Students in AWE: changing their role from consumers to producers of ITS content

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Abstract. We describe an authoring environment for an intelligent tutoring system and report on its successful use by fifth grade students. This research places students in the role of content authors for ITS and supports them to share their creations and discuss their use, bringing both students and teachers into the tutoring system development loop. The potential of the idea of students as authors is great. It provides a way to reduce development costs and to facilitate a school's adoption of ITS technology. It also provides a medium to pose word problems (and thus follow state-of-the-art educational theories) and integrate math, science and narrative. It is feasible and accomplishable, as students are willing and excited about doing it. It opens many other possibilities, such as providing a window to students' perceptions about student modeling and the misconceptions and cognitive processes underlying problem posing. The Internet-based authoring environment is titled Animalwatch Web-based Environment (AWE), and it supports creation of content for the Animalwatch mathematics Intelligent Tutoring System.

1. Introduction

A major burden in the development of Intelligent Tutoring Systems is content creation. A large amount of content is needed in an ITS to provide appropriate instruction, particularly because the system will individualizing tutoring for each student. If the pedagogical module concludes that a student would benefit from a problem of a specific difficulty level, then such problem should be available to the student. This is one major cost of having an adaptive system. If the system has run out of problems of that kind, then the benefits of intelligence in ITS are diminished.

Authoring tools have been developed as a way to reduce costs in intelligent tutoring system development. Murray [00] classifies authoring tools into several categories, including generic, which allow for the creation of tutoring systems in any domains, and specific, which allow for the expansion of a specific and existing system into a related domain. Many different people may author content with specific authoring tools, that is to produce content to enhance an existing system. Should the authors be system designers, domain experts, or the end users? Ritter[98] presents an authoring tool called pSAT to create problem sets for the PAT Algebra Tutor. The authoring tool is aimed for teachers. Thus, pSAT is an attempt to encourage a division of labor in the development of ITS, as authoring can be done by those in daily contact with the student.

Having teachers author content seems promising, as it supports teacher "adoption" of ITS. Bondaryk [98] talks about this as "the adoption process of media materials," which requires instructors to be aware of and willing and able to use them. Because computer tutoring involves mainly the student and the computer, teachers tend to be out of the loop. It is important that teachers feel comfortable with ITS and appreciate them as tools that will help them with teaching. Otherwise, teachers will not feel like using them in the classroom. Thus, having teachers author content seems appropriate. The main disadvantage of this approach is that teachers are extremely busy people, and the authoring process implies putting another burden on them instead of easing their load. This is enough to prevent teachers from using such content authoring tools, even if they think they would like to do it.

Instead of having teachers become content authors, we propose to have students create word problems with the guidance of a teacher. After all, problem posing is of central importance in the discipline of mathematics and in the nature of mathematical thinking. The National Council of Teachers of Mathematics of the United States has recently called for an increased emphasis on problem-posing activities in the classroom, encouraging teachers to "formulate problems from situations within and outside of mathematics" [NCTM standards, 1991]. Some experts say that problem solving consists of successive reformulation of an initial problem [Polya, 54], so both posing and answering are important parts of the problem-solving process. As a result, teachers encourage K-12 students to pose word problems, claiming improvements in students' problem solving as a whole [Larkin, 86]. Because of the recent appearance of such methods, little is known

about the nature of problem posing as a cognitive process, only few people have done research on students' problem posing [Silver, 96].

Having students author word problems implies a change in students' role, from consumers of word problems, narrative and science topics to a role of producers of this same content. Students as authors are not thinking about themselves only, but about others, the final users of their productions. As authors for ITS components, they assume the roles of educators. Kafai [96] had children design educational video games to teach fractions to younger children. She worked with them in a 6-month period of time. She claims that students learned not only through design, but also about design, and that they reached a level of reflection that went beyond traditional school thinking and learning. However, because of the complexity of the software they designed, they never finished the actual implementation of their games. One child commented: "... I started out with very high expectations thinking I could make a great game in a very short time. It turned out that I am still not done with it even after 4 or 5 months". It would be interesting to have a tool that allows children to create their own mathematics educational games easily.

This paper introduces an on-line environment called Animalwatch Web-based Environment (AWE), an on-line content authoring environment that supports the creation of word problem "adventures" for a mathematics ITS, called Animalwatch [Beal and Arroyo, 01]. AWE lets users author new material for the ITS, share their creations, produce comments about them, and in general collaborate with each other to enhance the content of the Animalwatch ITS. AWE was used with students in the classroom. This paper will present qualitative results of a 3-hour pilot study performed with 5th grade students authoring "endangered species mathematics adventures" with AWE. A videotape of the experience will be shown if this paper gets accepted.

In addition to describing AWE, this paper intends to demonstrate that the idea of having students use authoring tools to produce content for ITS systems is: 1) a way to facilitate schools adopt ITS technology; 2) a way to make ITS more interesting for students while still keeping the benefits of intelligent tutoring, as they are -in part- creators of the ITS; 3) in the case of Animalwatch, a way to have students integrate math, science and narrative; 4) feasible and accomplishable, as students are willing to do it, able to do it, and also proud of it; 5) a way to reduce development costs; 6) a door that opens to interesting research work.

2. Animalwatch

Animalwatch is a mathematics Intelligent Tutoring System (ITS) for 9-12 year olds. Animalwatch teaches mathematics with word problems, which are integrated into narratives about endangered species, to engage student interest and help them appreciate the value of learning mathematics. Thus, it integrates mathematics, narrative and biology [Beal, 00]. Animalwatch provides instruction in the mathematics topics most often taught in American fourth, fifth and sixth grades: whole number operations (addition, subtraction, multiplication and division), introduction to fractions, and addition and subtraction of like and unlike fractions.

Animalwatch has a large database of word problems. The ITS takes the student through a series of word problems that it dynamically chooses from this database, based on students' knowledge of the topics. In order to do that, the ITS maintains a Bayesian *student model* and makes inferences about the student's knowledge as s/he solves problems. Animalwatch increases the difficulty of the problems it gives depending on the student's progress, going from simple whole number addition problems to problems that involve fractions with different denominators. Animalwatch also customizes the help it presents when students make mistakes, providing hints with little information first and more structure and interactivity later.

Students log onto Animalwatch, choose one story about different endangered species (also known as an *adventure*), and then goes through a sequence of stages (or *episodes*) in the story. At the beginning of each episode they are greeted with a personalized letter (e.g., inviting them to serve as a wildlife biology consultant who will help to assess the status of the species by doing research in the National Oceanographic Library). Animalwatch shows the student a word problem that fits the narrative situation of the *episode* in the story. For example, a student working in the "library" episode of the Right Whale adventure might be presented with a book containing information about the average distance traveled per day on the whales' annual migration down the Atlantic coast, and

a problem that fits that context. Each problem is accompanied by an image that serves as an illustration, or that presents information needed for the problem such as a graph or a chart. The content information represented in the word problems is as accurate as possible: sizes and weights of the animals are within known ranges, related historical and geographical information is correct, and so on.

Animalwatch uses heuristics to present problems of appropriate mathematical difficulty, given the system's estimation of the student's mathematics knowledge. Once the student provides the correct answer to a problem, the system gives another problem, which has to be one previously unseen by the student. Animalwatch looks for a suitable problem, it switches to the next stage of the story, where an appropriate problem for this student should be available. These requirements generate a combinatorial explosion in the number of problems needed in the ITS: the system needs to have at least one word problem for every possible combination of topic and episode and problem difficulty (we currently have 700 word problems for 3 hours of instruction). Because if the student finishes all stories it is unlikely he would like to go through a story again, many word problems are never seen by the student, as "hard" problems will most likely not be seen in the first episode of the first adventure the student goes through. The task of creating content was one of the most tedious parts of the production of Animalwatch. Animalwatch has shown to be effective in reducing students' mistakes [Arroyo, 00] and also improved student's attitudes towards mathematics: mathematics ability self-concept, mathematics value and mathematics liking were increased [Beck, 99].

3. The Animalwatch Web-based Environment (AWE)

AWE allows us to bring the ITS to the general public. People can download the system for free, contribute and share content through the web site, and provide comments and feedback to each other and to the ITS developers. The ITS turns into a customizable tool which can enhance their curriculum across multiple areas (as adventures don't necessarily have to be about endangered species). AWE was not designed for children; it was originally thought for teachers and parents [Arroyo, 01]. Yet, AWE provides a medium of communication among Animalwatch users, content authors, and system developers, so that they can all give feedback to each other about their contributions. The next sections describe how AWE provides the required tools for this community to interact.

3.1 Interacting with AWE

The creation of adventures. Users create new adventures, which are complete stories about an animal, or add a story related to some existing theme. Authoring an adventure includes giving a name, a description, and uploading an image icon for an adventure. The web page administers each user's adventures, as shown in Figure 1. However, only the icon and the adventure's name is seen in this screen at this moment, as episodes (various stages of the adventure) still need to be defined for the adventure. After adventures and episodes are created and word problems defined, the adventure can be downloaded and used in Animalwatch. The user saves the file in the "adventures" folder and the next time Animalwatch is run the new adventure icon will show up as one of the available adventures. It is important to note that the intelligent engine in Animalwatch will still function with the new adventure, both for problem and hint selection.

The creation of episodes for an adventure. An adventure consists of a sequence of episodes. The user can creates the next episode. Defining an episode includes entering the name of the episode, and also defining an introductory screen with the text and image that the end-user will see during episode. Figure 2 shows an existing introductory screen in the Animalwatch ITS.

The word problem authoring tool. The author can create a word problem for an episode, Figure 3. The authoring tool is very simple, so that the cost of authoring is minimal. The author uploads an image to go with the word problem, enters the text of the problem, and specifies what operands and operation are needed to solve the problem. The author is the owner of this word problem, and only him/her is allowed to alter it. The user can access a personal space where he can administer his own word problems: delete them, modify them, etc.

Participation: Polls and comments. Surveys and polls in the web site serve to analyze the users general interest for new adventure themes and need for improvements in the ITS behavior or the web site. Comments are be posted at different levels. Space is available for comments about

Animalwatch and each adventure, episode and word problem in particular. When a user posts comments on a word problem owned by another person, the latter person receives an e-mail noting that a comment has been posted for the owned problem.

Figure 1. Administering a user's adventures. "Meet the Cheetah" episode for the "Expedition on Cheetahs" adventure.

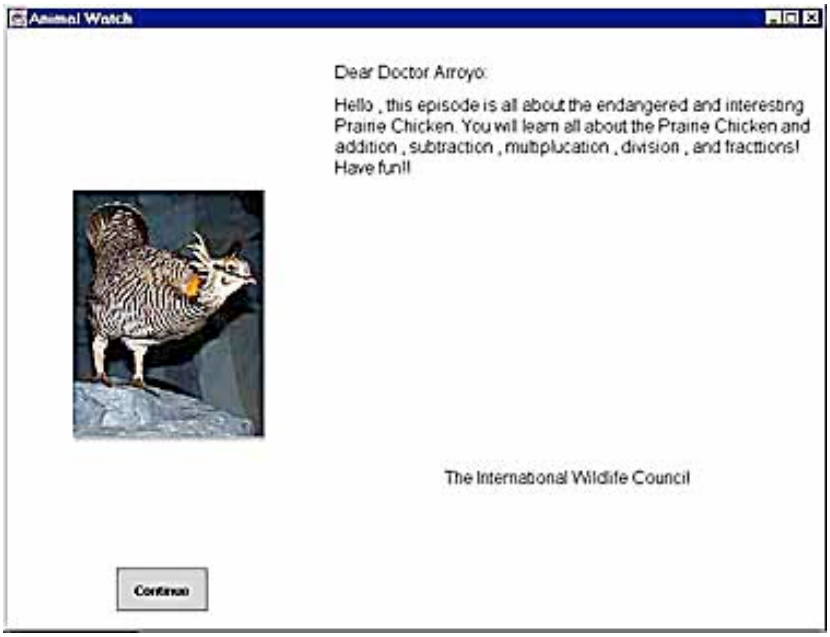

Figure 2. Introductory screen for the "Meet the Prairie Chicken" episode of the "Prairie Chicken" adventure, running inside Animalwatch.

Browsing the adventures. The user browses through authored adventures, episodes and word problems. Figure 4 shows a word problem for the “Peregrine Falcon” adventure on the web site. Users insert comment for this Peregrine Falcon word problem and provide a rating from one to five stars for the adventure. New users may decide to download specific adventures to run, and not run others, depending on the user ratings and user comments on each adventure.

3.2 From AWE to Animalwatch: the architecture

As mentioned before, Animalwatch runs as an offline application and can be downloaded from AWE in two steps: first, the user downloads the Animalwatch program. Then, the user downloads individual adventures. In this way, Animalwatch's content is independent from the core ITS. Each adventure consists of a zip file where the images and word problems are packed together. Animalwatch reads in all the adventure zip files at runtime from a specific folder, retrieving word problems and images for the user to see. AWE is a relational database-backed web site, running the MySQL RDBMS on the server side. AWE dynamically generates web pages using the PHP scripting language and querying a MySQL database. This way, the system can keep track of users, word problems, comments, poll results, adventure ratings, etc. Because adventures are created online but the Animalwatch ITS application runs offline, there is an integration of on and off line technology.

4. Evaluation of AWE

A pilot study was performed with six 10-year-old 5th grade students in a rural area of Massachusetts. The main goal was to evaluate the feasibility of having students create an adventure through the AWE web site. We wanted to check whether young students would be able to handle the level of abstraction that authoring implies. We also wanted to evaluate how challenging was the idea of posing word problems. The last objective was to see how motivating this activity was. It is important to note that AWE was originally not designed for children, rather for teachers and parents; so the interface is not child-appealing. We were concerned that children might not be able to cope with the AWE front-end.

Only a limited amount of time was available (two days, one hour each day). Students first used the existing mathematics tutor, Animalwatch, and then created new animal adventures for an endangered species that they had researched. They worked on one episode, created word problems for it, and then download their own adventure. They used existing Animalwatch adventures for about half an hour and then were told that they would create an adventure similar to the ones they had seen by going to the AWE web site. The children were guided at each step in the creation of their adventures, which implied defining the adventure, defining one episode for it, and defining addition, subtraction and multiplication word problems. They did not have time to create word problems for topics harder than multiplication. Students were given a short questionnaire at the end of the experience, and were videotaped and interviewed. Both the questionnaire and the interviews consisted of questions about what had been the best and the least favorite part of the experience, whether they would use it from home and whether they learned any mathematics or biology.

5. Results of using the Authoring Tool

Students had researched one endangered species on the Internet with their teacher. They came to the Animalwatch session with what we called “number facts” about the animals, which consisted of actual numerical data about the animal, such as *“Orangutans may live 35 – 40 years in the wild. They are 8 times as strong as the average human male.”* Students then began authoring their own adventures. They understood what an adventure was, since that they had gone through at least one adventure in Animalwatch before.

Students authored one episode for their adventure and called it something along the lines of “meet the <endangered species>". This included providing introductory and end screens for each episode, with images and a messages for the user, such as the one in figure 2, for the Prairie Chicken adventure. Students then authored addition, subtraction and multiplication word problems related to the number facts that had collected for their species. For example, a word problem created for the “Peregrine Falcon” adventure can be seen in figure 4. This screenshot resulted from a person browsing the adventures and word problems in the AWE web site after authoring. Students created word problems without major difficulties. They clearly had the ability to create problems for harder mathematics topics, but the time available for the study was too short to continue authoring.

Students understood the relationship between authoring an adventure in AWE on one hand, and solving word problems in Animalwatch while playing the role of a student, on the other hand. They were able to switch contexts easily. They also realized the collaborative potential of creating adventures: they realized (without being told) that other people could use the adventures they authored. They realized that they could continue their production of math problems on the Internet at home. Also, they felt proud of their productions, of their role as authors, and of the possibility of

other people valuing their creations. Creating word problems made them think about the nature of mathematics word problems, such as what things can be added and what things cannot.

Teacher supervision of the resultant word problems is obviously needed. Sometimes, students had misconceptions. For example, one student authored the following problem while trying to create a 175+175 problem: *A falcon can fly at 175 miles per hour. How fast can two falcons fly together?* The major misconception in this problem is that two falcons will still be flying at 175 miles per hour even if they are together, because speed does not add up in this case. This makes us believe that there is room for discussion with the teacher and/or classmates about how mathematics fits into real contexts created by the students. It also makes us believe that there are things to learn from the act of children posing problems.

Authoring word problems also implies formalizing equations for problems. Sometimes, even though the students knew the solution to their problem, they found it hard to formalize the equation that would solve the problem. For example, one student wrote the following: *95% cheetahs live on commercial farms. If 95% of all cheetahs live on commercial farms, how much of the percentage don't live on commercial farms?* This student knew that the solution to his problem was 5, but the asked for help because he was thinking of the problem as 95 + x = 100 (even though he did not go as far to formalize it this way), and he was struggling to transform it into 100 - 95 = x, the equation form that AWE was expecting. At this time students had not yet been introduced to the concept of equations and their properties. Thus, authoring word problems with AWE placed a student in a context where he *needed* more advanced topics for what he wanted to accomplish. The student needed algebra and had not yet studied it, thus, it opened a door to harder topics.

After one hour creating word problems, students downloaded their own and other student's adventures and saw them in action within Animalwatch. At the end of the evaluation study students were interviewed. Table 1 summarizes the frequency of different comments collected from the verbal interviews together with the written questionnaire that some of them finished. Comments fell into the following 14 categories:

A. Student was proud about the creations and about them being published in hyperspace: "our stuff is on the web!"
B. Student was excited about sharing creations with others through the web.
C. Creating adventures was fun
D. Because he already mastered the mathematics topics he is authoring, he didn't feel he learned much about mathematics by authoring.
E. Creating word problems is easy if you have enough number facts about the animals
F. "I cannot believe I have done this"
G. Hardest thing was creating word problems
H. Coolest thing was creating word problems
I. Creating word problems is easy after you get the idea
J. Hardest thing has to do with technical or interface issues (downloading, etc)
K. By using the Animalwatch ITS, I got problems on fractions, a topic I am learning at the moment.
L. Student continued working on authoring at home by his own choice.
M. Concerned about not having finished the adventure
N. Coolest thing was finding the pictures to go with the problems

	I	A	D	B	H	K	C	G	J	N	E	F	L	M
Casey	X	X		X		X	X	X		X			X	
Elizabeth	X	X	X	X	X	X	X	X						
Cambrian	X	X	X	X	X	X	X		X					
Michael	X	X	X		X	X	X		X		X			
Justin	X	X	X	X	X			X				X		
Jonas	X	X							X	X				X

Table 1. Occurrences of comments made by students (blanks correspond to missing values)

6. Discussion: the potential of students creating word problems for an ITS

Having a system that allows children to author mathematics word problems for an ITS opens many doors to new research. Some of these potential contributions have to do with students' learning

about the domain. In this particular case, children discuss what makes a good word problem and what makes a problem correct or incorrect. This is facilitated by the collaborative nature of AWE, where students can assign comments to specific problems. This supports the teacher's role as a mediator in discussions and as a guide. In addition, children are immediately talking about the nature of mathematics, (What are things can be added? What does it mean to multiply? What is a fraction?), and in particular about mathematics integrated into a real context, (What are interesting mathematics questions that are worth asking?). Also, by authoring word problems, students have to formalize equations from their written problems, which can push students into more advanced knowledge.

Other contributions have to do with the integration of other subject domain beyond the domain being tutored. There is plenty to think about when deciding the narrative structure of the adventures. Students have to define different episodes, so they may discuss in class about how a story should be structured (what makes good stages in a story? what's the climax?) similar to the work done by Machado and Paiva [01]. Students are learning about the endangered species that is featured in their stories. Moreover, there is room for the inclusion of other subjects such as social studies (for example, one of the episodes may be about the place where the endangered species live and the history of the place). Teamwork can also be developed around this kind of authoring, because of its collaborative nature. Children may be assigned to work in teams to build a whole adventure and split the work for different episodes or different topics, as AWE allows different users to collaborate in one same adventure.

Still other contributions have to do with students' emotions in relation to authoring and tutoring. Students perceiving themselves as authors feel proud for the owned and published work. Students were amazed that their creations were inside of the tutor. What's even better is that this motivation happens without sacrificing the intelligence in it, as Animalwatch keeps selecting problems and hints intelligently in student-created adventures. It also turns into something to share with friends and family thanks to the availability on the Web. Last, students enjoy the change in their role, as they are turned into teachers who are generating problems for other kids who don't know about these topics that they already master.
Some of these contributions have to do with students' perception about Intelligent Tutoring Systems. Having students be part of the development loop brings about their expectations about ITS behavior. For example, some students were disappointed when they realized that not all their word problems were showing (because of the problem selection mechanism). They were ready to start talking about what they would have liked the system to do, or what they thought that would be beneficial for other students, or what kind of help they would have liked to get, opening a window for studies similar to those done by Hammerton and Luckin [01].

A system such as AWE provides a link to different communities. While doing a workshop on Animalwatch for pre-service teachers, one of them stated that she was afraid that, due to such computer programs, teachers would not be needed any more. These feelings are understandable, as there is generally not a clear role for teachers within the ITS tutoring process. There is a clear role for the teacher in this process of authoring adventures, as guides in the problem authoring process. In this scheme, teachers may step aside when students use the ITS, but later on, when having them author, they still teach students about teamwork, about how to perform Internet searching activities, and they have plenty of opportunities to lead deep discussions about word problems and math. The teacher whose students we worked with was so excited about the work the kids had done that invited us to present students' work in a school fair for parents.

Finally, besides the intelligence in problem and hint selection available in the Animalwatch ITS, there is room for intelligence in the AWE authoring tool. Students would really benefit from some kind of agent that helped them in the creation of word problems. This may imply first understanding what the cognitive processes underlying problem posing are, what students' misconceptions may be at creating word problems. Analyzing students' posed problems is an opportunity to understand those underlying cognitive processes.

7. Summary

This paper described the Animalwatch Web-based Environment (AWE), an on-line authoring environment to support a community of users of the Animalwatch mathematics Intelligent Tutoring System. Instead of having teachers author word problems for the ITS, we had students author them,

share their creations and discuss its use. Students created and shared adventures through the AWE web site. They easily managed the level of abstraction that authoring implies. Students created correct word problems most of the time, but sometimes made mistakes. They enjoyed posing word problems even if they found it difficult. They enjoyed the whole process, and felt proud of their work.

The potential of the idea of having students author word problems is large: it is a way to facilitate schools adoption of ITS technology. While children are authoring word problems, teachers have a clear role and must accompany students: however, when the tutor is used, teachers usually step aside. As a medium to pose word problems, this authoring activity follows state-of-the-art educational theories. AWE is an across-subject tool, as it integrates math, science and narrative. AWE allows reducing the huge load of content creation. AWE is feasible, viable, and accomplishable, as students are willing and able to create adventures with word problems in them. Having students author content opens up many research paths, such as a window to students' perceptions about student modeling, and the misconceptions and cognitive processes underlying problem posing.

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