HIGH SCHOOL PHYSICS PATHWAY: TEACHERS HELPING TEACHERS THROUGH SYNTHETIC INTERVIEWS*

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ABSTRACT

This paper highlights the iterative development of a dynamic web environment for exploring physics pedagogy: the Physics Teaching Web Advisory, Pathway. The formative evaluation of the system, with high school physics teachers as users, uncovered a number of shortcomings in the synthetic interview presentation of expert teachers offering advice and instructional strategies. The problems and their solutions are discussed, with implications for the design of multimedia conversational interfaces for teachers helping teachers. The paper presents strategies for dealing with video assets to help teachers find relevant material quickly in addressing the pedagogy and full range of content taught in high school physics, while also promoting additional investigation and exploration of the synthetic interviews.

Index Terms— Synthetic interview, Physics Pathway, physics pedagogy, physics education

1. INTRODUCTION

Physics Teaching Web Advisory (Pathway) is a research and development effort to demonstrate the ability to address issues related to the lack of preparation of many high school physics teachers and to provide resources that can enliven even the most expert physics teachers' classrooms. Pathway's "Synthetic Interviews" are a unique way to engage inexperienced teachers in a natural language dialog about effective teaching of physics. These virtual conversations and related video materials are now providing pre-service and out-of-field in-service teachers with much needed professional development, and well-prepared teachers with new perspectives on teaching physics.

There is a need for Pathway in this subject area of high school physics teaching: high school physics teachers are not being graduated from Colleges of Education at a rate that is sufficiently high to meet the demand [1]. A large fraction of the instructors who teach high school physics are teachers of other sciences or mathematics who have been pressed into service in the physics classroom [1]. Frequently, these teachers are well intentioned and do the best that they can given their limited background in both the content and pedagogy of physics, but they need additional support. The goal of Pathway 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, Pathway conveys, by example and explanation, contemporary ideas about the teaching of physics. More specific goals include preparation of interactive, natural language web-based materials to address the pedagogy and full range of content taught in high school physics, and continual evolution of the system through assessment of its use and feedback from users.

These goals are the basis for criteria for success in terms of the value to physics teachers, particularly new teachers of physics. The summative measures of this success include the number of different teachers who report that our system had a significant impact on their teaching, the types of pedagogical changes that occur for these teachers, and expansion of content for which the teachers are able to offer instruction. This paper, however, discusses formative rather than summative evaluation, and the development of the Pathway interface over the past year, focusing on the synthetic interview interface which offers expert teacher solutions to high school teacher questions.

2. PATHWAY DETAILS, SYNTHETIC INTERVIEWS

Pathway makes use of two enabling technologies for teachers to investigate pedagogical issues. Pathway's Informedia Digital Video Library system organizes a corpus of physics educational materials. Synthetic interview (SI) technology, and Pathway's vast video recordings of answers employed by such interviews, capture pedagogical knowledge for use by in-service and pre-service teachers. Figure 1 illustrates these two components.

The Pathway video corpus contains hundreds of clips illustrating concepts in kinematics and dynamics from award winning videodiscs including Physics and Automobile Collision, Physics at the Indy 500, Physics of Sports, amongst others. Growth of the digital library shown at the left of Figure 1, the underlying Carnegie Mellon Informedia technologies to extract information from broadcast-quality video and audio content [2], and the architecture using XML representation of results and XSLT to transform pages into various views [3] will not be detailed further here. Rather, the focus is on the right side of Figure 1, the synthetic interview interface.

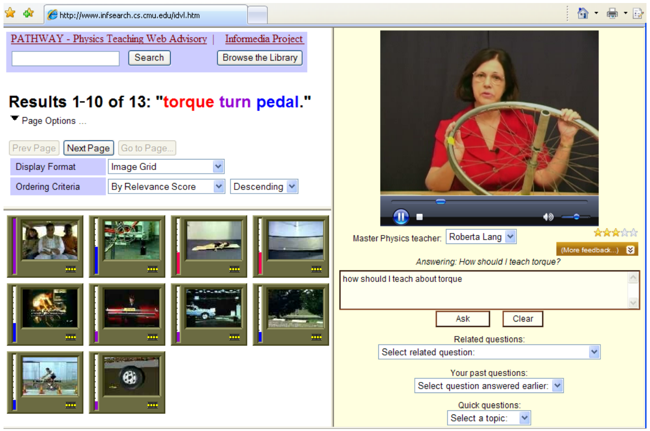

Figure 1. A Pathway page with SI at right, Informedia digital video library search results at left.

The evaluation of Pathway to date has been a combination of Contextual Inquiry and Heuristic Evaluation at physics teacher workshops and at professional meetings where we have made the system available to potential users, feedback for individual users, and the beginnings of an analysis of the questions which teachers ask of the system. Users of the system have had very positive comments, especially noting the effectiveness of searches and the ability to annotate video in the digital video library. In general, teachers who are relatively new to physics teaching have found the natural language "interviews" useful and at least as impressive as the video library. One-on-one interactions with a mentor are extremely valuable. However, teachers cannot be available 24 hours a day to answer questions from dozens of students, even via technologies like chat rooms.

During the infancy of the Internet, pundits predicted democratization of expertise and knowledge: email and chat rooms would provide a forum where anyone could ask any question of world-class experts. The obvious error in this reasoning is that in any specialty, the number of experts is very small. Experts, e.g., physics teachers, do not scale, and they do not want to spend all their time answering questions.

A solution to this dilemma is the Synthetic Interview (SI). The SI [4] 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. The user asks a question, either in free-form typed text or from pull-down prompts based on personal history, site-based or temporal-based favorites, or context-based related questions. The user is always free to listen to the response to the end while interacting with other portions of the page, e.g., the physics library materials, as well as redirect the SI to a related question, or type in a new question of interest interrupting the current response to get to another more pressing need. The stars and "more feedback" options shown in Figure 1 allow the user to comment on what works and what doesn't with the current dialogue, volunteering information mined to improve the language models and future conversational interactions in the Pathway system. The Pathway web site shown in Figure 1 is in the process of being upgraded from its current dependencies on Web 1.0 components such as an early version of Microsoft's MSXML, to a different architecture based on the latest advances in rich Internet application development to promote wider accessibility.

3. THE EVOLUTION OF PHYSICS PATHWAY

3.1. Foundation work on Physics Pathway

The Pathway SI began with a simple interface to query one expert teacher (Paul Hewitt). Experienced, new, and potential high school physics teachers at AAPT workshops and workshops hosted at Kansas State's Physics Education group gathered feedback on the interface, through contextual inquiry, interviews, questionnaires, and think-aloud protocol. In addition, the site was published to a web server but not widely advertised, allowing for a moderate amount of web transactions to be logged from users who happened to find the site or were led to it from KSU's Physics Education group. Tens of thousands of such transactions (at first, just queries and the returned responses; later, queries-responses and the expert being talked to as the corpus grew beyond just Paul Hewitt, and even later some volunteered feedback from users as well) were captured, augmenting the directed feedback from teacher workshops with the target audience for Pathway. Collectively, the information directed the development of Pathway in three iterations:

1. A simple interface to query and receive answers back from a single expert.
2. The interface of Figure 1 bringing in additional teachers to talk to and some extensions to free-form query input.
3. An interface to replace that of Figure 1, built with Adobe Flex 3 as a way to deploy the Pathway rich Internet application across a broader array of platforms with consistent behavior and deep linking, posted to www.pathway.cs.cmu.edu/2008Pathway.

The corpus began with one expert and 120 recorded responses before 2006. Feedback from users expressed a desire for more content and more authorities to question to get a broader representation of opinions. Three additional master physics teachers known for their success in the high school classroom were recruited by the KSU Physics Education Research Group: Leroy Salary, Roberta Lang, and Charles Lang. These four have been available in the Pathway interface since late 2006. Note that not all four have recorded video answers to all of the target areas produced by the KSU Physics Education Group. In particular, during 2007 numerous targets were added to cover other areas of physics such as uniform circular motion and thermal physics, but Paul Hewitt was not recorded again to get answers to these targets. Furthermore, some master teachers might bundle a number of targets in their video answer, e.g., Chuck Lang has two different answers for the two targets "How should I teach projectile motion?" and "What are some good examples of projectile motion?", but another teacher may answer both these questions with the same video response. Each target response identified by KSU is answered by at least one teacher, perhaps many. Each video answer from a teacher covers at least one target response, perhaps more. From the user's input, the target response is given from a search service which indexes various ways of stating questions per response.

A combination of physics pedagogy domain expertise and automated tools to multiply a few ways of stating a question into numerous possibilities were used to grow the index of question variants. For example, the two variants "How can I teach students to add perpendicular vectors?" and "How can I teach students to add vectors that are at right angles?" both map to the same target response. As question variants increased in the search index, the target space of responses grew as well: more interview answers were collected, especially for Charles and Roberta Lang. The corpus now boasts 450,365 question variants mapping to 6,598 unique responses, which each are covered by one to four master teachers in 7,600 video answers.

3.2. Lessons from teacher workshops

The first and easiest lesson from early teacher workshops pertained to coverage and diversity. Teachers needed to have more of the high school physics curriculum covered, and work is ongoing to grow Pathway to address waves, sound, light, optics, nuclear physics, and other areas of importance identified by national standards and teacher input. The availability of more than one SI master teacher lets the user contrast opinions given on questions of pedagogy, collect additional examples and insights for particular problem areas, and make use of a master teacher for which the advice resonates particularly well.

An analysis of the questions also helps to understand the type of content in which teachers are interested. The first 2500 questions logged from teacher workshops were classified by hand, showing only 11.6% about physics content (e.g., "What is light year?", "What is inertia?") while 70.5% asked about various issues of physics pedagogy (e.g., "When do you introduce momentum?", "How do you teach gravity?"). This result indicates the inexperienced teacher is much more interested in and concerned about the methods of teaching rather than the physics subject matter. Also, less than 1% of the teachers requested information about assessment (e.g., "What assessment techniques can I use to measure understanding of Newton's laws of motion."). Only a small number (1.4%) has asked questions related directly with student engagement in hands-on activities (e.g., "activities to introduce acceleration"). These small numbers for assessment and activities require some further investigation. Both areas are very important to contemporary teaching techniques [5]. It may be that activities and assessment are embedded in some of the other pedagogy questions. If not, future work with Pathway may need to focus on helping the inexperienced teachers see this importance as they develop into experienced teachers.

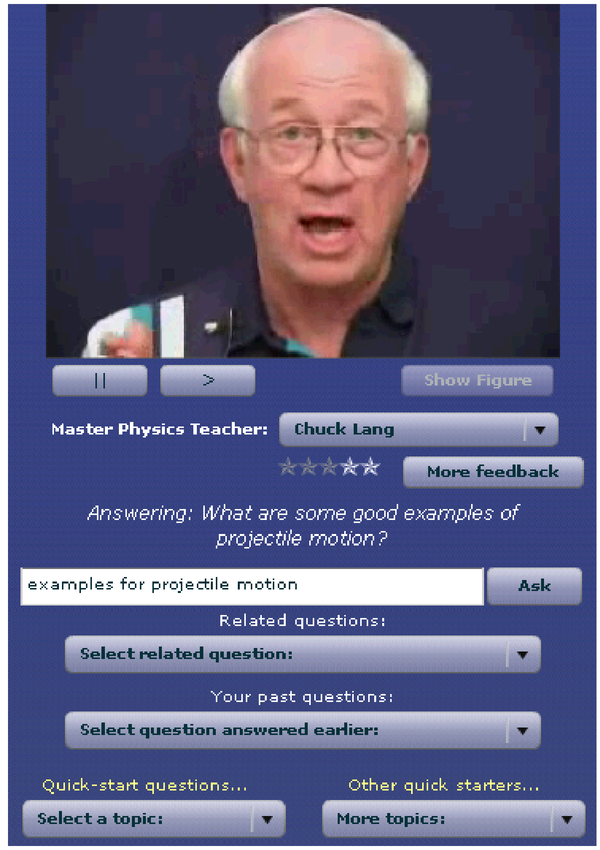

Figure 2. Latest Pathway SI interface incorporating updates discussed in Section 3.

To also maintain the illusion of an interview, the SI master teacher needed to respond to the questions not yet covered in the indexed target responses. Videos were recorded for each teacher for specialized situations to redirect the user, e.g., "Please rephrase the question" for questions not understood, and "Let's stick to physics" for irrelevant or irreverent remarks. In this manner, user input always generates some action by the interviewee. Even with a preponderance of teachers as sources of the analyzed 2500 questions, there were 6% of irrelevant questions needing a pooled response. With the system available on the open web, we witness much more "playfulness" as well as irreverence or outright hostility in the web users' questions to the Pathway SI. This is fully expected based on other fielded SI systems. For example, with a commercial sports celebrity SI, 188,304 queries were logged in a two month period. Of these queries, 2,806 (1.5%) were tagged as inappropriate, containing vulgar terms or otherwise obvious irrelevant remarks. Outright irrelevant questions historically have been captured quite well in SIs through word-spotting. Particular words are considered racist, sexist, or offensive in some regard, and if spotted in the query cause an override of the search service tf-idf index lookup to instead note the query as inappropriate. For Pathway, the recorded response to inappropriate queries is the redirection comment of "Please stick to physics" or "Let's focus on physics."

To date, we have not seen an abuse of the system in staying with such inappropriate queries. Web users seem to test the capabilities of the SI once with respect to offensive terms, note the response, and stop such lines of inquiry. More targeted, responsive action could be taken if the situation persists by leveraging session context through IP address or cookie identification to note that a user is continuing offensive lines of inquiry. The second response could be a more forceful video from the SI stating that such queries will not be tolerated and only physics topics will be discussed, with the system eventually locking down and not responding positively to the user unless some stated reset procedure is followed. Such draconian measures have not been needed, in part because Pathway is geared toward high school physics teachers and is not a general web entertainment site.

3.3. Pathway SI interface enhancements

Pathway users are more likely to test the boundaries of the system rather than persist in offensive lines of inquiry. For example, a user asks "What color is my dog's nose?" Obviously, the Pathway site is not a generic ask-anything site, but what has proved useful is a redirect of the irrelevant questions like this one into the domain of discourse that is understood by Pathway. Users, instead of leaving the site with the opinion that it covers little, instead are informed of what conversations with the Pathway teachers will be fruitful. Now at over 450,000 question variants, there are many possibilities for overlap between the indexed question variants and user's input, and we rely on the search service to return the top-rated response for the user's question. In this case, the question produces a video answer to "What are the common problems in teaching color?" A label stating what is being answered informs the user of our example that in fact it is "color" that is being discussed. Should a teacher ramble a bit, or cover a few target topics in a single video response, the label serves to let the user know that the listed question will eventually get covered in the reply.

The out-of-vocabulary words are also listed, so that the user knows to stop trying to ask about dogs or noses for example but can issue many queries on color. Common words like "is" and "the" are treated as stop words and never listed as out of vocabulary (shown in a "Words I don't understand" label) while also carrying no weight in the search service behavior.

Early users of Pathway were often ambiguous in their queries, entering single words 8% of the time. Such ambiguity led to disappointing results at times: the user wanted for example "How can I demonstrate color?" with the query "color" but instead received an answer to "Should I teach color?" Tweaking the search engine to improve the precision-at-one (the correctness of the top-ranked response) is an option, but unlikely to succeed when the query is underspecified. Rather, we expanded the interface (see Figure 2) with a "Related questions" pull-down menu that was based on context. Following a query, the ranked responses for the next 5, and then as the corpus grew for the next 9, were listed in the pull-down menu. This interface feature allows the metaphor of the SI to be retained – one question generates one response – while allowing for quick redirects of the conversation to related areas by the user.

A major remaining problem, especially with out-of-field teachers new to physics, was prompting the user for interaction with the Pathway SI. One means of prompting was provided by having 4 different people to talk with, while another was expanding their domain of discourse. A third is "quick questions" launching points identified by KSU physics pedagogical experts. Without having to think of a query, a new user can start exploring the system. Issuing a quick question brings up a video response, while populating the related questions list for continued branching and exploration into the video corpus.

4. CONCLUSION AND ACKNOWLEDGMENT

Overall, experiences to date indicate that Pathway has shown that the concept of engaging inexperienced physics teachers in a virtual dialog for continuing education is well received. Both the general approach and the specific answers to questions meet the teachers' needs and provide information in a comfortable format that enhances their knowledge of physics and physics pedagogy. The driving goal of the Pathway project is to be able to continually improve quality of knowledge available to physics teachers which will translate into better education for their students. This material is based on work supported by the National Science Foundation under grants ESI-0455813 and REC-0632657.

REFERENCES

[1] American Physical Society. High School Physics Teachers in Short Supply. *APS News 9(*3), March 2000.

[2] H.D. Wactlar, et al. Lessons Learned from Building a Terabyte Digital Video Library. *Computer* 32(2), Feb. 1999, pp. 66-73.

[3] M.G. Christel et al. XSLT for Tailored Access to a Digital Video Library. *Proc ACM/IEEE JCDL 2001*, pp. 290-299.

[4] S. Stevens et al. Virtual Pedagogical Agents as Aids for High School Physics Teachers. *Proc. Conf. on Interactive Computer Aided Learning* (Villach, Austria, June 25-29, 2007).

[5] E.G. Corpuz and N.S. Rebello. Hands-On and Minds-On Modeling Activities to Improve Students' Conceptions of Microscopic Friction. *Proc. Physics Education Research Conference* (Greensboro, NC, August 1-2, 2007).