitute the most effective family of cases? As pointed out in this chapter, in moving from general goals or theories developed from retrospective empirical work to specific, predictive, prescriptive visualization construction methods, suggestions are required.

Many theories do not inform practice; rather, they suggest explanations. A partial reason for this disconnect, as seen with cognitive flexibility theory and other cognitive theories, is that they have been constructed retrospectively and have not been validated with predictive experiments. Although based on scientifically sound studies, developing theories based on retrospective analysis without also testing these theories on predictive experiments means that we often turn to theory that has yet to be validated as to its predictive ability. In public health and other related fields, this lack of a full scientific attack on questions would be far more problematic. The author’s prescriptive questions are: Which visualizations will work effectively for which audiences? Why did they work? These questions still await research. Here, the reader should note the difference between scientific visualizations—which include predictive claims for practical applications to pressing social issues, for example predictive outcomes to problems such as the risk of an avian flu pandemic—and educational visualizations. Theories in education serve a different function—consolidating research into a compacted explanation—rather than provide the sort of systemic model seen in a scientific visualization that clarifies and predicts the likely results of a scenario proposed as a solution to a problem.

Benchmark testing of the ERV asked questions similar to those in other studies, but they were used formatively. We explored how best to fit together in a case detailed narrations and their accompanying images. The need for an empirical test of the use of narrations arose when focus groups of teachers reported trouble repeating the points made in the short narrative introductions to some of the five, major, classroom segments. Narratives are used in each of the five segments and are presented by voice-over. These narratives are fairly brief and attempt to provide the viewer with some background and a focal point for looking at the segments that present the major engines of the mathematics innovations. Initially, these explanatory narrations were constructed over live video shots of the classrooms. The narrations were about four minutes’ long and at the beginning of an approximately 14-minute, edited segment.

A series of benchmark studies were developed in which an introductory narration over live video was compared to introductions using simple pans and scans of still photographs—a standard method used in history documentaries. The solution selected uses a small step that eliminates complex, eye-tracking demands placed on the viewer by live video details. This is the most common solution used in media grammars for minimizing disruptions when hearing a narration and watching a picture simultaneously. With pan-and-scan, postprocessing software, the live video was replaced with a visually authentic view of work in the classroom, but one that is less distracting than a live video created from high-resolution, still images taken at the same time as the video. The still images were animated and turned into video by panning and zooming in the high-resolution frame—a technique used frequently in history documentaries broadcast on public television. The animation of still photographs is an old technique, one that is “tried and true” in the craft of film-making. Benchmark results showed that teachers were more able to repeat the summary points of the narrations when the postprocessed, pan-and-scan background was used as video, compared to the segments in which live video was used as background with the same narration. Clearly, in sections
containing more complex narration, less busy classroom detail on the screen improved attention to, and retention of, the information presented. However, it still left a visual focus on the classroom.

While narrations are being played, the ERV uses zooms and slow pans across a digital photograph of the classroom, rather than live footage, to minimize the viewer’s problem of eye-tracking. Mayer and his colleagues (Mayer & Moreno, 2003) do not measure eye-tracking in their experiments, so it is impossible to know whether film craft solutions or cognitive theories of overloading the human mind have been proven experimentally as the best way to hear narration in media. These factors may interact, but the ERV results suggest that any further laboratory studies must include the earlier traditions of film editing if they are to make important discoveries of all of the variables that affect narration. In general, the ERV used the tradition from film editing; this use accords with scientific methods in which the ERV researchers were guided by the most parsimonious explanations. Given that media construction is based on 100 years of simple explanations by film editors, testing explanations early in a project is warranted.

Further, research in multimedia forms is investigating media that are different in character, image size, resolution, and delivery from the ERV made for this project, which is a convergence of scientific visualization methods and ethnographic methods. Providing an exemplar from promising theory and laboratory experiments was an initial goal of the project; however, a few validated new grammars and advanced features were included in the final DVD. Rather than suggested grammars, the literature of film was the source of the ERV’s media grammars. The results suggest that, with each specific media creation and technology, education researchers must use an empirical, design-based process with increasingly demanding benchmarks that focus on both the learning design and on those aspects of the design that contribute to malfunctions.

**Benchmark Testing for Commercial Release**

Some of the results of, and the approaches used in, the ERV benchmark tests and the iterative design of the final commercial version are summarized below:

1. **Media grammars.** In general, complex media grammars decreased the teachers’ abilities to say where they were in the DVD cases, to identify the grade level, or to recount what they were seeing, even though they had been given this information by narration, graphics, and video effects. Complex media grammars were replaced throughout with standard film grammars. Silent-film-era inter-titles (of the kind used in silent film between the action to present the text of the dialogue) were used in graphics to indicate the grade level, and slow, pan-and-scan images were used when providing detailed information in narrations (as in history documentaries). Unexpectedly, although many promising ideas suggested by colleagues were tried, no advanced grammatical innovations were validated; therefore, none were used in the final commercial version.

2. **Innovative video graphics.** Computer graphics images helped to explain a mathematics domain. In the explanations section of the mathematics domain, where teachers are given the detailed steps of the new algorithms developed for students, enhanced video with zooms, complex graphics created with new digital tools such as Rotoscoping and 3-D software, and other, complex, graphical enhancements of the students’ chalkboard work were tried. Benchmark testing showed that they distracted teachers and, equally important for this project, these new media solutions concerned mathematics educators because the results looked unlike actual
blackboard work. Simple recreations of images from a blackboard made by off-the-shelf, image-editing packages were used instead.

3 *Multiple angles.* Some DVD features, such as a switch between two cameras giving alternative points of view, were unknown to most of the teachers. When such features were built into the menu, complications ensued. However, when an image contained both camera views, experienced DVD owners were able to switch between the camera angles. Nonetheless, this feature was not used in the final version because it was still too complex.

4 *Multiple audio commentary tracks.* In addition to the synchronous sound used in the classroom cases, two, additional, audio commentary channels were created. One featured teachers discussing their goals and classroom management issues while the DVD showed their classrooms. In the other one, mathematics educators discussed the domain-specific features of the new curricula. However, DVD production is time-consuming. Because so many video versions containing significant changes to all of the final major segments had been created, it was unclear when the audio commentary should be rerecorded. Moreover, because only those teachers who owned DVDs knew how to use this feature, it was excluded from the final product, although it remains a highly promising feature. Perhaps later, when switching between audio channels is made simpler by the hardware manufacturers and by personal computers’ DVD software and when more viewers are familiar with its potential, this option could be tried again.

Validation must use phase-appropriate benchmarks that test likely, real-world, audience adoption of domain and pedagogical innovations. Also, the goal of large-scale distribution required a shift from promising designs to those with clear empirical validation. Thus, in creating diffusion media, the possibilities offered should be limited mainly to tested theoretical formulations that produce positive, empirical, benchmarking results for learning, effectiveness, and usability, thereby providing empirical support for their inclusion in a package of media features.

Scientific visualizations owe their increasing warrants not only to their ability to support or refute theory, but also to the increasing number of experts who can gain traction on real-world phenomena by predicting the effect of possible scenarios or researchers who can suggest more productive areas for further study. In the education field, there is concern about the disconnect between theory and practice. Scientific visualization systems provide predictive outcomes for the sciences that they support, whether it is hurricane prediction or theories about the spread of epidemics. Central to the application of theories, in most fields, is that they must lead to increased understanding of the relative ability of various features to contribute to the probability of predicting outcomes. In medicine, health research, and public education, for example, researchers have to fit together the relative risks of various elements (family history, lifestyle, drug interactions, compliance, etc.) that are derived from biological theories but are based on large-scale, empirical results. At-scale solutions require multiple approaches, including real-world validation of the variables that support the outcomes; namely, communication of the innovations through wide-scale diffusion and through the variables that can be predictive of the adoption of these innovations. Although the results discussed in this chapter are pertinent primarily to this CMW innovation and to the ERV exemplar, in practice, the project’s researchers found that theory exists, as Wittgenstein predicted, not on a common landscape, but in a complex, fractured, and discontinuous manner. Thus, only by using formative benchmarks to guide design and development could the project’s researchers feel assured of having improved the design.
over the project’s life cycle. Throughout the chapter, attention has been called to problems unique to the ERV and the need for help in creating appropriate new benchmarks for learning effectiveness in time to predict and guide design.

Conclusions

The educational research visualization model was created for the Children’s Math Worlds project to meet the goal of communicating an effective set of new warrants for the CMW’s innovations. Results from this media format and from testing provided an initial finding that the design of a visualization method for education needs iterative, formative, benchmark testing across the range of its possibilities and media construction forms. Further, given that such constructions are design efforts, evidence of the usability and nonusability of the features appears early in the process and is one of the primary results of testing. Thus, a clear conclusion from the tests is that benchmarks must be developed in order to discover malfunctions. This should be a focus of all such research and design efforts.

Although the results support the broad application of visualization techniques to education research projects and argue for a subdiscipline in educational visualization methods, they do not contribute to generalizations about the theoretical value and predictive potential of the various possibilities. However, in the ERV project, an attempt has been made to provide an example of how removing malfunctions early in the design process is essential in the construction of video, case-based, media materials.

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References


