Pathway – Using a State-of-the-Art Digital Video Database for Research and Development in Teacher Education

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Abstract. To demonstrate how state-of-the-art video databases can address issues related to the lack of preparation of many physics teachers, we have created the prototype Physics Teaching Web Advisory (Pathway). Pathway's Synthetic Interviews and related video materials are beginning to provide pre-service and out-of-field in-service teachers with much-needed professional development and well-prepared teachers with new perspectives on teaching physics. The prototype was limited to a demonstration of the systems. Now, with an additional grant we will extend the system and conduct research and evaluation on its effectiveness. This project will provide virtual expert help on issues of pedagogy and content. In particular, the system will convey, by example and explanation, contemporary ideas about the teaching of physics and applications of physics education research. The research effort will focus on the value of contemporary technology to address the continuing education of teachers who are teaching in a field in which they have not been trained.

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INTRODUCTION

Although the problem is not new, [1] recent data indicate that high school physics teachers are not being graduated from our colleges of education at a rate to meet the demand. [2][3] Only one-third of the high school physics teachers are considered specialists in their field. An additional 40% have achieved certification which in some states requires as little as three college-level physics courses. Thus, many of our brightest high school students are attempting to learn physics with guidance from teachers who, though well-intentioned and doing the best that they can, have limited background in both the content and pedagogy of physics. They need additional support.

Exacerbating this difficult problem is a movement to change the order in which science topics are taught in high school. Encouraged by Nobel Laureate Leon Lederman a large number of scientists and educators are advocating teaching physics early in high school as a basis for the other sciences. [4] Schools which adopt this approach suddenly find the need to teach physics to all 9^{th} or 10^{th} graders and few or no teachers who can do it.

Addressing the needs for physics teachers requires in-service education to convert teachers who have not prepared to be physics teachers into competent and enthusiastic ones. These in-service activities need to be designed to be consistent with contemporary research in professional development activities, the national and state science education standards and active learning techniques.

Research [5] has identified, through a statistical analysis, components which are particularly effective in professional development of teachers. In part, this research indicates "that sustained and intensive professional development is more likely to have an impact, as reported by teachers, than is shorter professional development." Thus, finding ways to interact with physics teachers over a long time period is important for effective professional development activities.

To demonstrate the ability to address the lack of well-prepared physics teachers in a manner consistent with the modern ideas about professional

development, and to provide resources that can enliven even the most expert physics teachers' classrooms, we have utilized state-of-the-art software and a sophisticated digital video library system to create the prototype Physics Teaching Web Advisory – Pathway. This on-line, always available service uses questions generated by teachers as the beginning point of each session. Thus, it begins with the teachers' existing knowledge. It involves virtual conversations between the teacher and long-term expert teachers who focus on the needs and nature of students in physics classes. Each of the experts has his/her own approach to teaching each of the topics, yet all are committed to active (reform) learning. In their discussions they offer the in-service teacher a variety of strategies for increasing their effectiveness. Pathway is available 24 hours a day, 365 days a year, so its duration can be as long as the teacher needs.

These approaches can also be valuable for the pre-service teacher. [6] Our own work indicates the well-prepared teacher also benefits from the information in Pathway. The Pathway prototype has demonstrated an exciting new approach to providing pre-service and under-prepared teachers with much needed professional development and well-prepared teachers with new perspectives on teaching physics.

PHYSICS TEACHING WEB ADVISORY: PATHWAY

We have created a proof-of-concept system to help a teacher who is new to physics teaching make the very large step from having completed a physics course in college to teaching the topic to bright high school students. Pathway combines Carnegie Mellon University's state-of-the-art digital video library technology, pedagogical advances and long-term experience with pre- and in-service education at Kansas State University, and materials contributed by master teachers. This dynamic digital library for helping teachers goes beyond simply creating a collection of teaching and learning materials. It provides continuously improving assistance and expertise for teachers, all of which is related to the National Science Education Standards and to results of contemporary physics education research. The Pathway system has built on a unique collaboration between several longstanding research projects in digital video libraries, advanced distance learning technologies, collaboration technologies, and nationally known experts in physics pedagogy and high quality content.

The overarching goal of this project is to improve the quality of physics teaching and the number of available physics teachers by providing virtual expert help on issues of pedagogy and content. In particular, we are creating a system that conveys, by example and explanation, contemporary ideas about the teaching of physics.

Today, teachers who have questions about the teaching of dynamics and kinematics can visit the Pathway Web site (http://www.physicspathway.org) and ask a question to our on-line forum, which is monitored by virtual agents, including an agent representing one of the foremost introductory physics textbook authors, Paul Hewitt (see Figure 1). The virtual agent knows how to answer the question, and presents the answer using recorded video of Paul or other experienced teachers. This process, called a Synthetic Interview, provides a unique, interactive digital library for improving physics teaching and a model which could be followed in a variety of disciplines.

A second component of the present Pathway is a searchable digital video library of physics demonstrations and virtual video labs built on Carnegie Mellon's Informedia Digital Video Library. [7] Until the Pathway demonstration, Informedia focused specifically on information extraction from broadcast television video and audio content. Today it is ready to accept a wide range of material relevant to physics teaching. The initial Informedia component of Pathway has several hundred short clips of physics demonstrations and virtual labs covering the first few weeks of the typical high school curriculum. Figure 1 also shows an example query using Informedia in the Pathway system.

Synthetic Interview (SI)

The most significant Pathway effort to date has been the development of Synthetic Interviews. These SIs focus on good teaching practices which are consistent with the National Science Education Standards. They emphasize hands-on and minds-on activities as well as conceptual understanding of the physics concepts rather than algebraic or numerical approaches. Thus, the new-to-physics teachers, pre-service teachers, and experienced teachers are able to "converse" with knowledgeable experts on their classroom techniques and how those techniques are related to contemporary issues in physics teaching.

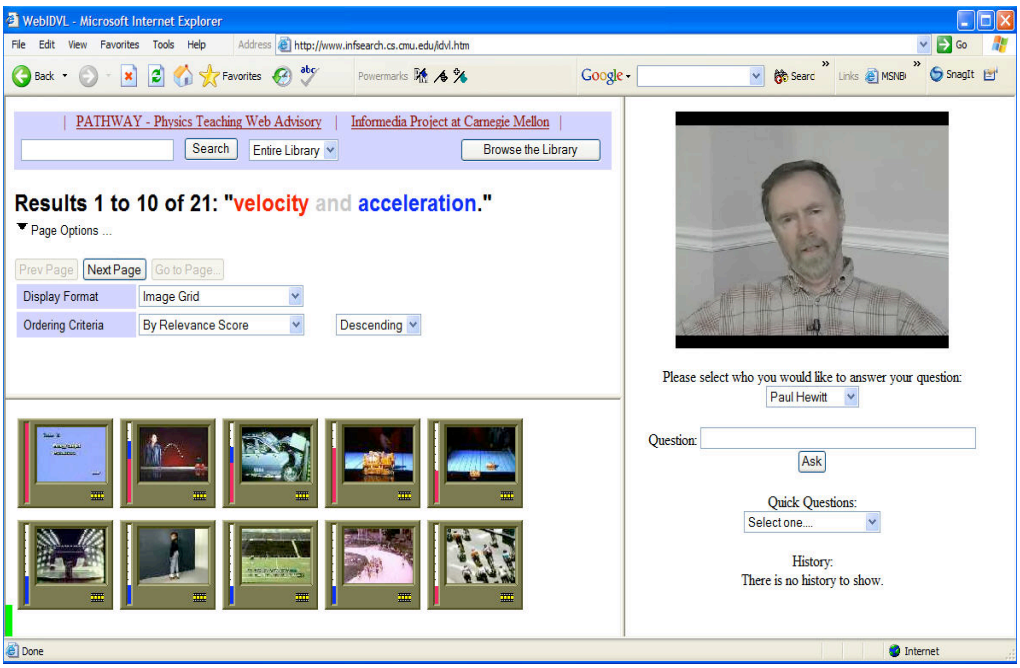

FIGURE 1. A Pathway screen with a Synthetic Interview on the right and Informedia search results on the left. The teacher is Paul Hewitt.

The Synthetic Interview [8] is a technology and technique that creates an anthropomorphic interface into multimedia data of a particular kind: video of a person responding to questions (interacting with another person). The responses of the interviewee are presented in such a way as to simulate the experience of interacting with the expert. Importantly, empirical studies have shown that anthropomorphic interfaces can have a strong motivational impact compared to text or traditional multimedia, with users perceiving the persona as being helpful, entertaining, and creating a more positive learning experience. [9][10]

Synthetic Interviews allow learners to engage in active inquiry by providing the means for conversing in-depth with an individual, permitting users to ask questions in a conversational manner (just as they would if they were speaking to the person face-to-face), and receive relevant, pertinent answers to the questions asked. SIs are highly interactive and vastly more useful than videotape. They provide a utility similar to an expert system, but through a development effort approaching the simple videotaping of a conversation.

At the present time, we have created Synthetic Interviews of four teachers in the domains of kinematics and dynamics. With additional teachers and domains, we will span both high school physical science and physics curricula with virtual mentors for pre- and in-service physics teachers at all levels.

Informedia Digital Video Library

As the Internet grows, finding appropriate information about virtual laboratories, demonstrations, and classroom techniques becomes an increasingly difficult task. To address this problem Pathway builds on the Informedia Digital Video Library. Pathway-Informedia operates similarly to a Web search engine, such as Google, but does so by searching on video and audio information. By combining computer speech recognition, computer vision, natural language understanding and machine learning, Informedia automatically creates metadata from video (see Figure 2). This sophisticated system provides users with easy access to examples of physics demonstrations and teaching techniques.

Informedia enables Pathway to provide an audio-video search engine, which is unprecedented in present science or science education digital libraries. In addition, fundamental research and prototyping is being conducted by members of the Informedia project in areas such as dynamic production of video information collages for summarizing salient points and presenting context across stories and collaboration using views of video segments.

RESEARCH AND EVOLUTION OF PATHWAY

Pathway is built on a substantial research base. We believe that additional research is needed to study the effectiveness of this technology in addressing the needs and continuing education of teachers who are teaching a subject in which they are not trained. Data gathered to date suggests the following improvements:

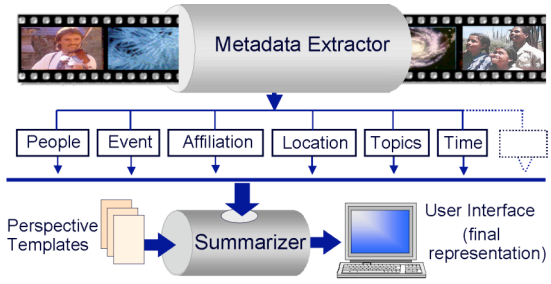

Figure 2: Overview of the Informedia Process

Pathway will expand on the existing prototype and create closer connections to other digital libraries serving the physics teaching communities as well as to the private sector which also serves our community. The Synthetic Interview will continue to be a central feature of Pathway. Because of limited funding the protype Pathway could only cover a small portion of the physics curriculum. Over the next few years, Pathway will cover all of the topics which are traditionally taught in a secondary school physics course. Also, we will expand the number of teachers in the SI. Connections to the Education Standards and educational research will be strengthened and made more visible.

The digital video library will also be greatly expanded in the near future. In addition to samples of video materials which can be used in the classroom we will include examples of teaching and workshop-style videos. Each of these videos will be relatively short in duration but connected to specific teaching about which a teacher will want to learn.

An example of the workshop-style materials we will add are two collections of videos developed by Paul Hewitt. In the first collection an extensive in-service workshop for secondary-school physics teachers was professionally recorded and produced for commercial distribution. Some of this material is currently available in Pathway. With additional resources, we will analyze the entire collection, creating stand-alone segments that help teachers learn how to present materials in an interactive, conceptual manner. The second collection was created to help students learn problem solving skills. To date these tapes have had very limited circulation. We will transform these tapes, developing materials that can be used by both teachers and students.

We believe that this continuously improving, always available, online system can contribute significantly to the problems surrounding teacher education and preparation. The authors welcome any suggestions for the further enhancement of this project.

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