VMCAnalytic: Developing a Collaborative Video Analysis Tool for Education Faculty and Practicing Educators

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Abstract

This paper describes the genesis, design and prototype development of the VMCAnalytic, a repository-based video annotation and analysis tool for education. The VMCAnalytic is a flexible, extensible analytic tool that is unique in its integration into an open source repository architecture to transform a resource discovery environment into an interactive collaborative where practicing teachers and faculty researchers can analyze and annotate videos to support a range of needs from longitudinal research to improving individual teaching performance. This paper presents an overview of the design and functionality of the VMCAnalytic, which is a key component of the NSF-funded Video Mosaic Collaborative (VMC), together with a description of the underlying repository service architecture. The paper also describes the synergistic collaboration between digital library technologists and education researchers to build a research environment that can integrate with the VMCAnalytic tool to create a digital collaboration space. The prototype tool is available in as of January 2010 at the VMC website: www.video-mosaic.org.

1. Introduction

In 2008, Rutgers University and the University of Wisconsin (Madison) received a National Science Foundation grant, Cyber-Enabled Design Research to Enhance Teachers' Critical Thinking Using a Major Video Collection on Children's Mathematical Reasoning. The grant is a collaboration among researchers at the Rutgers Robert B. Davis Institute of Learning, the University Wisconsin (Madison) Department of Educational Psychology, and the Rutgers University Libraries to develop the Video Mosaic Collaborative, an interactive research and teaching virtual environment where educators and researchers can utilize videos and digital tools to improve mathematics pedagogy [1].

The grant involves significant research and technical infrastructure components, but the heart of the grant is the goal to make the Robert B. Davis Institute of Learning (RBDIL) mathematics education video collection permanently accessible and actively used by researchers, teacher educators, and both pre-service and in-service teachers. The RBDIL collection contains more than 4000 hours of mathematics education interventions, conducted in a variety of mainly New Jersey school settings, over a twenty-year period, in many cases following the same student cohorts from elementary school through high school. The video interventions employ a variety of tools and techniques, with a strong focus on evidence of student reasoning and learning and student-centered teaching techniques for mathematics content areas such as fractions, counting and combinatorics, probability and calculus. Preserving these videos and making them accessible for future generations of researchers required something more than a digitization strategy and a website. It required a repository strategy where tools for managing and preserving resources are integrated with web-based strategies for making the videos accessible to users.

Videos that are preserved but not used are a critical waste of resources and effort. Thus another primary goal of the grant is to create a collaborative digital space where the RBDIL videos can be effectively utilized. A major innovation of the project is leveraging the different strengths of digital library professionals and mathematics education faculty to create a synergistic collaborative design that significantly benefits both domain specialists and by extension creates a collaborative environment that reflects the best practices in both professions, for the lasting benefit of the education community. The VMCAnalytic tool is a critical component of the VMC. It leverages the repository architecture to enable researchers and educators to collaborate in the use and analysis of videos and also to benefit future researchers by creating durable analytics that are information objects and also rich metadata about the digital videos, enabling researchers and busy educators alike to

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quickly select the most appropriate videos for their needs.

The VMC will build upon RUcore (Rutgers Community Repository), a mature digital repository infrastructure at the Rutgers University Libraries [2]. Repository architectures emerged in last decade to address the need to preserve and make accessible the unique intellectual assets produced at research institutions. RUcore is built upon the Fedora repository application suite, a service-oriented repository infrastructure that combines security, storage, discovery and access services utilizing web services, messaging, and XML standards for resource management and discovery [3]. The research educators desire a collaborative infrastructure for conducting research and working with pre- and in-service teachers that enables robust and flexible utilization of the RBDIL videos to significantly impact mathematics education. The VMC provides the Rutgers University Libraries with an opportunity to extend library expertise beyond the traditional organization and preservation of resources to a deeper understanding and active support of the user research and education workflow. The project work plan is designed to increase the understanding of both partners in the principles and practices of the other, to synergistically leverage the skills of both to benefit the target audiences and also to serve as a replicable strategy for other education portals that involve video analysis and reflection, particularly those wanting to integrate video analysis into a repository architecture.

1.1 Statement of Need

The importance of video for the professional development of pre-service and in-service teachers has been well-documented in recent literature. Some of the benefits noted by researchers include reflection leading to action, as teachers change their practice based on insights from digital video analysis [4] and the role that video can play in encouraging teachers to identify significant events in a classroom educational intervention and to engage in adaptive teaching—modifying the teaching strategy in response to changing cues from students [5]. A classroom intervention provides an immersive experience that provides the educator with immediate feedback from students. A video capturing the intervention is both more and less than the actual intervention. The educator watching the video lacks the heightened awareness of the physical participant and the immediacy of response from other participants and also may be seeing only a partial view of the intervention, as a result of camera placement or video editing. However, the viewer also has the advantage of an objective rather than a participatory viewpoint, as well as the ability to revisit aspects of the intervention to glean insights. The significant advantage of the ability to view and interpret a video, as opposed to reading educational theory or case studies of teaching practice, is that video is the closest approximation currently available to the immersive physical experience. As Harris, et al note, "much of the language for teaching is not only tacit, it is also nonverbal, physical and tactile [6]." A learning intervention cannot be recreated verbally or as text without significant loss of the ambient cues that provide evidence of beliefs, discourse, discovery—in sum, the elements of the learning experience. The VMCAnalytic seeks to combine the best of the video experience with textual analyses, including contextual metadata documenting camera placement and video characteristics such as editing, to compensate for the inherent artificiality of recreation and to provide more than the physical experience can provide not just through analytic tools but also through the linking of related resources, such as transcripts, teacher's notes, published papers, etc. to add depth and nuance to the analysis and reflection that the VMCAnalytic user can supply to the intervention.

2. Designing the VMC Analytic

2.1. The VMCAnalytic and the Repository

A number of tools have emerged, particularly in the first years of the 21st century, to enable researchers and teachers alike to interpret and reflect upon educational interventions in context, where the interaction of teachers and students in a learning situation can reveal insights into theory, practice and beliefs [7] [8]. While we discovered many sophisticated and mature analytic tools, the focus of the Video Mosaic Collaborative and thus the primary challenge for our tool design is the need to make a large, complex video collection available for both individual and collaborative analysis and use. We needed an analytic tool that would integrate well within a repository architecture containing a large digital video collection. Our research questions for tool design focused on how an analytic tool, and the analyses it creates, can best be managed and exploited within a repository environment. In order to determine the level of integration needed, we had to first answer a more basic question: what is the video analytic once it is created? This is not an existential, "if a tree falls in the forest" type of question but instead represents the core issue influencing the development of the VMCAnalytic. Our repository architecture manages the works of many creators. A primary goal of resource management is long-term availability, which requires documenting the provenance of the resource so that the terms and conditions of use are available over time and space. The video analytic had to be considered in terms of its context of creation as well as its relationship to the video it analyzes. The output of the VMCAnalytic tool needed to be defined as a repository resource in its own right before we determined the functionalities it would need to support video analysis and research.

When considered as an information object, a video analytic is first and foremost metadata, since it is data about data, and in fact it is data that has meaning primarily with respect to the video data that it analyzes. However, video analytics, which range from simple annotation and coding to complex interpretive essays, contain considerable creativity and independent expression, similar to a scholarly article or review of a video. A video analytic meets the test of a creative work expressed in tangible form required for copyright status. An analytic can contribute in a lasting manner to the corpus of scholarly information about a video resource. Others can cite and build upon its insights. A video analytic should thus be accorded the treatment in the repository that is afforded to the video resources. Its' provenance and creation should be documented in metadata including attribution to the creator(s), and it should be searchable and retrievable for use by others. The creator should be able to decide the level of access and reuse afforded to other users, ranging from keeping the analytic entirely private, to sharing with collaborators, to full publication as part of the open scholarly record. As with other published resources in RUcore, once a resource has entered the open scholarly record where it can influence the work of others, it can be hidden from view, at the request of the creator, but not removed or deleted from the repository, except in extraordinary circumstances. A metadata record will always be available to provide an audit trail for scholars who have cited or otherwise built forward upon the resource.

Choosing to make the analytic a full repository resource in its own right provides several advantages over the standard methodology of maintaining the analytic as dynamic or proprietary information within a user's personal or collaborative workspace, which is totally reliant upon the creating application for viewing and management. To begin with, the Fedora repository supports durable relationships among resources using RDF (Resource Description Framework) statements, known within the Fedora Repository as RELS-EXT statements. RDF is an XML schema specifically designed to document relationships between objects or concepts [9]. Analytics can be automatically bound to the video they analyze, so that a search that results in an analytic will always also retrieve the video being analyzed. Other resources, such as articles, dissertations, student work, etc. can also be related to the video and the analytic. Since this binding is metadata-based, rather than exclusively a function of the tool, the analytic can be ultimately exported to other environments with the linking metadata to link to the video and other resources. This is an important issue for future availability of the analytic resource.

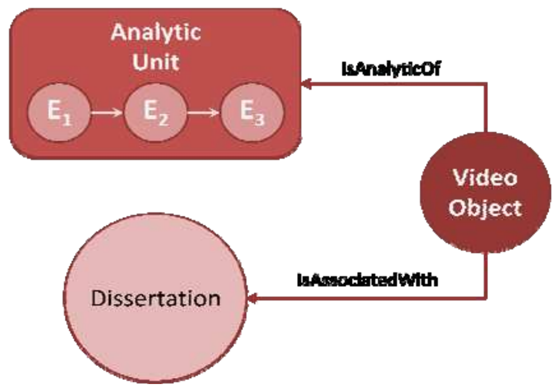

Figure 1: Related objects in the VMC Repository

As a repository resource, the analytic will receive full metadata cataloging, so that published analytics will be documented in search displays by the creator, the creator's affiliation and the creator's role in the organization (e.g., faculty member at X University, 4th grade teacher at Y school). Analytic creators will be prompted at publication to provide a brief abstract of the annotation which will also display in the brief record resulting from a repository search. The creator will also be prompted for additional context, such as whether the analytic is associated with a research project, a grant, or a course. This will enable users of the Video Mosaic Collaborative to quickly scan and select the analytics that best serve their research and pedagogical purpose to aid them in viewing and interpreting a video. This metadata will also enable the researcher to group analytics together in a meaningful way and to reuse analytics effectively in her own research. The analytic will also display the subject domain or sub discipline of its creation, such as middle school mathematics education, educational psychology, etc., thus affording the VMC user multidisciplinary analytic perspectives on a selected video.

One of the strengths of the Fedora repository architecture is its flexibility in organizing, managing and retrieving resources. Any type of resource can be managed by Fedora. A content model, which is used to associate applications for the display and reuse of resources and to select technical and source metadata appropriate to the format, is all that is required to ingest new content types into Fedora. The content model forces consistency and standardization upon digital objects managed by the repository. The VMCAnalytic resource is an XML document. An XML schema in development for the analytic will create a consistent document that can be shared outside the Fedora repository, ingested into XML-compliant databases and displayed on any XML-aware browser. The content model and schema will enable other libraries and organizations to utilize the open source VMCAnalytic tool and to create and manage analytics as resources in a repository. It will also enable users to export analytics to applications outside the repository, such as course management systems. The XML schema provides a robust structure for the analytic that can be readily addressed by any web service, stored in any type repository or simply in a server folder, and reused in any digital infrastructure, not just in a Fedora repository. In addition, the analytic can also be exported in PDF, enabling users to share their analysis in printed form.

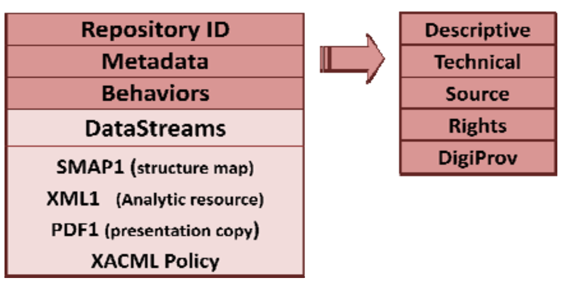

Figure 2: VMCAnalytic Object in Fedora

The Fedora repository also utilizes METS (Metadata Encoding and Transmission Standard), a powerful XML schema for organizing digital information into a package that can be stored, modified, shared with other METS-based repositories and made accessible to users. METS concatenates all the versions of a digital resource (including the transcript) with metadata about the resource, a structure map for navigating through the resource, and behaviors, such as video players that enable use of the resource. METS metadata includes a wealth of data elements for describing and managing digital resources, including descriptive metadata for discovery and access, technical metadata for documenting file characteristics, rights metadata, for documenting rights holders and reuse permissions, and source metadata, for documenting the original source object [10]. The Fedora METS implementation requires Dublin Core as the base descriptive metadata record but allows the repository the flexibility to layer additional metadata upon Dublin Core. One of the more recent types of metadata supported is XACML (eXtensible Access Control Markup Language) which enables the libraries to set access restrictions, such as who has permission to use the resource, within the METS package, in a format that can be addressed by standard authentication and authorization strategies, including Shibboleth. XACML enables the repository to keep annotations private, or make them accessible to collaborators or the general public, in an interoperable way that persists with the digital object, even if the digital object is moved to another repository or application [11].

2.2. Identifying VMCAnalytic Features

Once the decision was made to utilize the RUcore Fedora repository infrastructure, and to incorporate the VMCAnalytic as a managed digital resource within the repository, we realized we would not be able to reuse the many excellent and feature-rich analytic tools already available, although we are hopeful that our interoperable design may enable sharing analytic information across analytic tool platforms in future iterations of the tool. The development of the tool presented an ideal opportunity to work closely with domain experts in mathematics education, as well as pre-service teachers, to understand their research and teaching needs, their current workflow for analyzing video, and to determine ways to improve the analytic experience and to add the interactivity and collaboration within a repository environment that are important for the usability and transformative potential of the Video Mosaic Collaborative.

We observed, videotaped and interviewed education faculty in a variety of contexts—using multiple video annotation tools; viewing and analyzing representative RBDIL videos; and conducting research into pre-service educator analyses of student learning. We documented our observations and discussed what we observed with a larger group of librarians who specialize in metadata and research support services in order to design and construct a useful tool that meets the needs of teacher educators, graduate students, research faculty and teachers. As the research component of the grant moves into schools in the fall of 2010, the tool developers will have their first opportunities to observe in-service teachers viewing, interpreting and utilizing RBDIL videos with the prototype of the VMCAnalytic, which will further inform the first open source public release of the tool in spring 2010.

2.3. VMCAnalytic Context Metadata

One of the drawbacks of our observations to date is that we mainly observed users who are quite familiar with the RBDIL collection. They generally know exactly what videos they want to use in this large, complex collection, and why. In order to address both project goals: making the RBDIL collection accessible and useful and enabling the analysis of those videos, we needed to ensure that faculty and educators worldwide who will utilize the VMC can find the appropriate videos to use with the VMCAnalytic tool to meet their research and practice needs. The VMCAnalytic tool includes a search interface to discover videos and pull them into the analytic workspace, so the first functionality to address was to ensure sufficient metadata to discover and select videos from the large RBDIL collection, as well as future collections placed in the VMC by other participants. Context is critical for selecting a video for use.

Everyone has searched a library catalog for resources. An author search will find resources created by specialists in a field. A subject search will find information about a general area, such as fractions or mathematics education. But the RBDIL videos, which were created through many research projects over a 20 year history, are unpublished. Often they lack a title, and critical information such as creator, participants and school setting are generally not evident from the video content. A video intervention can be viewed to create a title and assign subject headings. But is this enough to make research reusable by other researchers or by practicing teachers?

To enable reusability by other researchers, more research-specific context is needed, including: where the research was conducted, who the research participants were, whether the research was funded by a granting agency, and what the IRB protocol allows for further use or citation of the video. The setting and demographics of the participants are also critical, both for interpreting the video and for selecting videos that conform to a research hypothesis or the setting of an in-service teacher, who is looking for a video intervention that mimics his own experience. Finally, critical information that is often missing concerns the physical creation of the video itself. Is the video the result of a single camera or a composite of multiple camera views? Is the video raw footage or footage that has been edited and if the latter, is the raw footage available and linked for comparison?

Current metadata standards do not include sufficient context to select videos for re-use in education research or for the professional development of pre- and in-service teachers. The need to enrich our metadata to support the needs of researchers and practicing educators was our first significant opportunity for library and domain experts to work together. The education faculty and graduate students at the Rutgers Graduate School of Education identified context information critical for reuse of videos in research and teaching, including information about the research parameters, demographic and socioeconomic information about the setting and participants, physical creation information and linkages to the wealth of associated information that would also be included as related digital information objects in the repository, such as grant reports and scholarly publications that resulted from the analysis of the videos. The linking of raw and edited footage can support both the busy educator who benefits from a high impact clip and the researcher who does not want any editorial filters. Education domain experts worked with library metadata designers to select data elements and controlled vocabularies for the source context metadata schema, which is currently being offered for public comment to the mathematics education and digital library communities worldwide [12]. We also worked with domain experts to identify metadata elements that could supplement the general descriptive metadata already available in the RUcore repository that would support browsing by categories such as school, grade level, mathematics content area, and type of mathematics problem.

2.4. VMCAnalytic Tool Functionality

Once we ensured that videos could be discovered for reuse, we turned our focus to the development of the VMCAnalytic tool itself, how it would be navigated and used and what interpretive and reflective information could be captured and analyzed. We benefitted from the many mature and developing tools either available or in development. We hoped to not only identify features in common use but to align our analytic with other tools for future opportunities to share data across tools. These tools commonly provide the ability to annotate, with codes or free-text notes, and to synchronize annotations with video, and often with the transcript, for playback [7]. One particularly interesting new tool, the Digital Replay System from the National Centre for e-Social Science at the University of Manchester, integrates digital activity logs from any digital event, such as instant messaging, video, audio, and any digital record, to create a sophisticated multitrack synchronized playback of a real or a completely virtual digital environment [13]. The Diver tool is also noteworthy for its integration into an intuitive web-based collaborative environment [14].

Our design research included a literature survey of articles that evaluated tools and documented the use of specific tools for such purposes as teacher self-reflection and collaborative analysis [7] [8] [15]. However, just as viewing a video rather than reading a transcript is critical for the full context, including visual cues and participant dynamics, the design of a new tool required observation, and even participation, in a range of activities that the VMCAnalytic tool must support in addition to identifying analytic tool features documented in the literature.

Our first opportunity for observation was a visit to the collaborating institution, University of Wisconsin (Madison), where we observed researchers using a number of annotation tools—Transana, Diver, nVivo and Anvil. We were fortunate to observe Sharon Derry, a principal investigator on the grant, who teaches a course on video analysis tools, and her graduate students, who demonstrated each tool. We engaged in a fulsome discussion of what worked well and what didn't, for each tool. We also observed several analytic activities at Rutgers. We observed faculty and graduate students analyzing a RBDIL video.

Finally, we observed researchers performing the preliminary analysis for a major research component of the grant, conducted by Carolyn Maher, the principal investigator, and co-principal investigator, Marjory Palius, of the Robert B. Davis Institute of Learning at Rutgers University. The research project is examining the effect of video viewing and analysis on pre-service and in-service teachers' understanding of student learning. The first phase of the research project involved video analysis in counting and fraction content areas. Pre-service teacher participants taking mathematics education courses at several New Jersey universities viewed a video segment, together with a transcript of the segment, and answered three interpretive essay questions. These questions asked the study participant to identify forms of reasoning exhibited by students in the video, whether or not the students in the video presented a convincing argument and why the argument was convincing to the participant. The interpretive essays were then scored by researchers in the presence of the library tool developers, using a rubric designed to determine whether or not participants can successfully identify and interpret evidence of learning and whether their beliefs about the students' abilities to learn mathematical concepts have changed as a result of viewing and analyzing the video.

We observed several interesting research behaviors that the VMCAnalytic must support, which are also validated in other video research literature [16]. Video analysis ranges from structured essays on specific topics such as evidence of learning and student discourse, to terminology codes that can be captured, exported to a database and analyzed in the aggregate. Often, these two broad documentation types are used in the same analytic exercise. The VMCAnalytic was thus designed to provide the user with the flexibility to construct a template to support free-text essay annotations (notes) which may respond to a topic or question as well as codes utilizing a controlled terminology. For each information element that a researcher wants to capture in a video segment, the researcher may select either note or code. Labels and terminologies may be constructed on the fly or reused from the ontology store described later in this paper.

The VMCAnalytic design also enables multiple researchers to contribute to the same analytic for multiple perspectives, iterative analysis and consensus building. Consensus building was particularly important for the researchers who were scoring participants' reflective essays, Evidence of a teacher's ability to recognize student learning is based upon independent coding of participant analytics. This independent coding identified areas of agreement among researchers but also areas of divergence. The researchers then negotiated their interpretations of student analysis to reach consensus about what the student had observed.

The benefit of a repository architecture, where resources can be related to each other in complex chains of relationship enables the VMCAnalytic to support a meta-analytic, or analytic of an analytic, a requirement we identified as we observed the researchers analyzing pre-service teachers' analyses of video examples of student reasoning. The pre-service student participant views and analyzes a video segment through the three essay questions. The researchers then construct an analytic that interprets and codes the student participant analytic based on a rubric that measures participant recognition of learning evidence, participant beliefs about student learning, etc.

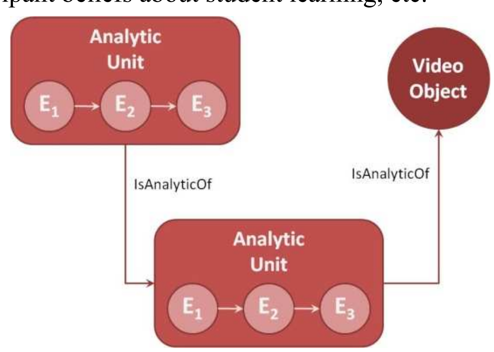

Figure 3: Complex Analytic Relationship

The participant and researcher each need to be able to construct an analytic, but whereas the participant analytic is an interpretation of the video, the researcher analytic is in fact an interpretation of the participant analytic. Our ability to durably relate an analytic to an analytic as well as to the video being analyzed supports both the pedagogical and the research needs of the faculty member teaching the course by bringing organization and efficiency to the faculty member's practices. This linking also makes the analytic relationships available to a co-instructor, graduate assistant and the student himself, who can align his analytic with the professor's analytic in a critical feedback chain.

2.5. VMCAnalytic Terminology Support

One of our first, and most significant, observations was that the terminology used to describe observed events in videos was fulsome and nuanced but not standardized. Participants would use synonyms, or even slightly different terms, with the ease and comfort of experienced researchers who understand the subject, and each other, very well. Adding the ability to capture standardized codes enables the researcher to export codes to a database for more extensive analysis. In a digital collaborative, analytics may be reused by many unknown researchers worldwide. Use of a published ontology enables other researchers to identify the codes used and their relationships to other codes. Precision must assume equal importance with nuance to make analytics reusable by others and to enable researchers to analyze many aggregated analytics for statistical probability. Other researchers have documented the importance of language for creating common ground for sharing insights discovered in videos [17]. Terminology development is a major area of expertise in the library domain, but the library researchers lack the in-depth subject understanding to construct a valid ontology of terms. Ontology construction thus becomes a major area of collaboration where the library participants contribute the structure and the educators contribute the bulk of the terminologies,

An ontology can be simply defined as the representation a subject domain through the hierarchical organization of the key concepts or terms in the domain. A critical need, particularly for research conducted across disparate physical locations and shared with a worldwide audience, is a nuanced vocabulary that supports hierarchies, synonyms and the discovery and reuse of ontology terms across education sub domains (mathematics education, educational psychology, language acquisition, etc.). The ontology provides a common ground for researchers in specific domains to collaborate on research projects, for researchers and teachers to interpret videos together using a common terminology to avoid confusion and enable precision in analysis, and for users to discover analytics and reuse analytics that are beneficial to their own research or teaching practice, . The ontology also ensures that the individual researcher can analyze aggregated data accumulated across many videos and video segments with confidence.

At the same time, researchers need to be able to create terminologies "on the fly" that reflect current concepts or fresh insights that the researcher did not identify in advance of the video analysis. Both controlled vocabularies that support shared understanding, collaboration and reuse as well as less formal vocabularies constructed on the fly needed to be supported by the VMCAnalytic.

Constructing an ontology for a whole domain of knowledge would be a research project in itself, requiring years of effort by dedicated specialists. We decided instead to integrate a robust ontology tool into the VMC repository infrastructure, to support controlled terminologies created in advance of a research project and available for reuse by others as well as the dynamic building of vocabularies at point of need, while engaged in video analysis. The VMC will support authoritative ontologies that have been developed and edited with the collaboration of domain specialists, as well as ontologies created by VMC users for their own needs, which are privately accessible from the participant workspace. A participant will be able to suggest ontology terms for inclusion in published ontologies in the VMC which will be referred to the ontology creator for review. There are many open source ontology builders that are flexible, feature rich and conform to the prevailing standard for ontology building, Web Ontology Language (OWL). We examined and tested a number of options and selected the open source Protégé ontology builder, developed by Stanford University [18].

2.6. VMCAnalytic Prototype Design

Our observations and analysis of existing tools resulted in a prototype tool that is flexible, customizable and feature rich and supports the identified needs of the VMC. The first open source version and any subsequent versions will focus primarily on usability and navigation, as well as additional features to support the innovative research and teaching efforts that we hope will be enabled by the Video Mosaic Collaborative. Future iterations of the tool will also focus on the interoperability of the analytic objects created, for sharing with other repositories and applications and for exchanging data with other tools. Our schema, currently in design, will be published at the VMC website to promote this interoperability.

The integration of the VMCAnalytic tool with the repository infrastructure supporting the VMC enables the tool to draw upon repository services, such as the search and ontology services, which are described more fully in the next section. The VMC search service is integrated into the tool to enable a user to search the collection and select one or more videos relevant to her needs. The VMCAnalytic is currently designed to work with the Flash video format in common use by portals such as YouTube®. The analytic creator can set start and stop points that limit or structure playback to the video segments the creator wishes to analyze. Once a video is selected, the analytic has access to the context metadata of the video, which includes participant identification, setting identification, research context, creation context etc. This enables the creator to be specific and detailed in her analysis and to accurately capture relevant information across multiple videos and analytics to perform a cumulative analysis (e.g., a statistical analysis of codes from a series of analytics documenting the progression of the student identified as "Mary" as she works through several problems intended to teach fractions). As noted earlier, the creator can select multiple note or code annotation types—as many as are needed—for each video segment, or "event" within an analytic. The creator is prompted to search for a relevant ontology or to create her own, for each annotation. The ontology captures both the label assigned to the annotation (e.g., evidence of student learning) and the controlled vocabulary terms within a code annotation (e.g., argument, gesture, etc.) Hierarchical codes can be nested, e.g.,

Evidence of Learning
- **Gesture**
  - **Nod**
  - **Smile**

The ontology service interface to add a vocabulary is being designed as a simple "drag and drop" from the ontology into the analytic.

The analytic consists of events and units. The "event" is the base component and is situated in place and time by start and stop points on the video. The creator may group multiple events together into a unit of analysis. Events can be selected from multiple videos, duplicated, and reordered to create units, through a simple drag and drop. Both events and units can be annotated with codes or notes and can use the same or separate ontologies, depending on the creator's need. Each event becomes a component resource and utilizes the same RELS-EXT relationship functionality to create and maintain relationships among events.

The final analytic object is a composite of its events and units, which encompass the unique content and conceptual analysis provided by the creator. This analysis can be at the top level of the analytic, as well as associated with each event and each unit. During audiovisual playback of the analytic, the annotations are synchronized to the appropriate events and units.

A transcript of the video is considered an alternate form of the video and bundled as a datastream into the METS video package. In a future version of the VMCAnalytic, the transcript will be synchronized to the video, so that the relevant excerpt of the transcript appears with the segment. Currently, the VMCAnalytic tool allows you to cut and paste the relevant segment of the transcript into an annotation note for synchronized viewing on playback.

Data analysis of the annotations within the analytic can be performed by exporting the data to relevant applications. Specific annotations can be selected and exported to an SQL database for statistical analysis. Code annotations can also be exported to visualization tools to create charts and graphs. The Video Mosaic Collaborative will offer at least one open source database (MySQL) and one visualization tool (Grapher) to enable further analysis.

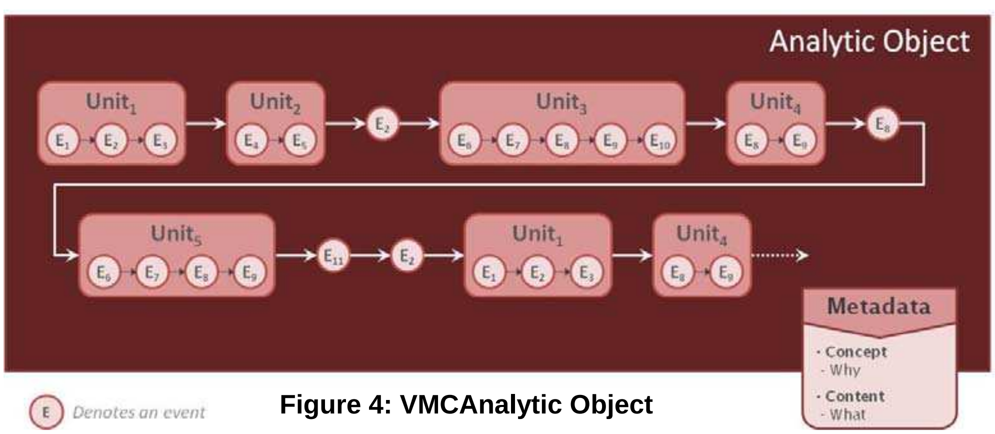

Figure 4: VMCAnalytic Object

3. VMC Service Architecture

Much of the functionality and power of the VMCAnalytic results from its integration with the repository architecture and the resource collection that is being analyzed. The RUcore architecture is a repository-based infrastructure designed to meet the research and education needs of the faculty and students at Rutgers, the State University of New Jersey. RUcore is a layered architecture of services and applications that support the creation, management, access and reuse of digital resources.

The Video Mosaic Collaborative will draw upon applications and services created for RUcore and for the VMC, which is an RUcore domain portal, to create a collaborative environment for the analysis and use of videos and related resources to support research and teaching in mathematics education. Its ambitious goal is to transform the use of videos in mathematics education through building communities of practice around compelling research concepts, such as teacher beliefs, and through tools that enable practicing teachers to leverage videos for self-reflection and for structuring their own student interventions. The VMCAnalytic is the first such tool for the VMC, but there will be others.

Four major services are currently being developed to support the analysis of video within the Video Mosaic Collaborative. These services were identified and prioritized for development through the intensive needs analyses conducted by the library researchers.

3.1. Repository Service

The core of the architecture is the Fedora repository service. Fedora provides native services for storage, preservation and access to digital resources and exposes the managed resources to further functionality through well-defined Application Programming Interfaces.

3.2. Search Service

This service provides a gateway to search and explore resources stored and preserved by the repository service. Final delivery of content is provided by the repository service with the search service only serving as an exploratory agent of the repository service. The search service is dependent on two other services for content and terminology control. The repository service supplies objects for indexing and resources for delivery. The ontology service provides controlled vocabularies for performing consistent and reliable browse searching. These ontologies are configured by search service users in the configuration layer of the search service. The Search Service consists of a COM layer using Representational State Transfer (REST) design methodologies. Using REST, the search service relays data over HTTP without the overhead of an additional messaging layer such as Simple Object Access Protocol (SOAP). The search service is a read-only service which translates perfectly as a HTTP GET method. The Search Service is highly configurable, enabling different configurations and search methodologies for different user portals. This is very important for scalability and flexibility of the RUcore architecture to support domain portals such as the VMC, since the indexing, retrieval and display needs of the education domain are very different than other domains, such as marine sciences or physics.

3.3. Collaboration & Messaging Service

An integral part of the VMC will be the ability for researchers, instructors and practitioners to collaborate virtually. Leveraging commonly used social networking methodologies, the collaboration and messaging service will provide a conduit to support these work interactions. Creation and management of invitation-only research groups is a core function for providing viable virtual collaborations. Virtual research groups will allow for the development of research to occur either synchronously or asynchronously depending on the availability of the research group members. Chat functionality is another feature the collaboration and message service will provide. The service-oriented implementation of the chat functionality allows a user in the VMCAnalytic tool to chat with a user in another application that also incorporates this services function. By providing a messaging system, communication between members of a group or individuals can occur as an integrated function of any application using this service. Implementing this service across multiple platforms provides seamless levels of communication between users across applications.

Conclusion

The VMCAnalytic builds forward upon and represents a significant enhancement to current video analytic tools in several significant respects. The tool creates a durable information object that conforms to an XML schema that can be stored, managed, shared, and linked to video resources and other relevant documents (scholarly papers, dissertations, etc.) to form part of the permanent scholarship surrounding video use. The VMCAnalytic is also unique in its integration into a repository infrastructure, which enables the analytic to draw upon services and resources in the repository, such as search and retrieval services, access control services and metadata. The VMCAnalytic is also unique in its ability to call upon the wealth of context information and associated resources that are critical to a full understanding of the video being analyzed. As such, the development of the VMCAnalytic can serve as a roadmap for other institutions wishing to integrate video analysis more fully into their repository and collaboration environments.

References

[1] National Science Foundation. Award Abstract #0822204. Collaborative Research: R&D: Cyber-Enabled Design Research to Enhance Teachers' Critical Thinking Using a Major Video Collection on Children's Mathematical Reasoning. (website) Washington, DC: NSF, 2008. http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0822204

[2] RUcore: Rutgers Community Repository (website), New Brunswick, NJ: Rutgers University Libraries, 2009. http://rucore.libraries.rutgers.edu/

[3] DuraSpace. "Key Features of Fedora Repository Software", Fedora Commons Documentation [website]. http://www.fedora-commons.org/about/features/?searchterm=key%20features%20of%20fedora

[4] Wright, G. A. "Using Digital Video to Improve In-service Teacher Performance by Increasing their Reflection for Action Aptitude and Ability", in K. McFerrin et al. (Eds.), Proceedings of Society for Information Technology and Teacher Education International Conference 2008, .Chesapeake, VA: AACE, 2008, pp. 4374-4380.

[5] Sherin, M.G. and van Es, E.A. "Using Video to Support Teachers' Ability to Notice Classroom Interactions", Journal of Technology and Teacher Education 13 (3), Chesapeake, VA: AACE, 2005, pp. 475-491.

[6] Harris, R.C, Pinnegar, S. and Teemant, A. "The Case for Hypermedia Video Ethnographies: Designing a New Class of Case Studies that Challenge Teaching Practice", Journal of Technology and Teacher Education 13 (1), Chesapeake, VA, AACE, 2005, pp. 141-161.

[7] Rich, P.J and Hannafin, M. "Video Annotation Tools: Technologies to Scaffold, Structure and Transform Teacher Reflection," Journal of Teacher Education 60 (1), Thousand Oaks, CA, Sage Publications, 2009, pp. 52-67.

[8] Pea, R. and Hoffert, E. "Video Workflow in the Learning Sciences : Prospects of Emerging Technologies for Augmenting Work Practices" in R. Goldman, R. Pea, B. Barron, and S.J. Derry (Eds.), Video Research in the Learning Sciences, Mahwah, NJ: Erlbaum, 2007, pp. 427-460.

[9] W3C Technology and Society Domain, Resource Description Framework (RDF) (website), 2001. http://www.w3.org/RDF/

[10] Library of Congress, METS: Metadata Encoding & Transmission Standard Official Website (website), Washington, DC, Library of Congress, 2009. http://www.loc.gov/standards/mets/

[11] Fedora Commons, Fedora Authorization with XACML Policy Enforcement (website) http://fedora.info/download/2.1b/userdocs/server/security/AuthorizationXACML.htm

[12] Video Mosaic Collaborative, Research Context and Video Reuse: Making Research Reusable, the Role of Metadata (website), 2009. http://www.video-mosaic.org/cr_contextreuse.php

[13] National Centre for e-Social Science. "Digital Replay System" Detailed Information (website), 2009. http://www.ncess.ac.uk/research/digital_records/drs/details/

[14] Pea, R., et al. "The Diver Project: Interactive Video Repurposing" IEEE Multimedia 11 (1), Los Alamitos, CA, IEEE, 2004, pp. 54-61.

[15] Edyburn, D.L. "Collecting and Coding Observational Data" Journal of Special Education Technology 23 (2), Arlington, VA, Council for Exceptional Children, 2008, pp. 56-60.

[16] Sherin, M.G. and van Es, E.A. "Using Video to Support Teachers' Ability to Notice Classroom Interactions"., Journal of Technology and Teacher Education 13 (3), Chesapeake, VA: AACE, 2005, pp. 475-491.

[17] Halldén, O., Haglund, L., and Strőmdahl, H. "Conceptions and Contexts: On the Interpretation of Interview and Observational Data," Educational Psychologist 42 (1), Mahwah, NJ: Erlbaum, 2007, pp. 25-39.

[18] Stanford Center for Biomedical Informatics Research. Protégé (website), Palo Alto, CA: Stanford University, 2009. http://protege.stanford.edu/