Building Multimedia Artifacts Using a Cyber-enabled Video Repository: The VMCAnalytic

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Abstract

Video is an important resource for understanding how people learn, but it can also have a life beyond its initial use. In the Video Mosaic Collaborative (VMC), we provide networked opportunities for teaching and learning through the use of a cyber-enabled video repository that provides resources for the creation of networked multimedia artifacts, the VMCAnalytic. In this paper, we describe the VMCAnalytic technology and the initial uses of the VMCAnalytic, based on the online data source created.

1. Introduction

Although there are a number of approaches to creating multimedia artifacts, understanding how artifact design can be used for learning in ways that build on a coherent and extensive video collection in a collaborative web environment remains an open question [1-3]. Video Mosaic Collaborative (VMC) is a multifaceted research and development project, for which we have developed a repository containing a collection of research video that features a longitudinal study of the development of students’ mathematical reasoning. The VMC has evolved through deep collaboration between the learning and information sciences in order to design a cyber-enabled learning environment that is simple to use, flexible in purpose and extensible in its multiple approaches. The development has involved extensive collaboration with researchers and teachers engaged in professional development in order to reflect the needs of the teacher, teacher educator and researcher in both design and approach [1]. The VMC is comprised of two major components: a searchable repository that builds on an extensive video collection (described below) and the VMCAnalytic tool.

The VMC site conforms to best practices for usable websites, including simple and clear activity choices, primary activities (e.g., searching for resources) that are prominently placed, and clear definition of the mission, audience served and content. The current website and VMCAnalytic tool were designed based on workflow analyses of the researchers and teachers.

At its center, the VMCAnalytic is a tool that enables networked users to search and select video, interpret and annotate the collection of video data as a whole, as well as to annotate each of the clips produced from the video collection. It supports social scholarship that takes advantage of the collective intelligence of a community of users with the potential to substantially augment and transform research practices by linking
the formal world of researchers with social practices of even a broader community [4]. It is a networked multimedia artifact. It differs from learning analytics as defined by Siemens [5] in that it does not involve automated analysis; rather, it is a multimedia narrative created by the learner for a specific purpose. It is a new object that is created from a video or set of videos with interpretations. The learner can create a story arc that might be for research purposes or might be to support teacher professional development.

2. Video for Teaching and Learning

Video has become an important resource for teaching and learning, ranging from early work with anchored instruction [6], to current efforts that are focused on helping teachers and others learn more about cognition, development, and learning. Increasingly, video data are being used for instruction and for helping teachers to study classroom practice and student learning (e.g., [7-10]). Further, video shows in detail how learning unfolds in rich contexts. [9, 11]. A range of different pedagogical approaches to using video for learning include lesson study, video clubs, problem-solving cycles, and problem-based learning (e.g., [1,6, 12, 13]).

Because of the complexity of learning and teaching that the study of a video can convey, a user initially could be overwhelmed. Therefore, providing assistance in filtering video data and guiding user interaction with video can reduce the complexity. Earlier research has emphasized the use of video from teachers’ own classrooms (e.g., [7, 12]), however there may be good reasons to use video from other sources for teacher professional development. First, pre-service teachers do not, necessarily, have access to a classroom. Second, it may be important for teachers to have virtual access to teaching practices and student learning experiences from multiple environments. This can enable teachers to engage in comparative reflection as they consider their own experiences with learners in relation to the interactions they see on video [10]. To this end, existing video collections have great potential for developing resources for teacher professional development and, we argue, in particular for learning to understand student reasoning.

2. Learning through Artifact Design

With the VMC project, we see that the potential for use of many existing video resources still remain untapped. Even when employed, they are not used in ways that maximize their potential. For example, one might watch the same video interactions through different lenses and in diverse contexts and create various interpretations [9]. Thus by using video in multiple ways, different classes of learning outcomes are afforded [14]. In particular, video offers learners opportunities to discern what is important in a particular situation; it can also provide a rich context for analysis and discussion. However, users are not necessarily experienced in working with video, as for example, when they have to construct interpretations with respect to reasoning and learning, as opposed to more familiar textual resources, where much is explained in detail. A challenge that remains is how to successfully engage learners in working effectively with video.

Several researchers in the learning sciences have demonstrated that collaborative design with computer tools can foster productive collaborative learning processes [15-18]. Zahn et al [18] distinguish between video playback tools and video editing tools. Building on the notion of representational guidance [19], specific editing features in video tools afford particular kinds of epistemic and collaborative practices in working with video. For example, by being able to select and annotate video clips, users may initiate discussions about what is important as well as what might enable comparisons among different segments, or even different videos. Specifically, video editing tools, such as WebDiver [20], may support learners in better planning their analyses; they also can help learners structure how they provide information. Because of the generative activities required in the video editing tasks, learners can develop initial ideas for comments and then have opportunities, both individually and collectively, to reflect on the ideas proposed and on the video clips selected relative to their task goals. Thus, there are opportunities for self- and peer-assessment, reflection, feedback, and revision. Zahn et al. [18] demonstrated that new ideas are generated through critical reflection as learners consider their ideas both within and across video clips that they select. Other tools that support video construction are generally geared towards a study of one’s own teaching practices [21], while others are generic tools that support many applications (e.g., [18, 22]). However, few of these tools integrate a substantial video collection with a tool designed to work seamlessly with these (and other) major video repositories. As Hawkins [23] noted, the use of technology can support teacher learning by inviting teachers to move beyond their own experience to see processes of change and student exemplary performances that they might not otherwise have experienced. We argue in support of Hawkins’s vision in which she indicates that “true knowledge — understanding — develops through exploration.
rumination, interpretation, judgment, and the application of information” [23]. By creating multimedia artifacts that can be readily shared in a web environment, learners can be provided with those opportunities.

Consistent with other approaches to learning through design, we argue that the creation of multimedia artifacts provides opportunities for learners to become deeply engaged in their learning through the process of planning, evaluating, revising and reflecting on the object(s) they have constructed [17, 24, 25]. Although video can make powerful examples visible [1, 26], it does not necessarily provide opportunities for learners and experts to make their thinking about those examples visible. The process of creating multimedia artifacts can give learners objects to think with, as they make their ideas visible as representational objects that can be discussed, reflected upon, and revised [22, 27].

3. Building on a Major Video Collection

The VMC builds on extensive prior research that includes a longitudinal study that followed the same cohort of students doing mathematics from elementary through high school and beyond in which they provide justification for their solutions to strands of problems. The strands include algebra, geometry, fraction and rational number, probability, pre calculus and calculus. In our work with the VMC, we have built on over a quarter of a century of research and in multiple contexts – urban, working class, and suburban. In formal and informal settings, researchers have collected over 4500 hours of video as part of cross-sectional and longitudinal research studies. An overarching goal of all the studies has been to follow groups of students over time to enable the tracing of how they build mathematical ideas and forms of mathematical reasoning when situated in a learning environment that encouraged thoughtfulness, building meaning of mathematical ideas, collaborating with others, and sharing of ideas in the establishment of justifications for problem solutions [28, 29]. The collection, housed at the Robert B. Davis Institute for Learning (RBDIL) at the Graduate School of Education, Rutgers University, provides the basis for the Video Mosaic Collaborative (VMC; videomosaic.org). As one views the Repository, one can identify three portals for viewing video: researcher, teacher educator, and teacher (shown in Figure 1). Examples of studies are identified to characterize the portal.

One example for the teacher-educator portal shows a model for professional development using the VMC resources [30]; another example for the researcher portal highlights a seventeen-year study [31] and a third example for the teacher portal follows the development of inductive reasoning of a nine-year old student [32]. The search engine for the VMC allows the user to search from a number of lenses: student, grade level, context, task, content, researcher, etc. and enables the user to follow mathematical learning over time in multiple settings. All video clips contain transcripts and related metadata such as student work, accompanying publications, etc.

The resources of the VMC are being used for current research in teacher education to conduct instructional interventions in an iterative program of design research. Interventions are conducted in a variety of contexts: graduate courses in mathematics education; professional development workshop series for in-service teachers; interventions in courses for pre-service teachers at the elementary, middle and secondary levels; interventions in a learning science graduate course [1, 26]. Initial interventions were implemented in face-to-face settings with videos watched together as a whole group. In other course settings, students watched videos individually for homework assignments. Subsequent interventions have made increasing use of online learning environments, with one fully online intervention setting in the fractions and rational numbers strand and several hybrid course settings in the counting, combinatorics, and algebra strands that blend classroom sessions and online learning activities. In all these previous studies, the course instructors selected videos. More recently, with the development of the VMCAnalytic tool, editing and annotation of videos provide a new means for engaging learners [3] with video as collaborative project work. The addition of this tool (described below) provides new and powerful opportunities for learners to create artifacts that are “tools to think with.” [21]. We show an example in Figure 2 that focuses on
Figure 1. VMC Portal

Figure 2. Example VMCAntalytic
learner engagement. Our hypothesis is that engaging approach across a variety of disciplines within education, psychology and related fields.

The research question that guides this study is to learn how the VMCAnalytic has been used to date and how users may have been influenced by courses or personal goals. In order to do this, we describe the multimedia artifacts that have been created.

4. Methods

We examined, in detail, the 27 VMCAnalytics that were created by participants from 4 courses, including three VMCAnalytics that were published by faculty researchers. We collected information on the length of the VMCAnalytics, number of events, ratings of coherence, clarity, and depth in both mathematics education content and learning sciences lenses. The VMCAnalytics consisted of a set of video clips created by the user, their interpretive comments for each clip and an overall description of the VMCAnalytic that sets out its purpose. All ratings were conducted by two independent coders with expertise in mathematics education and/or learning sciences. These ratings were independently examined by another researcher.

It is reasonable to expect that the VMCAnalytics would be influenced by the users’ goals, and for this reason we describe the context in which the courses provided the opportunity for students to make analytics. Members of the research team who were not mathematics educators created three VMCAnalytics that were not part of courses. The four courses that provided the context for creating VMCAnalytics were: Introduction to Mathematics Education (n=12), Critical Thinking and Reasoning (n=5), Mathematics Education Practicum (n=3), and Design Based Research (n=4).

Introduction to Mathematics Education is a required course for all students pursuing a post baccalaureate M.Ed., Ed.D. or Ph.D. degree with a specialization in mathematics education. A group project, in which students build a VMCAnalytic together, is a requirement of the course. The course format was a blend of in-person, on-campus sessions with interactions done asynchronously online through a Sakai course web site. As a hybrid course, there were eight class sessions together on campus. During these sessions, activities included working in small groups on mathematical problem-solving tasks and studying VMC video clips to learn about how K-12 students might engage mathematically as they build solutions to similar problems. Central to the course was the VMC repository as a resource for video assignments related to the mathematical activities covered in class sessions. For this assignment, participants first studied a series with tasks related to these videos serves as a useful five clips, entitled Guess My Towers, from a fifth grade classroom where children were solving a set of problems within a probability context that dealt with building towers, selecting from two colors, with unifix-cubes available. The graduate students were asked to work in pairs to develop a VMCAnalytic focusing on some selected mathematical and pedagogical theme(s). Constraints included that the VMCAnalytic should include no fewer than three events and no more than six and that the time for the entire sequence should be between four and ten minutes.

The Critical Thinking and Reasoning course is an elective, online, mathematics education course for graduate students developed and designed around a collection of videos that enabled the tracing of mathematical reasoning and problem solving of a class of fourth graders over several months as they explored fraction ideas prior to formal instruction. Videos from this project showed the reasoning of the children and allowed for the careful study of the children’s forms of arguments in their justifications for solutions to problems.

The Mathematics Education Practicum is a summer research experience for graduate students in which some chose to build VMCAnalytics. These students worked alone or in pairs with each other or another researcher.

Design-Based Research is a doctoral level course in the learning sciences. The focus is the design of learning environments. A two-week intervention involved the video analysis and the creation of VMCAnalytics. Students were asked to analyze a small video clip either from the VMC or other sources. Four of nine students created VMCAnalytics. Only one of the students had prior experience as a math teacher. Minimal structure was created for the assignment.

5. Results

5.1. The broad brush

The mean number of events in the VMCAnalytics ranged from 4.22 events in the Design-Based Research course, 4.88 for Introduction to Mathematics Education, 8.22 for the Research Practicum and 12.25 events for the Critical Thinking class. Mean times were 255 sec, 332 sec, 1228 sec, and 888 sec, respectively.

Table 1 shows mean ratings for students in terms of math content, learning sciences (LS) ideas, clarity, and coherence. This table shows a trend for a higher level of math depth for increasingly advanced mathematics education training. The LS depth is highest for the
course that focused on critical thinking, which is a course that we would have expected to focus on key learning sciences ideas as well as math education.

The greatest coherence ratings occurred among the analytics produced by practicum students and researchers. It is interesting, while not surprising, that these analytics were those that were published on the VMC repository, which can be explained, at least in part by, the publication review process. Analytic creators pursuing publication often went through cycles of revision. These cycles may not have occurred or been as rigorous as part of a course requirement. Math depth and LS depth are only moderately correlated ($r=0.42$). Math depth has a low correlation with clarity ($r=.31$) and coherence ($r=.27$). LS depth is moderately correlated with clarity ($r=.41$) and coherence ($r=.39$). Clarity and coherence are highly correlated with each other ($r=.91$).

<table>
<thead>
<tr>
<th>Table 1. Mean VMCAnalytic Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
</tr>
<tr>
<td>Math Depth</td>
</tr>
<tr>
<td>Design-based Research</td>
</tr>
<tr>
<td>Intro to Math Ed</td>
</tr>
<tr>
<td>Critical Thinking</td>
</tr>
<tr>
<td>Practicum</td>
</tr>
<tr>
<td>No Class</td>
</tr>
</tbody>
</table>

Beyond these quantitative indicators, there were qualitative indicators that show both ways in which the content of the analytics was influenced by the course and ways in which it was not. All of the analytics were coded according to a variety of categories.

In the Design-Based Research course, the four students who built VMCAnalytics included as themes: collaboration, representations, facilitation/scaffolding, and engagement. Not surprisingly, there was no discussion about the mathematical content.

In the Introduction to Mathematics Education course, the majority of students (90%) focused on mathematical ideas. At least 30% of the VMCAnalytics created addressed particular mathematical content areas to include combinatorics, probability, fractions/rational number, and algebra. Also included were pattern recognition, modeling, and a variety of forms of reasoning to include direct and indirect arguments. Also, 60% included students’ building generalizations; 30% tracked student representations; and 10% focused on mathematical language and communication. The analytics also included ideas related to the learning sciences – 80% dealt with collaborative learning; 30% addressed communication; 50% discussed student explanation and argumentation. A range of other learning science ideas were identified in students’ analytics.

In the Critical Thinking and Reasoning course, 80% of the VMCAnalytics dealt with specific mathematical content. Of the analytics built, 40% were coded as representations; 40% as mathematical learning and communication; 40% dealt with student reasoning. A range of other ideas was included for various analytics to include modeling, problem solving, generalization and language. Also, all students included student collaboration in their analytics; 60% addressed teacher questioning; 60% included explanation/argumentation; and 40% addressed facilitation/scaffolding. There was also an assortment of other learning science themes addressed by individuals in their analytics.

All three VMCAnalytics designed by graduate students enrolled in the research Practicum dealt with mathematical content, and addressed student representations. Isomorphisms were addressed in two of the analytics. In terms of learning science themes, two out of three included collaboration and discussion.

Three other analytics were constructed by faculty-researchers. Two thirds of them addressed representation, problem solving, collaboration, and reasoning.

5.2. Contrasting cases of strong and weak analytic use

For a deeper look at how the analytics were used, we conducted a contrasting case analysis. Two analytics are described that illustrate ideas being explored, examples provided, and connections made, if any, to other ideas. Both examples are selected from the mathematics content domain—the first in counting/combinatorics with 11th grade students and the second from early algebra with 5th graders. Example 1 is a published VMCAnalytic that serves as an exemplar, created by Muteb Alqahtani and Elizabeth Uptegrove as a collaborative summer research project (available at [http://videomosaic.org/viewAnalytic?pid=rutgers-lib:35783](http://videomosaic.org/viewAnalytic?pid=rutgers-lib:35783)).

5.2.1 Example 1: Moving from Specific to General

In this example, four 11th graders work together in an evening, after-school session to explore ideas in permutations and combinations.
Table 2: Students Exploring Pascal’s Identity

<table>
<thead>
<tr>
<th>Clip</th>
<th>Math Idea</th>
<th>Example(s)</th>
<th>Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Binomial Expansion</td>
<td>Expand ((a + b)^5)</td>
<td>Towers, selecting from 2 colors</td>
</tr>
<tr>
<td>2</td>
<td>Permutation: why multiply?</td>
<td>Arranging people in a line; building towers</td>
<td>Towers, selecting from 3 colors</td>
</tr>
<tr>
<td>3</td>
<td>Combination 2: why divide?</td>
<td>Dividing by ((5-2)!) or 2! eliminates objects not distinguishable</td>
<td>Eliminate duplicates for same colored blocks</td>
</tr>
<tr>
<td>4</td>
<td>Addition Rule for Pascal’s Identity</td>
<td>4-topping pizza problem</td>
<td>Addition Rule from row 4 to row 5</td>
</tr>
<tr>
<td>5</td>
<td>Addition Rule using “choose” notation</td>
<td>Using the Pizza Problem, students explained the meaning of: (\binom{3}{1}) and (\binom{3}{2}),</td>
<td>Pizza problem</td>
</tr>
<tr>
<td>6</td>
<td>Pascal’s Identity</td>
<td>Addition Rule with “choose” notation for specific values</td>
<td>Formal proof of Pascal’s Identity</td>
</tr>
</tbody>
</table>

Their conversations lead them to make connections between the binomial expansion and rows in Pascal’s triangle. They represent relationships from particular examples from earlier problem solving of building towers and making pizzas to generalize their findings in expressing the addition rule of Pascal’s Identity using standard notation.

These concepts are clearly articulated in the descriptions that accompany video events selected for the analytic, and the actions of the 11th graders in those video events show the substance and depth of their mathematical understanding across related concepts and multiple notations. In this table, for each event, we show the central mathematical idea explored by the students; an example that the user selected to illustrate the idea; and what the user recognized as the connection the children in the video made to another idea(s). The entries in the table show the identification of the mathematics that is being explored by the students in the video as well as the connections if any that they make to other mathematical ideas. It is indicative of a designer’s understanding of the students’ learning trajectory.

5.2.2 Example 2: Teacher Questioning in Early Algebra Explorations

Example 2 summarizes an analytic that was created as part of a group project for an Early Algebra course. It differs from Example 1 in several respects and it represents a “work in progress”. First, the video clips that were used for this “faux” analytic have not yet been ingested into the VMC, and thus it was not made as a permanent object with the VMCArticulate tool, as were those analyzed in Section 5.1. Second, some claims made in the description of events are not supported by the video data. Finally, claims made about the questioning of the teacher are vague and not backed up carefully with video examples.

In this example, teacher Robert B. Davis introduces 5th graders to finding solution sets to linear and quadratic equations. The focus is reported to be on teacher questioning to elicit engagement of students.

Table 3: Students Discovering Patterns in Equation Solving

<table>
<thead>
<tr>
<th>Clip</th>
<th>Math Idea</th>
<th>Example(s)</th>
<th>Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Truth sets &amp; legal substitution</td>
<td>(X + X = 8; {4})</td>
<td>Open sentence</td>
</tr>
<tr>
<td>2</td>
<td>Reading &amp; writing math sentences</td>
<td>(1–6= –5; ) reads: one minus 6 equals negative 5</td>
<td>Distinguish between minus operation and negative integer</td>
</tr>
<tr>
<td>3</td>
<td>Quadratic Equation</td>
<td>(X^2-16X+55=0; {5, -11})</td>
<td>One or two solutions</td>
</tr>
<tr>
<td>4</td>
<td>Solution set for quadratic equations</td>
<td>One or two solutions</td>
<td>Degree of equation &amp; number of solutions</td>
</tr>
<tr>
<td>5</td>
<td>Identifying a rule</td>
<td>(X^2+102X+200=0 {2, 100})</td>
<td>Sum/product rule</td>
</tr>
<tr>
<td>6</td>
<td>Checking the rule</td>
<td>Has any one checked?</td>
<td>Substitution</td>
</tr>
</tbody>
</table>

Despite what the students claimed to be the focus of their analytic, the video segments selected did not illustrate how the teacher’s use of questioning resulted in student engagement in the mathematical activities. Textual descriptions of events were vague, and the video events selected were not well chosen for conveying the intended purpose of the analytic; that is, the relationship of teacher questioning and student engagement.
We offer the contrasting cases to illustrate how we, as instructors, can gain insight into the initial ideas of students working to make their multi-media artifacts public with the VMCAnalytic tool. This provides us with data to provide useful feedback for attention and revision. The process of building an analytic can offer valuable exchanges between instructor and students, and can show the flow of student ideas and the care that evolves in providing support for claims that are made.

7. Discussion

Our analyses suggest that users selected a variety of themes clustered around course goals, but also situated within the broader context of cognition and instruction. We observed that students in mathematics education courses engaged with issues of the complexity of learning mathematical content to include collaboration, discussion, building representations, transfer within the broader milieu in which learning occurs. Among the users, there was a diversity of backgrounds and goals. Different users bring various lenses that offer the opportunity for creative insights into their observation of student learning. Future research will address how these factors influence the construction of multi-media artifacts such as the VMCAnalytic.

The VMCAnalytics that were prepared by a variety of users have provided us with a window into the details of how users support their claims with video data. These descriptions in the VMCAnalytics offer specific examples in support of interpretations that make context and content visible. The VMCAnalytic offers the user an opportunity to illustrate connections that a learner may make to earlier ideas and potentially trace the growth of an idea as well as the cognitive obstacles that might arise along trajectories of learning. Depending on the goals of the analytic creator, particular focus can be given to the process by which ideas are built by individuals or groups as captured in an existing video collection. This provides a window into student thinking and cognitive development. The VMCAnalytic tool can be especially useful for instructors who are seeking to guide users in expressing their ideas with clarity and backing. The video should flow as part of building a grounded narrative. The results of this study provide a foundation for how VMCAnalytics might be used in learning tasks.

We have also learned that VMCAnalytics can be a powerful tool for developing and practicing researchers in demonstrating particular learning trajectories, across multiple topics, in a variety of contexts and content domains. These VMCAnalytics have been shown to be helpful in tracking how ideas are built over time, how connections are made, and how collaboration enhances learning. The role of teacher questioning is another theme for analytics that makes possible the analysis of pedagogical approaches to facilitate learning. With the VMC, it is possible to publish (i.e., make publically accessible via the internet) one’s VMCAnalytic, which generates opportunity for innovative, digital...

![Figure 3. Word Cloud of coded Mathematics Education themes](image1)

![Figure 4. Word Cloud of coded Learning Sciences themes](image2)
scholarship. For example, graduate students can structure research papers around VMCAnalytics that they build as they engage in multi-media publication.

8. Implications for Future Work

The networked technology of the VMC and VMCAnalytic can empower teacher-leaders to be creators of multimedia artifacts that can inform their own use of video and use of networked video for professional development. This technology can also provide opportunities for researchers to collaborate over high-speed networks using shared video data. We are beginning to explore the possibilities that networked technology offers for the use of major cyber-enabled video collections and the multimedia artifacts that allow such collections to be repurposed for professional development and research.

Further research might explore how automated learning analytics could be used for formative assessments to provide timely feedback to assist in assessing these multimedia artifacts. It will be important to understand how people make use of networked video collections to design and use multimedia artifacts. The study reported here provides some suggestions of how goals influence the design; however, more research is needed to understand how these digital tools are used for learning and research. For researchers, use of networked tools like the VMC and VMCAnalytic allow opportunities for immediate feedback, collaboration and the exchange of knowledge within the research community, thus facilitating social scholarship. Implications for system development will include the addition of social tools that will allow alternative interpretations of video and ongoing social negotiation of meaning with newly constructed VMCAnalytics.

9. References


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