

# Cooperatively created On-line textbooks with randomly generated assignments

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**Abstract-PathFinder is a developing online entity that will ultimately combine aspects of on-line referred encyclopedia, online-textbook creator, and online exercise generator/administrator/scorer. It is written in html, asp.net 2, C#, JavaScript, xml, and mathML. Professors can collaborate to create on-line textbooks with automatically graded exercises. PathFinder has been used in three different courses in the Civil & Environmental Engineering Department at Rowan University. In each course PathFinder was used to administer multiple choice and calculation exercises. Multiple choice exercises made up Preparation Assessment Tests (PATs), used to get students to read course materials before covering them in class. Calculation exercises were used as homework (HW) to provide students with practice related to the methods introduced by the course. PathFinder was also used to deliver an e-textbook in one course. Evaluations of PathFinder can be based on keystroke activity recorded as students use PathFinder, scores on PATs and HW, scores on tests, and surveys of students. The purpose of this paper is to describe PathFinder and present the results of evaluations of textbook and exercise features used in Civil Engineering Systems in Fall 2008 and 2009. Fall 2008 results indicate that there is little difference between PathFinder and traditional assignments regarding grade outcomes. Results of student evaluations from Fall 2009 indicate that students are favorably disposed toward PathFinder. PathFinder saves class times by allowing PATs to be completed outside of class. It saves instructor time by scoring PATs and HW automatically. Copying opportunities are reduced because each student is assigned different problems.**

**Index Terms-On-lineTextbook, On-line Exercises, Random Assignments.**

## I. Introduction

During a sabbatical in 2005-2006, the author started PathFinder, a developing online entity that will ultimately combine aspects of online encyclopedia

and online textbook with exercise generator, administrator, and scorer. It is coded in html, asp.net 2, C#, JavaScript, xml, and mathML. Content is stored modularly in txt and xml files. Current content includes units, variables, equations, definitions, articles, images, examples, exercises, etc. The modular nature of the storage allows content to be efficiently stored, used, reused, rearranged, reordered, and improved. Modular content storage will make for efficient collaboration, once PathFinder moves out of the Beta phase and professors from multiple universities begin to create and share content.

PathFinder has been used in three different courses in the Civil & Environmental Engineering Department at Rowan University: Civil Engineering Systems (CES, Fall 2008 and 2009), Environmental Engineering I (Spring 2009), and Freshman Clinic I (Fall 09). In each course PathFinder was used to administer multiple choice and calculation exercises. Multiple choice exercises made up Preparation Assessment Tests (PATs), used to get students to read course materials before covering them in class. Calculation exercises were used as homework (HW) to provide students with practice related to the methods introduced by the course. PathFinder was also used to deliver an e-textbook in CES. The purpose of this paper is to describe PathFinder and report the results of evaluations to date.

## II. Background

The Internet is well suited for storing, sharing, and organizing information. If stored in a modular way, this information can be easily used, reused, rearranged, reordered, and improved. Previous to PathFinder, the author and others developed the Garden City website that allowed faculty to coordinate multi-course projects.<sup>1</sup> Garden City was a virtual place where Civil & Environmental Engineering students could build infrastructure, from bridges to waste water treatment plants. Garden City used html, asp.net, and visual basic to create an active website where faculty could jointly post and review elements of student projects and students could find assignments and data and store reports. A

cohort of students could “work” in the same virtual city, using the same set of data and gaining an understanding of the “big” picture. Faculty could asynchronously add and share content, from data to project descriptions.

PathFinder is a website used to store knowledge in a modular fashion so that it can be easily accessed and assembled into online textbooks. One of the best known Internet “knowledge” sites is Wikipedia, an on-line encyclopedia with content contributed by anyone with access to the internet. Users self-police content. In January 2004, Wikipedia had 190,000 articles in the English language. Just over two years later, in April 2006, it had 1,080,000 articles. In December 2009 the number of articles reached 3,129,000. A study completed by the British journal Nature examined a range of scientific entries in Wikipedia and the Encyclopedia Britannica and found few differences in accuracy.<sup>2</sup> Because content on PathFinder is created by professors, it is expected that accuracy will be as good or better than Wikipedia.

A number of academics have begun to develop electronic textbooks. The EBONI project (Electronic Books ON-screen Interface), based at the Centre for Digital Library Research at the University of Strathclyde investigated the proper “look” and “feel” of an electronic textbook.<sup>3</sup> Evaluations conducted with university students and lecturers suggested that the onscreen appearance of information should retain some of the aspects of paper textbooks, but text should be “scannable”. Issues of concern include display technology, size, weight and ergonomics. According to Landoni et al., also participating in the EBONI project, e-textbooks should have a sense of directness, engagement, and text.<sup>4</sup> A sense of directness means that users feel that changes on the screen are the result of their actions. Sense of engagement is the level of interest the e-textbook engenders in its users. Sense of text is related to the reader’s understanding of the structural and semantic structure of the text. When reading paper books, readers can remember the position of text within a book and on a given page. Factors influencing a sense of text are page size, legibility and responsiveness while scrolling. In evaluating different versions of the same e-textbook, the authors found: tables of contents and indexes are essential features; a book template has to be used strictly; titles, pagination, typographical aspects have to enhance text readability and scannability; and visual clues should be used to aid the reading experience. Additional recommendations based on EBONI results were given by Wilson et al.<sup>5</sup>

- The reader’s progress through the book should be visible.
- A “cover” enhances the reading experience.
- Page length should be the same as a printed book.
- Images and diagrams are expected.
- Bookmarking and annotation should be possible.
- Color can be used to produce a consistent style.
- Multimedia and interactive elements are desirable.
- Abstracts and keywords help students find information.
- Hypertext must be used to enhance cross-referencing.
- Search engines should supplement primary navigation.

A number of these recommendations are incorporated in PathFinder.

Jamali et al. report the results of a survey of over 16,000 academics concerning e-books.<sup>6</sup> The two main advantages of e-books for students were easy access and searchability. Students appeared to favor e-books for pragmatic reasons, including avoiding the library and convenience, but search and copy/ paste procedures could generally be improved. The biggest problems were difficulty of reading them from the screen and poor printing features. Appleton reported on an evaluation of library oriented e-books at Edge Hill, a medium sized higher education institute in Liverpool.<sup>7</sup> Overall, approximately 90 per cent of the responses regarding e-books were positive, ranging from 92 % finding that “the speed of access to books is acceptable” to 73 % agreeing that “Navigation around NetLibrary is easy”. Of course, not all experiences with the e-books were positive. Negative comments included: “Reading electronic text puts a strain on the eye” and “I prefer to hold a printed book”. The overall positive experience led to embedding e-books within WebCT courses. WebCT is a software package (now called Blackboard) that helps professors add and maintain on-line content and interaction in courses. Appleton recommends that e-book promotion and embedding be customized and targeted at particular user groups.

Dong et al. adopted a Web-supported curriculum approach to make Earth system science education more accessible and exciting to students.<sup>8</sup> Based on student reflections, the authors conclude that Web-based instruction improved accessibility and dissemination would benefit wide audiences and the ability to convert theory to visualized and interactive

contents has great impact on learners' attentions and promotes their learning interests.

Ravid et al. describe a wiki-textbook that was developed collaboratively by faculty and students.<sup>9</sup> After two years, the wiki-textbook had 564 sub-chapters, co-authored by undergraduate and graduate students in over 20 classes in seven academic departments across three Israeli universities. Their purpose, achieved, was to apply the collaborative notions of wiki to that of textbooks and to explore empowering students and curricular subject matter through the realignment of power structures. Though not explored in detail, the authors suggest that the wiki-textbook could be a new textbook business model. They also acknowledged that the impact of the wiki-textbook learning environment was not assessed and that issues remain regarding the quality and validity of the information generated by wikis. Crestani and Melucci designed, developed and tested a tool for automatically authoring hypertexts from full-text documents, targeting textbooks.<sup>10</sup> The results of an evaluation of one of the hyper-textbook created by the project indicated that the hyper-textbook was more useful than the textbook.

Online homework is gaining in popularity and can be as effective as traditional homework. Kodippili and Senaratne tested MyMathLab (MML), software that creates interactive mathematics homework.<sup>11</sup> Seventy-two students enrolled in college algebra participated. There was insufficient evidence to claim that students completing MML homework performed better than the students using traditional paper-based, instructor-graded homework (at a significance level of 0.05). However, the student success rate (final grade of A, B or C) was 70% in the MyMathLab group and 49% in the traditional homework group. In another study, introductory physics students completed homework using either the Web or paper.<sup>12</sup> Performances on regular exams, conceptual exams, quizzes, laboratory, and homework showed no significant differences between the two groups. Students in an electrical engineering signals and systems course used online homework.<sup>13</sup> Student reaction was generally positive. Qualitative assessments indicated an increase in student learning and engagement. Instructor benefits include grading time saved, grading consistency, confidence regarding student accountability, and information regarding when and where students work.

This brief literature review indicates that exciting efforts are underway regarding online e-textbooks and assignments. PathFinder can be an important element of future efforts because it provides a way

for professors from multiple fields and institutions to jointly create modular content that can be easily rearranged into e-textbooks with automatically scored multiple choice and calculation problems.

### III. PathFinder

#### A. Content Areas

Knowledge in PathFinder is stored in content areas. A content area can cover topics that are broad (e.g., Engineering) or narrow (e.g. a composting windrow). At a minimum, a content area has a ca.xml file containing a name and definition, e.g., "Engineering" and "Application of science and math to solve problems". The ca.xml file can also identify other content areas that are "based on" or "lead to" the content area. Figure 1 shows examples of "leads to" and "based on" relationships. The content area at the base of an arrow leads to the one at the head. The content arrow at the head is based on the one at the base.

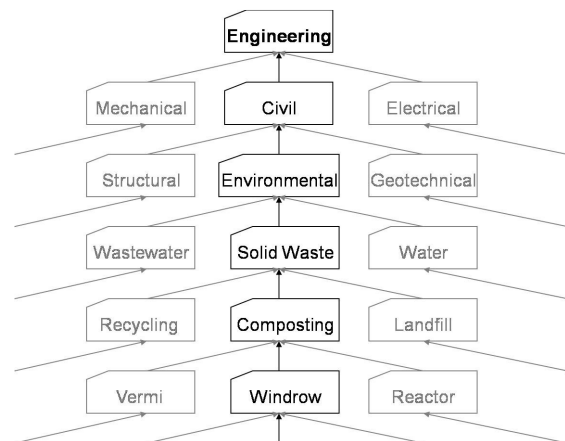


Figure 1: Leads to relationships

The "Windrow" topic in Figure 1 leads to an understanding of "Composting", so the Windrow ca.xml will identify Composting as a "leads to" content area while the Composting ca.xml will identify Windrows as a "based on" content area.

#### B. Navigation and Display

In a "based on" navigation tree, the Composting node (Figure 1) will have a Windrow child-node. In a leads to navigation tree, the Windrow node will have a Composting child-node. There is a fundamentally hierarchical aspect to PathFinder content areas. "Windrow" and "Compost" are general content areas, i.e., content areas that are used to describe a small amount of knowledge. PathFinder also uses special content areas to define units, people, and references.

Figure 2 shows the navigation (based on) and content trees for an unregistered user of PathFinder. The topic “Knowledge” heads the navigation tree, in the upper left. Five child nodes are shown. The “Engineering” and “Science” child nodes have their own child nodes: “Engineering Economics” for Engineering and “Mathematics” and “Economics” for Science. An understanding of science is based on Mathematics and Economics. Mathematics and Economics lead to an understanding of Science. To date, content areas in PathFinder have been added only in support of three courses, so large gaps in content remain. Unregistered users cannot access e-textbooks or scored problems.

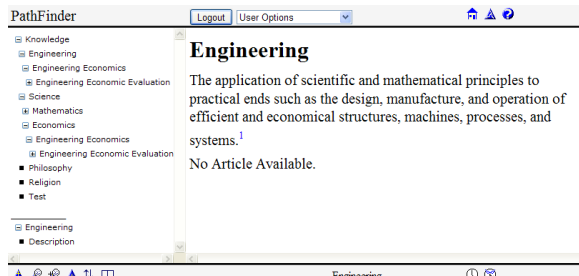


Figure 2: PathFinder with unregistered user

Navigation is accomplished by populating nodes to reveal childnodes. Clicking on node-text opens the associated article in the display area (right side of Figure 2). The display is created on the fly, by reading appropriate content area files. If an article is not available, a short definition is shown. The definition of engineering is shown because it is the selected node and no article is available.

The selection of navigation tree node-text also creates a content tree in the lower left (“Engineering” in Figure 2, below the line). Selecting any of the content types shown in a content tree displays them in the display area, i.e., the right side of the screen. The engineering content area only has a description (the definition). Each content area has its own folder for the storage of associated electronic files. Various content types are described in Table 1. A number of the content types are stored as txt files that contain html and PathML. PathML is a simple markup language created for PathFinder that is used to embed modular content, such as images, equations, links, and variables. For example, PathML in the Composting content area article could be used to display an equation stored in the Windrow content folder. The equation is only stored in the PathFinder system once, but can be displayed in any content area article using PathML.

Table 1: Content types available in PathFinder

Content Type	Description
Article	Short document describing a Content Area topic
Image	Visual content
Variable	Symbol and associated definition and units, e.g., F/Force/N (Newtons)
Equation	Mathematical combination of variables, recorded and displayed using MathML
Derivation	Combination of statements and equations that derive an equation
Example	Solved calculation problem visible to all users
Exercise	Multiple choice or calculation problem that is solved by user
Project	Word problem solved outside PathFinder
Study	Case study
History	Description of an event or person related to the content area
Reference	Description of a book, journal article, website used to provide evidence
Link	Hyperlink to external content
Audio	Audio content
Movie	Audiovisual content

### C. Multiple Choice and Calculation Exercises

The multiple choice and calculation exercises for a given content area are stored in an exercise.xml file. Multiple choice problems (Figure 3) are used to administer PATs. Calculation problems (Figure 4) are used to administer HW. The calculation problem in Figure 4 has a single step, but calculation problems can have as many steps as needed. Problems use randomly assigned input values and MathML equations to determine and display solutions. The equations and solutions displayed in Figure 4 are not images, they are real equations created on the fly using MathML, MathPlayer (a MathML plug-in for Internet Explorer), a Math parser developed specifically for PathFinder, and the randomly assigned input values.

The coding used in PathFinder to allow the creation of problems from modular information is described in the Appendix. This is included to demonstrate how PathFinder uses modular information, allowing for dynamic updates, asynchronous content creation from multiple contributors, and efficient use of information across multiple content areas and problems.

PathFinder problems are different from traditional paper assignments in a number of ways. First, each student can be assigned problems or, if the same calculation problem is assigned, different input values. Students cannot copy, as there is no one to copy from. A student can pay someone to complete their PathFinder work, but that is also true of traditional problems. Second, students obtain immediate feedback on whether they completed a

problem or problem-step correctly. Though not currently incorporated into PathFinder, there is no reason why feedback cannot include hints based on the specific answer and cumulative performance. Third, problems are linked to the appropriate section of the PText, allowing students to review material as they attempt a problem. Fourth, calculation problems can be linked to practice problems that student can complete without fear of losing points. Finally, instructors determine how many tries (and points) students get for each step of a problem.

Figures 3 and 4 also show PText navigation and content trees for the Civil Engineering Systems (CES) Fall 2009 PText. A PText is a PathFinder e-Textbook. A user can only access PTexts that have been assigned to them. PTexts can only be assigned to registered users. The nodes in the Navigation Tree (upper left of either Figure) are the chapters in the PText. Populating a chapter node shows the appropriate child nodes, leading to general content areas. Selecting a Chapter node opens a content tree (lower left) that, in addition to the typical content, also includes HW and PAT exercises. In Figure 4, the “Prob Dist” (Probability Distributions) chapter is populated and selected. A number of childnodes are shown. The content tree has six HW and six PAT exercises. Placing the cursor over a HW or PAT node displays its due date. Checks indicate which exercises are completed. A cross indicates an exercise was not completed before the due date.

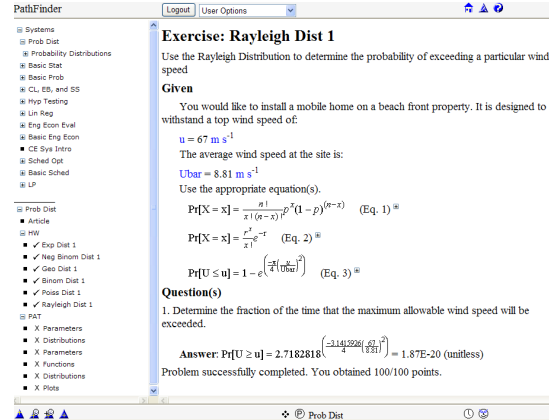


Figure 4: Calculation Problem

PTexts are created using a Class.xml file. It includes a name, description, chapter IDs, student IDs, and exercise statements that identify each HW and PAT. When PathFinder processes a Class.xml file it creates a PText.xml file for each student that includes the same information plus uniquely assigned input values for each calculation problem. The same file will also be used to store each student’s scores. Chapter IDs are used to create a PText navigation tree that points to chapter content areas. Student IDs in a Class.xml file identify the students in a class. Exercise statements identify the exercises in the PText. They also assign each exercise to a chapter.

#### IV. Evaluation

Evaluations were conducted in Fall 2008 and 2009 in Civil Engineering Systems (CES), a course covering Engineering Economics, Scheduling, Probability, Statistics, and Linear Programming (2009 only). This course is taken by students majoring in Civil & Environmental Engineering, including students emphasizing environmental engineering. In Fall 2008, two sections were taught, as the course was moving from the Junior to the Sophomore year and changing from 2 credits to 3. Because a number of topics were the same in each version of the course, a test of PathFinder was made. As only two sections were offered, it was not possible to attempt to match sections based on demographic characteristics or grade point average. Instead, the treatments were varied such that each section in turn was exposed to PathFinder.

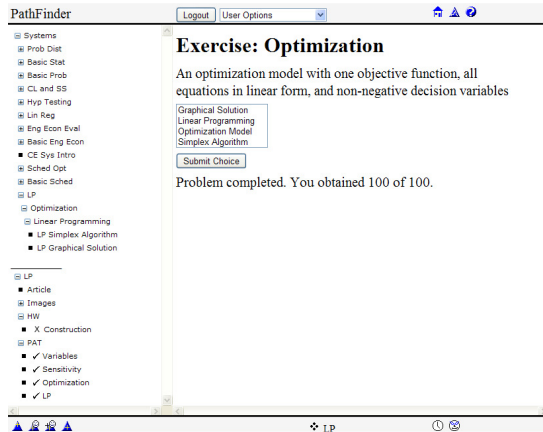


Figure 3: PathFinder Multiple Choice Problem

First, section A completed PATs and HW assignments on Engineering Economics using PathFinder, while section B completed PATs and HW assignments on the same topic in a more traditional manner. Non-PathFinder PATs were completed using clickers and traditional HW was completed on paper. Second, the two sections

switched on a second topic, Scheduling. Finally, both sections completed PATs and HW assignments on Probability and Statistics using PathFinder. The results are given in Table 2. Project assignments were summative in nature, requiring students to use skill developed in earlier homeworks.

For probability and statistics PATs and HWs, where both sections used PathFinder, there were no significant differences between average scores for the two sections. Where one section used clickers and one used PathFinder to complete PATs, the PathFinder sections scored higher ( $p < 0.05$ ). This is expected given that Students could complete PathFinder PATs at their own pace using the readings, while clicker PATs were conducted in class without access to readings. Results were mixed when one section used PathFinder and one used paper to complete HW. With the Engineering Economics HW, the students completing the paper assignment scored higher ( $p = 0.001$ ), while the students using PathFinder to complete the Basic Scheduling HW scored higher ( $p = 0.002$ ). When both sections completed a traditional HW after differing on PATs and previous HW (e.g., Engineering Economics Project, MS Project, Scheduling) no significant differences were observed ( $p > 0.05$ ).

Table 2: Evaluation of PathFinder in CE Systems, Fall 2008

Topic	Section A	Section B	Ave. Score A/B (%)	T-Test
<i>Engineering Economics PATs</i>	<i>Clickers</i>	<i>PathFinder</i>	62/75	0.04
Engineering Economics HW	Traditional	PathFinder	100/91	0.001
Engineering Economics Project HW	Traditional	Traditional	89/80	0.08
<i>Basic Scheduling PAT</i>	<i>PathFinder</i>	<i>Clickers</i>	81/56	0.00001
Basic Scheduling HW	PathFinder	Traditional	85/100	0.0002
MS Project HW	Traditional	Traditional	100/99	0.33
Scheduling Project HW	Traditional	Traditional	90/83	0.07
<i>Basic Probability PAT</i>	<i>PathFinder</i>	<i>PathFinder</i>	96/95	0.87
Basic Probability HW	PathFinder	PathFinder	97/97	0.82
<i>Probability Distributions PAT</i>	<i>PathFinder</i>	<i>PathFinder</i>	96/93	0.12
Population Problems HW	PathFinder	PathFinder	89/92	0.45
<i>Statistics PAT</i>	<i>PathFinder</i>	<i>PathFinder</i>	93/91	0.45
Probability Distributions HW	PathFinder	PathFinder	100/92	0.74
<i>Distribution Checking PAT</i>	<i>PathFinder</i>	<i>PathFinder</i>	85/74	0.17
Distribution Checking HW	PathFinder	PathFinder	97/100	0.15
Probability Distributions HW	Traditional	Traditional	87/82	0.26

Section A – Sophomore, 3 credits, 28 students; Section B – Junior, 2 credits, 32 students; T-Test: probability, two-sample, unequal variance.

This was even true of the summative project assignments. It appears that PathFinder is little different than traditional HW, as far as student grades are concerned.

Clear benefits are realized regarding class time, instructor effort, and copying. PathFinder saves class times by allowing PATs to be complete outside of class. It saves instructor time by scoring PATs and Homework automatically. Copying opportunities are

reduced because each student is assigned different problems.

Another way to evaluate PathFinder is to examine student perceptions. This is done for the Fall 2009 class, as a number of improvements were made between Fall 2008 and 2009. One significant improvement was the ability to add problems to a PText during its use in a course and the ability to change due dates. Chapters were added to PTexts and HW and PAT child nodes to Chapter content trees. These changes allowed for a much simpler presentation of PTexts and assignments, making it easier for students to use PathFinder.

In Fall 2009 PathFinder was used for all PATs (10) and 10 of 17 HWs in CES. Thirty-nine students took the class. Readings were made available in pdf form and on PathFinder as an e-textbook. At the end of the semester, an anonymous survey was administered to evaluate PathFinder. The results reported in the remainder of this section are from that survey.

Students found PathFinder a useful pedagogical tool. Only 6 % of students said they were not comfortable using PathFinder and only 15 % disagreed somewhat or strongly with the statement "PathFinder has the potential to be a valuable part of a college education". Seventy percent of students believed that completing PathFinder PATs better prepared them for class. As PathFinder is improved and students grow more accustomed to it, these numbers are expected to become even more favorable.

Students preferred completing course readings using handouts over PathFinder articles. Seventy-five percent of students completed readings using handouts; however, 48 % of students used PathFinder articles during the completion of at least 50 % of the PathFinder PAT problems. Thirty-three percent of students referred to PathFinder articles during the completion of at least 50 % of the PathFinder calculation problems.

Students found value in Pathfinder calculation problems. Seventy-three percent of students believed that PathFinder calculation problems helped significantly in preparing for tests, with another 19 % believing they helped somewhat. Fifty-four percent of students believed that PathFinder calculation problems were better or much better than traditional homework at helping them learn to solve problems. Another 31 % believed they were the same. Eight-two percent believed that PathFinder calculation problems were a reasonable component of course assignments, with an additional 15 % neutral.

Students in particular liked getting multiple tries at problems (88 %), immediately finding out if they completed a problem step correctly (83 %), and having links from problems to related content (73 %).

## **V. Conclusions**

PathFinder is a developing online entity that can combine aspects of on-line referred encyclopedia, online-Textbook creator, and online problem generator/administrator/scorer. It is written in html, asp.net 2, C#, JavaScript, xml, and mathML. Content is stored modularly in txt and xml files. Current content includes units, variables, equations, images, definitions, articles, examples, exercises, etc. The modular nature of the storage allows content to be efficiently used, reused, rearranged, reordered, and improved.

PathFinder textbooks currently include two types of exercises, multiple choice and calculation. PathFinder problems are different from traditional paper assignments in a number of ways. First, each student is assigned different problems (PATs and HW) or, if the same HW problem is assigned, different input values. Students cannot copy, as there is no one to copy from. Second, students obtain immediate feedback on whether they completed a problem or problem-step correctly. Third, problems are linked to the appropriate section of the PText, allowing students to review material as they attempt a problem. Fourth, calculation problems can be linked to practice problems that student can complete without fear of losing points. Finally, instructors determine how many tries (and points) students get for each step of a problem.

Evaluations of PathFinder in Civil Engineering Systems were presented here. Fall 2008 results indicate little difference between PathFinder and traditional assignments regarding grade outcomes. Results from the Fall 2009 survey indicate that students are favorably disposed toward PathFinder.

Clear benefits are realized regarding class time, instructor effort, and copying. PathFinder saves class times by allowing PATs to be complete outside of class. It saves instructor time by scoring PATs and Homework automatically. Copying opportunities are reduced because each student is assigned different problems.

Future work involves making PathFinder more user friendly for people creating content, exercises, and e-textbooks. Once this is completed, collaboration with professors at multiple colleges will be encouraged.

Content will be created to allow for PathFinder's use in more courses. Feedback mechanisms for calculation and multiple choice problems will be improved to allow the delivery of hints when students submit incorrect answers.

The evaluation of PathFinder will also continue, encompassing multiple sections of courses taught by different professors at different universities. Future evaluation should also investigate the level of effort required of professors that create PathFinder content and Textbooks.

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## Appendix – The Coding behind PathFinder

### A. Units, Variables, and Equations

Special content areas are used to define units, e.g., liters, meters and kilograms. The unit "liter" is defined in its folder using the xml  
<name>Liter</name><symbol type="normal">l</symbol> <type>unit</type><description source="Website" CAID="14" submission="1" Month="6" Day="25" Year="2008">A unit of volume equivalent to the volume of a cube with sides of 10 centimeters</description>. Each unit is given a name (Liter), symbol (l), and definition (A unit...). The definition source is also given. This unit can then be referenced, using PathML, by any variable, equation, or content area.

A general content area can have any number of variables. The content area "Concentration" has six variables. The first is defined using the xml  
<variable submission="1">  
<symbol type="normal">A</symbol><unit unitCAID="17" position="numerator"></unit>  
<unit>unitCAID="18" position="denominator"></unit></variable>. Concentration "A" has the units "moles/liter", from unit content areas 17 and 18, respectively.

Equations are stored and displayed using MathML and PathML. As an example, the MathML  
<reln><eq/><ci>[[275,1]]</ci><apply><divide/><apply><times/><ci>[[276,1]]</ci><ci>[[263,2,t]]</ci></apply><ci>[[278,1]]</ci></apply></reln> displays as



$$v' = \frac{K G}{n}$$

where  $v'$  is the groundwater flow,  $K$  is the hydraulic conductivity,  $G$  is the groundwater gradient and  $n$  is the aquifer porosity, each defined in its own content area.

The numbers surrounded by double-square brackets are PathML used to identify variables, e.g., “275,1” is  $v'$ , variable 1 in content area 275. Code found in content area 275 uses content areas 135 and 17 to define the variable’s units, “m/s”. Changing the unit definitions in content areas 135 or 17, or the variable definition in content area 275, would change the representation of variable “275,1” in the equation described above and anywhere else it was called.

The modular nature of knowledge storage in PathFinder results in automatic updating. Storing equations in MathML and PathML allows PathFinder to use equations to solve calculation problems, thus calculation problems use the same equations that are displayed in articles. A math parser applies input values to equations, determining correct numerical results.

### B. Multiple Choice and Calculation Exercises

The multiple choice and calculation exercises for a given content area are stored in an exercise.xml file. Multiple choice problems are simple to store. The problem shown in Figure 3 is stored with the simple xml: <question>An optimization model with one objective function, all equations in linear form, and non-negative decision variables</question> <incorrect>Optimization Model</incorrect><correct>Linear Programming</correct> <incorrect>Simplex Algorithm</incorrect> <incorrect>Graphical Solution</incorrect>.

Calculation problems are more complex. The problem shown in Figure 4 uses the code below. Repetitious code is replaced by “...” to save space. Bolded code is referred to in the discussion that follows. The code is <introStatement>Use the Raleigh Distribution to determine the probability of exceeding a particular wind speed</introStatement><given><line>You would like to install a mobile home on a beach front property. It is designed to withstand a top wind speed of:</line><assignment>8s,303,1,s,67</assignment> <line>The average wind speed at the site is:</line><assignment>8s,303,5,u,6,12,3</assignment> <part><question>Determine the fraction of the time that the maximum allowable wind speed will be exceeded.</question><answer><b>4,410,3,3</b></answer></part> <line>Use the appropriate equation(s).</line>

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<hiddenAssignment>8,283,1,s,3.1415926</hiddenAssignment>
<hiddenAssignment>8,129,1,s,2.7182818</hiddenAssignment>
<assignment>4,122,1</assignment>...<assignment>4,410,1</assignment></given>
<part><question>Determine the fraction of the time that the maximum allowable wind speed will be exceeded.</question><answer><b>4,410,3,3</b></answer></part>
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PathML is used in “hiddenAssignment” and “assignment” statements to assign values to variables, e.g., the PathML “8s,303,5,u,6,12,3” inside an assignment statement displays the symbol (8s) of variable “303,5” and assigns it a random value (u, uniform) between 6 and 12 with 3 significant digits. This appears in Figure 4 as “ $\bar{U} = 8.81 \text{ m s}^{-1}$ ”. PathFinder has a number of ways to assign numbers to input variables. Using random methods ensures that each student gets a different problem. “hiddenAssignment” statements can be used to assign values to variables without displaying the result. The variable can be used to solve exercise parts, but is not displayed, e.g., “8,283,1,s,3.1415926” assigns the value 3.145926 to variable “283,1”, i.e., pi. The “s” (static) is used to indicate a non-random assignment. An “assignment” statement can also be used to show an equation in the “Given” portion of the problem. The PathML “4,122,1” shows the first equation of content area 122, equation 1 in the given information of Figure 4..

PathML is used in “answer” statements to determine numerical answers, e.g., “4,410,3,3” uses the 3<sup>rd</sup> equation in content area 410 and the input values assigned in the given section or from previous parts (for multiple part problems) to calculate and display a numerical value with “3” significant figures. The final result is displayed in Figure 4 as Answer:  $Pr[U \geq u] = 2.7182818 \frac{-3.1415926}{4} \left(\frac{67}{8.81}\right)^2 = 1.87E-20$  (unitless). The answer statement also causes “1.87E-20” to be stored in the variable “Pr[U≥u]”, which is then available for use in subsequent steps. This is particularly useful in exercises with multiple steps.