

Cracking Dams: An Interactive Web Site for K-12

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Cracking Dams module by Megann V. Polaha and Prof. Anthony R. Ingraffea. Students in grades K-12 learn about engineering skills, civil and environmental engineering topics, the use of computer simulation in engineering, and the impact of engineering on society in the Cracking Dams module (<http://simscience.org/cracks/>). The Cracking Dams module specifically teaches students about concrete dams and engineering fracture mechanics using interactive multimedia, such as video and audio clips, still images, hypertext, and a Java applet. WebQuests provide a lesson plan for scaffolded, motivated use of the module in the classroom. WebQuests were developed for the Cracking Dams module to promote collaboration, reflection, case-based reasoning, and problem-solving as students are guided through the module. Students learn how to perform and actually perform a computer simulation of cracking in a dam as well as learn what the societal impacts of dams are. By using interactive multimedia and the web, Cracking Dams brings engineering concepts to K-12 classrooms in a non-traditional, motivated manner.

Cracking Dams is one of four modules of SimScience (<http://simscience.org>), which is a web site about areas of science that use computer simulation. SimScience has been developed at Cornell and Syracuse Universities as a National Science Foundation project; the Principal Investigator of the project is cognizant of this submission.

This document presents a description of the Cracking Dams module and WebQuests, the objectives of the module and WebQuests, the levels of the module, a brief literature review, results from evaluation and testing, and how the Cracking Dams module meets the criteria for the 1999 Premier Award. With this submission, NEEDS may become a non-exclusive distributor of the Cracking Dams module and WebQuests.

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Description of the Cracking Dams module

As President Clinton has declared initiatives in the Technology Literacy Challenge to connect every public classroom in the U.S. to the Internet, the web presents a new medium to teach students in an innovative, interactive manner (National Center for Education Statistics, 1998). Institutions such as the American Association for the Advancement of Science, the National Research Council, and the Regents of the State of New York have suggested that students in grades K-12 would develop a rich understanding of science with the introduction of real-life problems and engineering concepts (Soloway, 1996; Regents, 1996). The Cracking Dams module seeks to combine the opportunities of the Internet and the need for engineering education in K-12.

The Cracking Dams module has five main sections: Dams, Cracks, Case Histories, Scenarios, and Simulation. Each of these sections introduces new concepts about engineering while building on what the student has learned in the previous section. The forward button at the bottom of each page takes the learner through the main parts of the module. First, the student moves through the Dams section to begin with the less technical of the two subjects of cracks and dams. Services, problems, and technical issues of dams are presented, an indication that structures such as dams are not just built and then left alone; dams have a societal impact. Once the student has learned about dams, these structures become a vehicle for the student to learn about cracks; thus the Cracks section is next. The Case Histories section then shows the student examples of real world applications of fracture mechanics to concrete dams. Finally, the user can apply both the social and technical knowledge learned in these first three sections in the Scenarios and Simulation sections. In Scenarios, the student can consider the issues in the planning, construction, maintenance, or failure of a dam. A web-form allows the student to estimate the loss of life due to a dam failure and consider the estimation itself as well as the impacts of the failure. In the Simulation section, the student can actually perform a fracture analysis of a dam using a web-version of the finite element program FRANC2D through a Java applet. The interactive applet allows the student to constructively apply the simulation steps he or she has learned in the Dams and Cracks sections.

There are several supporting sections that provide help, motivation, general information, and communication. Supporting sections for help include Search, Glossary, Site Index, and Help. Supporting sections for motivation include the Quiz, Summary, Hometown Cracks, Hometown Dams, Dam News, Cracking the News, and Dam Entertainment. Hometown Cracks and Dams are pages that display pictures of cracks and dams from all over; students can send in photos of their own. Dam News and Cracking the News are news headlines on dams or cracking from January through July of 1999; students are directed on how to look up recent headlines on their own. The Dam Entertainment page lists books, movies, and other forms of entertainment that involve dams to show the students the dramatic nature of a dam failure or societal issue. General information sections include Authors, Acknowledgements, Goals, Fair Use, and References. Finally, intra- and inter-classroom communication is promoted by an electronic bulletin board set up for use with the Cracking Dams module.

Description of the Cracking Dams WebQuests

The WebQuest framework was created by Bernie Dodge to provide a lesson plan for using the web in the classroom combining collaborative, constructivist, problem-based, and scaffolding learning theories (Dodge, 1995). A WebQuest can be about any subject, but it should be a subject that is controversial or can be looked at from several points of view. WebQuests are usually interdisciplinary as well; the Cracking Dams WebQuests involve applications of math, science, and social studies. To facilitate use in the classroom, several WebQuests were written for the Cracking Dams module; there is a link to these WebQuests from the main page of Cracking Dams or the address is <http://simscience.org/cracks/webquests.html>. The parts of the WebQuest are all contained in one web page to which the student returns frequently. The parts of the WebQuest and their purposes are described below. The teacher's guide and an example Cracking Dams WebQuest may be found in Appendix A.

Parts of the WebQuest	
Quest	Sets the stage and draws the student in with a question that must be answered during the WebQuest. The Quest should interest and motivate the student. For the Cracking Dams WebQuests, the Quests involve the consideration of the positive, negative, and technical impacts of concrete dams.
Tasks	Describe what must be accomplished during the WebQuest. The tasks usually require the group to create something collaboratively, such as a position on the Quest controversy. In the Cracking Dams WebQuests, collaboration should produce a posting on an electronic bulletin board that states the group's position on the impacts of dams.
Roles	WebQuests are intended for groups of students. Each person in the group has a role in which he or she should become an expert. The roles also define the parts of the process that students should lead. Roles are not intended for the students to split up the work, but rather that they take some responsibility for certain parts and lead the group in those parts. The Cracking Dams WebQuests are intended for groups of three or four and thus define three or four roles. All of the roles are engineers; in this way, students see that engineers are concerned with not only the technical aspects of dams, but also the positive and negative social and environmental impacts.
Process	Lays out the steps an expert would follow to investigatively reason through of the Quest. Each group follows this Process. Each step in the Process includes a link to a web page that will provide the student with some pertinent information. Students should return to the Process after each step; thus it is recommended that they bookmark the WebQuest page at the beginning of the activity. Each step of the Process is numbered.
Worksheet	Cracking Dams WebQuests are scaffolded with a worksheet to guide students in gathering information during the Process. The steps on the worksheet are numbered corresponding to the steps in the Process. At each step, the worksheet reminds the student to return to the Process on the web to continue.
Conclusion	Reiterates what students have learned during the WebQuest and the Process they went through.

For the teacher	The page for the teacher is separate from the rest of the WebQuest. This page suggests several tips for using the WebQuest in the classroom, such as bookmarking the WebQuest page and having the students read through it fully before beginning. The skills and concepts used in the WebQuest are also detailed here to help teachers decide on an appropriate point in the curriculum to use this resource. The need for the teacher to make the connection between classroom topics and the WebQuest topics is stressed.
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The WebQuests essentially provide a lesson plan for using the Cracking Dams module in the classroom. The activity should begin and end with the teacher providing connections between classroom material and the module to make learning as effective as possible. Curriculum topics addressed in the module are listed below for each level. The teacher should be familiar with the WebQuest itself so he or she will be able to scaffold the students as they move through it. Particularly, the teacher should be comfortable with the simulation applet as it is the core hands-on experience of the module. A tutorial on how to use the applet is available as a link from the regular simulation applet page. The tutorial is intended to walk the user through each step of the simulation, providing some suggestions on what to do and why to do it.

The teacher must explain the format of the WebQuest activity, as students will likely not be familiar with it, and have the students read through the WebQuest before they begin. The teacher should remind the students to bookmark the WebQuest page and to return to the Process after each step. The teacher should hand out the worksheet, which may be printed directly from the web, to each of the groups and tell them they should use the worksheet for each step of the Process.

Students should then begin the WebQuest after they have read through it once and bookmarked it. Roles should be assigned to each person in the group. The group should proceed through the steps of the Process, which entails reading the step on the web, following the hyperlink, and finding the information as directed by the worksheet for that step. At several points during the WebQuest, the groups are asked to post a message on the bulletin board; a link to the bulletin board is provided. The WebQuest steps the students through the sections of the module in the same order as described above. Students first learn about the positive and negative impacts of dams in the Dams section. Next, students learn each of the steps, or tools, to perform a computer simulation of cracking in a dam in the Dams and Cracks section. Next students review a case history to determine measures taken in the past to remedy cracking in a dam. Students then perform a simulation themselves. The estimation of the loss of life due to dam failure is considered. Finally, the group must come to a decision on the fate of a dam: should it be decommissioned because of cracking and environmental impacts or should it be repaired to continue providing service? The group should post their statement on the bulletin board as directed by the Process. The worksheet scaffolds movement through the Process by prompting appropriate organization of information, such as the calculation of loads on a dam.

Following completion of the WebQuest, the teacher should facilitate discussion on the final statements of each of the groups and look at the final statements posted on the bulletin board by other classrooms. As there are no “correct” answers to the WebQuests, discussion of the group’s positions is important to help the students develop an understanding of how other groups came to

their decisions. Teachers may develop their own WebQuest for the Cracking Dams module if they find other aspects they would like to stress. A link is provided from the teacher page to a template for creating a WebQuest by the originators of the WebQuest.

Objectives of the Cracking Dams module and WebQuests

The objectives of the Cracking Dams module are to teach engineering skills, civil and environmental engineering topics, when and how to use simulation, and the societal and ecological impact of engineering. The student has several opportunities to learn the skills and topics and then apply their knowledge as directed in the WebQuest process. The communication of the objectives within the module and WebQuests is reviewed below.

Objectives	
Engineering skills	Engineering skills promoted in the module include teamwork, iterative design, and problem solving. Students see examples of teamwork in the Case Histories and Scenarios sections and then apply teamwork skills in the WebQuest. Iterative design is emphasized throughout the module: in the history of each dam type, in the history of fracture mechanics, in the Case Histories, and in engineering simulation. Students use iterative design as they perform their own simulation with the Java applet and estimate loss of life with the web-form. Examples of problem solving are also apparent in the histories of dams and fracture and in the Case Histories. Students use case-based reasoning and problem solving in the WebQuests, in performing a simulation and estimating loss of life.
Civil and environmental engineering topics	The module is intended to show students examples of what civil engineers do. A “cee” icon is placed throughout the module to point out processes a civil engineer might perform or be interested in. Such processes include the design, planning, and construction of dams, the use of simulation, and the testing of materials.
Use of simulation	Students learn about the useful applications of computer simulation in the Cracks History section, Case Histories, and Simulation section. The basic steps to perform a simulation of cracking in a dam are embedded in the sections on Dams and Cracks so that the student learns them as he or she moves through the beginning of the module or WebQuest. The student is actually able to perform a computer simulation of fracture in a dam in the Simulation section.
Impact of engineering	Technical issues of dam engineering, such as planning, construction, and computer simulation, are presented throughout the module. To provide a well-rounded view of engineering, the positive and negative impacts of dams on society and the environment are also presented in the Dams and Scenarios sections. At several points, the student is prompted to reflect on

	the impacts of engineering and post a statement on the electronic bulletin board.
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Levels of complexity

The Cracking Dams module has three levels of complexity: Beginning, K-4; Intermediate, 5-8; and Advanced, 9-12. The Intermediate and Advanced levels are accompanied by slightly different WebQuests. Topics covered in each level and specific points in the curriculum suggested for the introduction of the module into the classroom are listed below. Other comments on each level are also noted.

Three levels of Cracking Dams		
Level	Topics	Comments
Beginning (K-4)	<ul style="list-style-type: none"> • Shapes • Geography • Forces • Sizes 	The Beginning level is intended for grades K-4. Evaluation and testing has shown that Kindergarten and first graders need an adult to assist students with the reading. Because of the amount of reading and writing required to complete a WebQuest, WebQuests were not developed for this level. Worksheets for this level are provided to motivate and scaffold movement through the site. A cartoon beaver, Dammy, narrates the Beginning level. Dammy is a friendly face that helps young students realize that they already have some existing knowledge about dams – beaver dams.
Intermediate (5-8)	<ul style="list-style-type: none"> • Scale modeling • Two-dimensional drawing • Calculating dimensions • Applying concepts of force and energy • Performing a computer simulation 	WebQuests for the Intermediate level are shorter than those for the Advanced level; Intermediate level WebQuests are intended to be completed in one class period. The Intermediate level WebQuests make an immediate personal connection between the student and the subjects by having the students find a dam in their city or county in the National Inventory of dams online database to investigate during the WebQuest. In general, the information in the Intermediate level is simpler than that of the Advanced level to reflect the student's base of knowledge.
Advanced (9-12)	<ul style="list-style-type: none"> • Algebra: algebraic notation in equations 	Students should achieve a personal, real-world understanding of the information

	<ul style="list-style-type: none"> • Geometry: shapes of dams • Trigonometry: calculation of dimensions of dams • Calculus: rates of change • Physical science: environmental factors in the cracking of dams • Chemistry: chemical reactions in concrete • Physics: force diagrams of dams 	presented in this level. Advanced level WebQuests use a real-world setting: government engineers have found several problems with a certain dam and have charged the group with the investigation and evaluation of the situation. The Advanced level could perhaps be used at an undergraduate level as well as high school level.
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Literature Review

The literature provides support for the use of interactive multimedia and the Internet in K-12 classrooms, the use of case studies, and the introduction of engineering to K-12. Advantages of multimedia include that it allows information to be accessed in multiple ways, allows learning to be non-linear and self-paced, improves motivation and focus, and increases retention and learning rates (Bagui, 1998; Naijar, 1996; Iskander *et al*, 1995). The Internet allows for the combination of audio and video clips with hyperlinks and Java applets. This in turn allows for non-linear, self-paced, motivated learning, different and often more effective than traditional methods of learning (Hill *et al*, 1998; Baecker *et al*, 1995). The Internet also provides access to information that is not usually available in the classroom. For example, the Cracking Dams WebQuests has students look up dams in the National Inventory of Dams database, a resource not typically found in classrooms (<http://crunch.tec.army.mil/nid/webpages/nid.html>). Case-based reasoning has been used at both the K-12 and university level to teach engineering (Billington and Mark, 1983; Fitzgerald, 1995; Hsi and Agogino, 1994; Jarz *et al*, 1997; Sansalone, 1990; Valenzuela, 1993). Case studies provide a full view of what actually happened and encourage the development of intuition. Finally, several authors have found that the introduction of engineering to K-12 can provide a more profound understanding of math and science, attract a greater number of more diverse students to engineering, connect technical concepts to daily life, and develop teamwork skills (Crawford *et al*, 1994; Wilson *et al*, 1995; Muller *et al*, 1995; McKenna and Agogino, 1998).

Evaluation and testing

Evaluation and testing on several aspects of the module and the WebQuests have been completed and are reported in the table below.

Evaluation and testing matrix			
Group	Purpose	Feedback	Results and comments
STAR Academy of Lehigh University (date:	Evaluation of appearance, navigation, and	Evaluation form (see Appendix B)	85% liked the appearance of the site. 80% had little or no trouble navigating through the site. 75% found the

<p>2/99; before the development of the WebQuests)</p> <p>80 students grades 6-12</p>	<p>content of the Intermediate and Advanced levels of the module</p>		<p>information on the site interesting. Students noted that the best part of the site was the simulation applet. Comments included “It’s better and more interesting than reading a book,” “It would make class easier and fun,” and “ It is as good as a hands-on.” More motivation and scaffolding to move through the site was necessary, though.</p>
<p>Expanding Your Horizons program at Cornell University (date: 4/99)</p> <p>6 students grades 6-8</p>	<p>Evaluation of the module and a new activity for the Intermediate level (pre-cursor to the Webquest)</p>	<p>Evaluation form (see Appendix B)</p>	<p>The activity did provide motivation and scaffolding for movement through the site; the activity was developed into a WebQuest. Worksheets filled out by the students during the evaluation indicated that students were able to apply their math and science skills. Students reported that the best things about the activity are that the activity is on a computer and that students are able to actually perform a simulation and estimate the loss of life due to a dam failure.</p>
<p>NASA-Sharp + program at Cornell University (date: 6/99)</p> <p>19 students grades 10-12</p>	<p>Evaluation of the module and Advanced level WebQuest</p>	<p>Evaluation form (see Appendix B)</p>	<p>Students reported that they liked the WebQuest because of its organization, the roles, the hyperlinks, and the detailed explanation of instructions. Descriptions of the WebQuest included “unique interactive environment,” “easy access to links made it fun and efficient,” and “allowed us to explore for ourselves.” Answers on the worksheets indicated that the worksheet does scaffold organization of information and that students are using case-based reasoning in their consideration of cracking in a dam. Specifically regarding engineering, comments on the worksheets included the following: “Engineers must weigh safety, environment, cost, and usefulness;” “Engineering can save lives;” “It [engineering] affects everything;” “It [engineering] affects our lives directly;” “Engineers are concerned with social issues.”</p>

			These comments indicated that students' views of engineering are not limited to the technical aspects. There was some indication that the module succeeded in introducing the students to a wider view of engineering than the students originally held, a view of engineering as requiring teamwork and a balance of issues. The majority of the students said they would like to use the module and WebQuests in the classroom.
Cornell University Summer Day Camp (date: 7/99) 20 students grades 6-8	Evaluation of the module and Intermediate level Webquest	Group discussion	Students noted that the simulation applet was the most interesting part of the module and WebQuest. The WebQuest did provide structure for movement through the site, but there was some difficulty with motivation. Several students were distracted by the ability to surf the web during the activity. Most students did note that they would like to use the module in class.
Greater Ithaca Activities Council Summer Camp (date: 7/99) 44 students grades K-4	Evaluation of the Beginning level	Group discussion	A worksheet was developed over the course of four evaluations with this group; the worksheet proved to scaffold use of the site. Students indicated appreciation for Dammy the Beaver, the roll-overs, and the quizzes in this level. Many students were able to discuss what they had learned about cracking and dams followed the testing of the module. Students in Kindergarten and first grades had difficulty reading; it is suggested that students of this age be accompanied by an adult to use the module.

In general, feedback from the evaluation and testing sessions was positive regarding the appearance, navigation, and content of the module and WebQuests. Most students indicated that they would like to use the module in the classroom.

As there will be no "correct" answers to the Cracking Dams WebQuests used in the classrooms in the future, student learning must be assessed by evaluating responses on the bulletin board and in discussion following the WebQuest. For example, students should support their posted

positions on dams with ideas they learned during the WebQuest. The worksheet may also be used to evaluate student performance.

Courseware Criteria

The Cracking Dams module and WebQuests meet the Premier award criteria on many levels as described below.

Part I Criteria Instructional Design	Applications in the Cracking Dams module and WebQuests
Interactivity	Students must interact with the WebQuest at each step of the Process. Interaction is particularly required for the use of the simulation applet and the loss of life estimation.
Cognition/Conceptual Change	Reflection and decision-making are encouraged by the WebQuest and promoted by postings on the electronic bulletin board. Students problem-solve and analyze results of their simulations and estimations of loss of life.
Content	Module content is sequenced to support a building of knowledge. WebQuests scaffold movement through the content. Hyperlinks and a side menu allow the student to move non-linearly if desired.
Multimedia Use	Multimedia elements include video and audio clips from movies, JavaScript roll-overs, a Java simulation applet, and a web-form. Direct connections between the multimedia and the textual content and objectives are provided at each instance. The simulation applet particularly promotes interactivity and an opportunity to apply knowledge learned in the module.
Instructional Use/ Adaptability	The use of the module in the classroom is facilitated by the WebQuests, which are explained in the module. Teachers may use the available WebQuests or develop their own. Communication with other classrooms is encouraged with the electronic bulletin board. Finally, there are three levels of the module for different levels of schooling.

Part II Criteria Software Design	Applications in the Cracking Dams module and WebQuests
Engagement	By presenting technical and societal impacts of engineering, the module can attract more diverse students. The engineering skills introduced in the module are fundamental in nature and applicable to other subjects. Finally, the interactivity of the simulation applet and loss of life estimation intrigue and motivate students.
Learner Interface and Navigation	There are several options for navigation through the module: forward and back buttons, a side menu, and a site index. Consistency within the module was maintained with respect to appearance, layout, and navigation.

Technical Reliability	Every effort has been made to ensure the reliability of the module. Any problems can be reported by email and will be dealt with in a timely manner. One advantage of the web is that if any corrections to the module are made, the new version is immediately available to everyone, without the need for a new software release.
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Part III Criteria Engineering Content	Applications in the Cracking Dams module and WebQuests
Accuracy of Content	Reliable publications were used as references for the material in the module. All references used are listed on the site.
Organization of Content	The content of the site is structured as seen in the side menu on the left of the web pages. Each section builds on the user's knowledge and previous sections to provide a logical progression through the module. The WebQuest scaffolds movement through the sections.
Consistency with Learning Objectives	The module is divided into three levels of complexity to accommodate learners of different ages. Learning objectives are communicated as discussed above in the Objectives table.

Conclusions

The Cracking Dams module and WebQuests seek to bring non-traditional topics to K-12 in a non-traditional manner: engineering fracture analysis of dams on the Internet. The use of interactive multimedia, particularly the simulation applet, provides an engaging introduction to engineering for K-12 students. Although the module has just recently been completed, testing and evaluation by students has shown that the module and WebQuests have a great deal of potential for the classroom.

References

- Baecker, Ronald M., Grudin, Jonathan, Buxton, William A.S., and Greenberg, Saul, editors, 1995. "A Historical and Intellectual Perspective," *Human-Computer Interaction: Toward the Year 2000*. San Francisco: Morgan Kaufmann Publishers, Inc.
- Bagui, Sikha, 1998. "Reasons for Increased Learning Using Multimedia," *Journal of Educational Multimedia and Hypermedia*, Vol. 7, No. 1, pp. 3-18.
- Billington, David P. and Mark, Robert, 1983. "Structures and the Urban Environment," *Structural Studies 1983*.
- Crawford, Richard H., Wood, Kristen L., Fowler, Marilyn L., and Norrell, Jeffrey L., 1994. "An Engineering Design Curriculum for the Elementary Grades," *Journal of Engineering Education*, April, pp. 172-81.
- Dodge, Bernie, 1995. "Some Thoughts about WebQuests," [online].
http://edweb.sdsu.edu/courses/edtec596/about_webquests.html
- Fitzgerald, Nancy, 1995. "Teaching with Cases," *ASEE Prism*, March, p. 18.
- Hill, M., Bailey, J.D., and Reed, P.A.S., 1998. "Hypermedia systems for improving knowledge, understanding and skills in engineering degree courses," *Computers & Education*, No. 1, Vol. 31, August, pp. 69-88.
- Hsi, Sherry and Agogino, Alice M., 1994. "The Impact and Instructional Benefit of Using Multimedia Case Studies to Teach Engineering Design," *Journal of Educational Multimedia and Hypermedia*, No. 3, Vol. 4, pp. 351-76.
- Iskander, Magdy F., Catten, J. Corey, Jones, Antony, Jameson, Rex, and Balcells, Albert, 1995. "Interactive Multimedia Lessons for Education," *1995 Frontiers in Education Conference*, pp. 3a2.1-12.
- Jarz, Ewald M., Kainz, Gerhard A., and Walpoth, Gerhard, 1997. "Multimedia-Based Case Studies in Education: Design, Development, and Evaluation of Multimedia-Based Case Studies," *Journal of Educational Multimedia and Hypermedia*, No. 6, Vol. 1, pp. 23-46.
- McKenna, Ann and Agogino, Alice, 1998. "Integrating design, analysis, and problem solving in an introduction to engineering curriculum for high school students," *Proceedings of the 1998 Annual ASEE Conference*, Seattle, WA, p. 1052.
- Muller, Carol B. and Collier, John P., 1995. "Engineering Concepts in the High School Classroom: The Dartmouth/Thayer Problem-Solving Methods," *1995 Frontiers in Education Conference*, pp. 4b1.15-18.

- Naijar, Lawrence J., 1996. "Multimedia Information and Learning," *Journal of Educational Multimedia and Hypermedia*, Vol. 5, No. 2, pp. 129-50.
- National Center for Education Statistics, 1998. "Internet Access in Public Schools," February, [online]. <http://nces.ed.gov/pubs98/98031.html>
- Regents of the University of the State of New York, 1996. *Learning Standards for Mathematics, Science, and Technology*. New York: State Education Department.
- Sansalone, Mary, 1990. "Teaching Structural Concepts Through Case Studies and Competitions," *Engineering Education*, May/June, pp. 472-3.
- Soloway, Elliot, Krajcik, Joseph S., Blumenfield, Phyllis, and Marx, Ronald, 1996. "Technological Support for Teachers Transitioning to Project-Based Science Practices," *Computer-Supported Collaborative Learning 1996*.
- Valenzuela, Mark L., 1993. Use of Case Studies and Multimedia in Structural Engineering Education. M.S. Thesis, Cornell University, Department of Civil and Environmental Engineering, January.
- Wilson, Denise, Hudson, Tina, Fletcher, Susan, Harris, Brannon, Knight, Clinton, Morris, Tonia, Patel, Girish, and DeWeerth, Stephen, 1995. "Establishing the Foundations for Engineering Education in K-5," *1995 Frontiers in Education Conference*, pp. 3b2.5-9.