2004 Premier Award  
c/o NEEDS  
3115 Etcheverry Hall  
University of California at Berkeley  
Berkeley, CA 94720-1750

Dear Committee Members,

It is a pleasure to submit my courseware “MecMovies: Instructional Software for Mechanics of Materials” for consideration in the 2004 Premier Award competition.

Courseware Description

MecMovies is an extensive collection of examples, theory, and games designed to complement the entire Mechanics of Materials course. The software features impressive graphics and animation that are highly effective in visually communicating course concepts to students. Special emphasis is placed on developing the learner’s understanding and proficiency in basic concepts and skills through interactive exercises and games. Classroom implementation of the software has produced improved student performance and more positive student attitudes regarding the Mechanics of Materials course.

MecMovies is located at http://web.umr.edu/~mecmovie/index.html. The complete courseware can be downloaded at http://web.umr.edu/~mecmovie/MecMovies.zip.

Contributors in the development effort include University of Missouri – Rolla (UMR) Professors Richard Hall, David B. Oglesby, Nancy Hubing, and Ralph E. Flori and staff programmer Vikas Yellamraju. UMR student workers on the project included John Thomas Barnett, Sreeram Ramakrisnan, Wesley J. Merkle, and Arun S. Balasubramanian. All contributors have been contacted regarding this submission. The primary author and the copyright holder of all materials on the site is Timothy A. Philpot. This includes all text, graphics, animations, and navigation programming. As the copyright holder, I grant NEEDS the non-exclusive right to link to the web site and to distribute the material for non-commercial use.

Very truly yours,

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MecMovies
Instructional Software for Mechanics of Materials

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Synopsis

MecMovies is a second-generation suite of instructional software for the Mechanics of Materials course. The MecMovies collection consists of over 100 animated example problems, drill-and-practice games, and interactive exercises. The software has been used and assessed extensively at the University of Missouri – Rolla (UMR) for the past three years and at selected universities during the past year. Formative assessment studies have demonstrated a statistically significant performance improvement between Mechanics of Materials students who used MecMovies and those who did not. Student opinions of MecMovies, as indicated by subjective quantitative ratings and comments, have been very positive. Students find the software to be very helpful, particularly with regard to visualization of course concepts. In addition to measurable performance improvements, student have reported that using the software throughout an entire semester has helped them to feel more confident about their understanding of course concepts, to become more interested in the course, and to enjoy the course more than they would have expected.

Background

Mechanics of Materials course is one of the core courses for students in a number of engineering and engineering-related disciplines. The course introduces students to fundamental principles involved in designing common structural and mechanical components, and it teaches students how to analyze the effects of external forces and loads on the internal stresses and deformations in the components.

Engineered objects are inanimate and frequently stationary objects. The internal response of these objects to external forces is often invisible or at best hardly noticeable to the human eye. Educators understand the components and processes that constitute our discipline—we can visualize various effects in our mind’s eye—and one of the first challenges we face in teaching our subject is conveying our visual comprehension to students. In Mechanics of Materials, a workable mental image is particularly desirable because the ability to visualize stress and strain distributions within a solid body will guide the learner to specific concerns critical for the successful engineering design of the object. Once the learner develops an appropriate image of the internal state of a solid object, the relevant theory and associated problem-solving skills needed to become proficient in specific topic areas become much more meaningful.

Computer-based instruction offers many capabilities that cannot be readily duplicated within the traditional lecture format. Concepts that are difficult for the student to visualize based solely on static, two-dimensional images become much more understandable when computer graphics are combined with animation techniques. With three-dimensional (3d) modeling, rendering, and animation software, realistic images of various components can be shown in motion and from various viewpoints, presenting a more easily understood representation to the student. Better images can facilitate the mental visualization that is so necessary to understanding and solving engineering problems in this subject area.

Animation also offers a medium for a new generation of computer-based learning tools. The traditional instructional device – example problems – can be greatly enhanced through animation to emphasize and illustrate desired problem solving thought processes in a more memorable and engaging way. Animation can also be used to create interactive tools that focus on specific skills students need to become proficient problem-solvers. These computer-based tools can provide not only the correct solution but also a detailed visual and verbal explanation of the process needed to arrive at the solution. Since
these learning tools are available on the Internet, students have easy access to them. They can use them at times that suit their study habits, and they can work with the learning tools without external pressure until they feel comfortable with their understanding of a topic.

Students generally respond favorably to instructional software; however, much of the data that has been gathered to assess the effectiveness of this type of instructional software has been anecdotal. The method by which instructional software is incorporated into the engineering class is partly responsible for this lack of systematic evaluation. Often, software packages have been implemented in the classroom as supplemental material – recommended but not required.

**MecMovies Description**

One of the primary objectives and promises of instructional software is to provide one-to-one instruction to all students, similar to the model of a tutor. Although the technology is not quite advanced enough to fully accomplish this, MecMovies moves another step along this path. The software is structured so that complex concepts and broad tasks are divided into more narrowly focused units. Wherever practical, MecMovies asks students to interact with the software by performing basic calculations, making decisions, and receiving feedback. The software attempts to sequence topics from simple to complex; however, the intention is that this progression leads from simple tasks in the software to complex reasoning and advanced problem-solving tasks in the classroom, guided by the experience and wisdom of the instructor. Through the one-to-one nature of the software instruction, it is anticipated that all students in the class will become more quickly oriented about the overall topic and more quickly adept at the basic calculation skills. With a more uniform understanding of the fundamentals, the instructor will be much better positioned to develop the desired proficiency in the subject area in the classroom.

A large number of animated example problems are included in MecMovies, covering the entire course content. Topics include basic stress and strain concepts, axial members, torsion members, flexural members, members subjected to combined loadings, stress and strain transformations, beam deflections, and section properties. The MecMovies example problems offer several advantages over traditional static, two-dimensional presentations. A number of topics discussed in Mechanics of Materials involve three-dimensional geometry and loading. Such topics are difficult to adequately describe to students using hand-drawn illustrations in class. For these types of topics, three-dimensional rendering and animation software can be quite effective in presenting a clearer explanation of the concepts involved.

The Mechanics of Materials course is a problem-solving course, and many of the MecMovies animations seek to more clearly and more memorably explain the procedure required to solve various problems. The computer as an educational medium provides a wide array of possibilities for interaction between the student and the software. A number of MecMovies animations include two types of features called “Concept Checkpoints” and “Try One.” The purpose of these features is to encourage students to immediately apply the concepts and procedures presented in the animations. For some topics, a simple multiple-choice format can be effective. Most Mechanics of Materials topics, however, are better suited by a numeric response format. In these cases, a problem is presented to the student that requires only a few basic calculations to answer. After the student enters their calculation results, the software indicates whether the answer is correct or incorrect. Should the student enter an incorrect value, the software will, in many instances, provide a brief explanation of the correct solution procedure.

It is often assumed that repetition leads to proficiency; however, few students relish working dozens of problems on a particular topic. To make the learning process more enjoyable, repetition and drill on a specific topic can be encapsulated in a game context. Through the challenge of the game, the student can receive the benefits of repetition without the sense of labor that they might feel otherwise. A game context provides students with a structure for learning and permits students to develop their skills at their own pace in a non-judgmental but competitive and often fun environment. Since the computer is a medium that is well suited for repetitive processes and for numeric calculations, computer-based games focused on specific calculation processes offer great potential as a new (or perhaps updated) type of learning tool for engineering mechanics courses. Several games are included in MecMovies. These
games focus on fundamental calculations such as centroids, moments of inertia, and Mohr’s circle transformations that are building blocks employed to solve problems in a variety of situations.

Assessing MecMovies in the Classroom

Experience has shown that students will generally not begin to take advantage of instructional software unless they are required to do so in some manner. This student behavior has been dubbed “The Least Effort Principle,” meaning that students tend to consult a minimum of study materials in order to complete their tasks. Further, there has been research which suggests that support systems (such as software) that are merely “add-ons” to the learning environment may increase the gap between weak and strong learners. This conclusion helps to explain why courseware implemented in the classroom as suggested supplemental material often fails to attain its full promise as an instructional medium.

Since the Least Effort Principle generally seems to be a common trait of many undergraduate students, it was important that the formative assessment study described here incorporate MecMovies as a mandatory (i.e., graded) portion of the course requirements. For this study, four professors teaching six Mechanics of Materials sections (167 students total) in the Fall 2003 semester at UMR were involved. Students in one section, comprising the experimental group, were given approximately 21 MecMovies assignments, spaced intermittently throughout the 15-week semester while the other five sections, constituting the control group, were taught in the traditional manner. Generally, the MecMovies assignments replaced one regular homework problem with a comparable assignment consisting of a Concept Checkpoint or a game. In each MecMovies assignment, a summary form incorporated in the movie was printed out and turned in for homework credit by the student. Student performance in the experimental MecMovies section was compared to performance in the other five control sections throughout the semester by means of common problems included on the four mid-course exams and through a common final exam. At the end of the semester, students who used the MecMovies software also completed a survey questionnaire consisting of a number of subjective rating items. Complete details of the assessment study summarized here are described in the paper “Comprehensive Evaluation of Instructional Software for Mechanics of Materials,” included in the Appendix. Sample assessment questionnaires are also included in the Appendix.

As an instructional medium, the computer is very well suited to repetitive tasks while it is less well suited for topics requiring intuition, experience, or other less quantifiable reasoning. The MecMovies homework assignments focused on introductory concepts, fundamental calculation skills, and other topics and skills that consistently pose difficulties for students. The Concept Checkpoints features usually consist of 4-10 questions, and early in the semester, it was made clear to students that they should continue working with these assignments until they achieved a perfect or near-perfect score. Students were free to work with the software modules at their own pace, repeating the Concept Checkpoints and the games until they attained proficiency. The educational objective for assignments of this type was to establish a firm basis of fundamentals outside of class so that the limited class time could be devoted to the higher-order thinking skills and more difficult calculation procedures.

Scores on a common final exam given to all six sections (167 students total) were used to compare the performance of the experimental group with the five other sections. Statistical analysis of the data, corrected to account for student ability as indicated by cumulative GPA, revealed that there was a statistically significant performance improvement between students who used MecMovies and those who did not. The 29-student experimental group outperformed the 138-student control group as a whole, and in section-to-section comparisons, they outperformed each of the other five Mechanics of Materials sections, which were taught by three different professors. Student opinions of MecMovies, as indicated by subjective quantitative ratings and comments, were very positive. Students generally found the software to be very helpful, particularly with regard to visualization of Mechanics of Materials concepts. In addition to measurable performance improvements, student reported that using the software throughout the semester helped them to feel more confident about their understanding of course concepts, to become more interested in the course, and to enjoy the course more than they would have expected.
Comments on Implementation

While the software apparently contributed to the significantly better performance of the experimental group compared to the control group, the realization of this improvement only occurred because students were required to use the new instructional technology. Most students in the experimental group finished the course with high compliments for the software, as the ratings and the comments show (see Appendix). However, they would have never tried the software if they had not been required to do so. From this, one could predict that any instructional software package, regardless of merit, would be destined for failure if not carefully implemented into the course and the course assignments.

In the assessment questionnaire, students were asked the following open-ended question: “In your opinion, what would be the best way of incorporating the animated movies into the Mechanics of Materials course?” Students’ most commonly suggested continuing to use MecMovies as a part of the regular homework assignments. A number of students also commented that they liked seeing the instructor use selected movies as a part of the lecture. Several students also suggested that movies appropriate to the next lecture might be announced beforehand so that students could look over them before coming to class.

From an instructor’s viewpoint, the integration of MecMovies into the course subtly improved the character of the classroom in several ways. Using MecMovies to supplement lecture allows the professor to spend more of his or her time talking to faces, rather than the blackboard. Because there is no need to make notes for movies that are readily available, students seem freer to think about and discuss concepts and aspects associated with various situations. Since MecMovies was available to introduce topics and provide rudimentary drill exercises, a portion of class time that was previously devoted to the most fundamental concepts became available to answer more student questions, conduct active learning exercises, and generally improve the learning atmosphere in the classroom. And finally, students seemed to ask better questions on some topics following their MecMovies assignments.

Impact of MecMovies

MecMovies has been used in Mechanics of Materials classes at UMR since 2001. Early use involved only selected topics such as stress transformations and beam deflections by the superposition method. Complete integration and implementation of MecMovies throughout the entire Mechanics of Materials course began in the Fall 2003 semester. Roughly 400 UMR Mechanics of Materials students have participated in MecMovies formative assessment studies during the past three years. The software has also been used in Statics classes at UMR for topics such as centroid calculations, moment of inertia calculations, and Mohr’s circle for moments of inertia. More than 100 UMR Statics students have participated in MecMovies assessment studies.

A dissemination study was conducted during the Fall 2003 semester involving five US schools and five International schools:

**US Schools**
- Georgia Tech University, Atlanta, Georgia
- Texas Tech University, Lubbock, Texas
- Ohio State University, Columbus, Ohio
- Virginia Western Community College, Roanoke, Virginia
- Monroe County Community College, Monroe, Michigan

**International Schools**
- Tec de Monterrey, Monterrey, Mexico
- Waikato Institute of Technology, New Zealand
- Instituto da Tecnologia da Amazonia, Brazil
- University of Sarajevo, Zenica, Bosnia and Herzegovinia
- University of West England, Bristol, Great Britain

Participating professors were asked to have their students use and evaluate three groups of MecMovies topics: stress transformations, Mohr’s circle stress transformations, and centroid/moment of
inertia calculations. The MecMovies groups and the survey instruments can be accessed online at http://web.umr.edu/~bestmech/stress.htm and http://web.umr.edu/~bestmech/sectprop.htm. A total of 280 student responses were submitted: 170 from the US schools and 110 from the International schools. Although no controlled quantitative assessment was possible, qualitative feedback from professors and students was very positive. Unsolicited and anonymous comments were received from a number of student participants:

- **Very clear and concise way of learning the fundamentals of section properties. Very easy to follow.** (referring to the Moment of Inertia Game)
- **That was actually fun homework** (referring to The Centroids Game)
- **I think this exercise is great. The simple math is sometimes overlooked for so long that we may forget it. This type of exercise is just what is needed to refresh our memory and exercise the learning mind.** (referring to The Centroids Game)
- **Surprisingly I understood what I just did.** (referring to The Amazing Stress Camera)
- **Excellent web site, very productive and instructive. Also, excellent drawings. I learned more here than what I’ve learned with the MM of RC Hibbeler!!!!**
- **Excellent Website... Just Excellent !!!**
- **These web modules are EXTREMELY helpful.**

Portions of MecMovies have also been used at other US and International institutions, although an exact count is not available. Comments from three of these professors are quoted below:

> The whole course was based upon the software. Assignments, quizzes, and small workshops were carried out using it. The performance of the students has been "dramatically" improved. I'd like to ask if we can have MecMovies on our website at the Faculty of Engineering and Technology – University of Jordan. It will be of a great help to our students.

Moudar H. Zgoul, Ph.D., Assistant Dean for Computer Affairs, Assistant Professor of Mechanical Engineering, University of Jordan, Amman, Jordan

> I loved the material you sent me. The effect on my students was incredible. I used only three of the lectures with my students but the effect on the final result was incredible. I had only 5 failures in my summer exam which was a lot better result than all my previous years. The new MecMovies is brilliant. It is comprehensive and complete. Now, one can use it to cover everything. I really need to have a copy of it. As I said, I have two new degrees validated with this software in mind. I am now relying heavily on its availability and continuous upgrade etc. I also need to have a copy so that we can install it on our intranet network and link it to our website for all my students to have access to. I would like to use it properly and completely this year hoping for 100% success. I can’t say enough about how good this software is and how much I appreciate you allowing me to use it in my teaching. Could you please advise me on how I can download the new MecMovies as soon as possible?

Siamak Noroozi, Ph.D., Principal Lecturer, University of West England, Bristol, Great Britain

> Fantastic. I love the idea of the virtual stress camera. You are making the teaching of a subject that could be 'dry' much more inviting. I look forward to more as this is definitely going in the right direction.

Alan Arbour, Professor of Mechanical Engineering Technology, School of Technology and Applied Science, Lambton College, Sarnia, Ontario, Canada

Acknowledgements

This work was supported in part by a grant from the United States Department of Education Fund for the Improvement of Post-Secondary Education (FIPSE #P116B000100) and in part by National Science Foundation grant number DUE-0127426.

http://web.umr.edu/~mecmovie/index.html
Specific Response to 2004 Premier Award Evaluation Criteria

Specific responses to each of the Premier Award Evaluation Criteria are detailed in Table 1.

<table>
<thead>
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<th>Table 1 - Response to 2004 Premier Award Evaluation Criteria</th>
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<tbody>
<tr>
<td><strong>INSTRUCTIONAL DESIGN</strong></td>
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<tr>
<td><strong>1.1 Learning Objectives: Learning objectives and goals are clearly stated and supported by the software and learning experience.</strong></td>
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<td>Part 1</td>
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<td>Part 2</td>
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<td>Part 2</td>
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<tr>
<td>1.2 Interactivity: The learner is actively involved in the learning process—the interaction enhances learning.</td>
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<tr>
<td>There are questions and challenges to help the learner monitor his or her progress.</td>
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<tr>
<td>Learners are presented with relevant problems to solve; exemplary solutions are included.</td>
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<tr>
<td>There is an analysis of learner input and useful, appropriate feedback.</td>
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<tr>
<td>The system adapts … based on learner actions.</td>
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</table>

1.3 It appears that learners will be able to demonstrate or apply the concepts introduced by the software in meaningful ways. Mechanics of Materials is a problem-solving course. Accordingly, MecMovies focuses on teaching problem-solving approaches for various types of engineering design situations. Learners are challenged by the software to transfer the problem-solving skills and methods demonstrated by example problems to different problems involving similar concepts and solution techniques. In all instances, however, the problem-solving approaches taught by MecMovies are representative of the skills that are required for engineering analysis and design. 

Part 2

http://web.umr.edu/~mecmovie/index.html
Mechanisms are provided so learners can monitor their own understanding and correct their misconceptions...

Roughly half of the movies in the software include some sort of interactive exercise in which learners are asked to respond to questions or to perform a calculation. In addition to immediate feedback on the correctness of the answer, the software responds to incorrect answers with a brief explanation of the correct procedure. In all cases, provision is made for learners to immediately repeat the exercise.

### 1.4 Content: The content is well chosen and structured.

<table>
<thead>
<tr>
<th>Part 1</th>
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<tbody>
<tr>
<td>The scope…is appropriate for the intended audience.</td>
<td>There are useful links between content areas.</td>
</tr>
<tr>
<td>The content builds on prior knowledge that learners can be expected to have; the required background knowledge is clearly stated or understood.</td>
<td>Organization facilitates…exploration … both inside and outside the learning experience.</td>
</tr>
<tr>
<td>The structure of the knowledge to be learned is clearly conveyed.</td>
<td>MecMovies is organized in individual movies within topic areas. Links within a movie to other relevant movies are not provided.</td>
</tr>
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### 1.5 Multimedia use: Multimedia is used effectively and promotes the learning objectives and goals.

<table>
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<th>Part 1</th>
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<tbody>
<tr>
<td>None of the multimedia representations used are ambiguous…</td>
<td>Media elements are of high…quality.</td>
</tr>
<tr>
<td>MecMovies animations and illustrations generally begin with a broad context before focusing on a specific aspect of theory. Student feedback indicates that the graphical content is very successful in helping students visualize the context associated with the theory.</td>
<td>The MecMovies graphical elements are outstanding.</td>
</tr>
<tr>
<td>Media is used appropriately and not gratuitously.</td>
<td>Multiple representations are used to help learners construct inter-related knowledge.</td>
</tr>
<tr>
<td>MecMovies animations and illustrations are appropriate and often reveal the internal effects produced in solid objects in ways not possible through classroom sketches or textbook drawings.</td>
<td>See Transverse Shear&gt;Shear Flow&gt;Determine nail spacing for U beam as an example of augmenting traditional static two-dimensional illustrations with three-dimensional animations to demonstrate the purpose and rationale associated with an aspect of theory.</td>
</tr>
<tr>
<td>Multiple representations are used to help learners construct inter-related knowledge.</td>
<td>Media elements are of high…quality.</td>
</tr>
<tr>
<td>Media elements are of high…quality.</td>
<td>The MecMovies graphical elements are outstanding.</td>
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MecMovies does not include alternative media types. Early prototypes containing audio narration received mixed reactions from students. While some students liked audio narrations, many students found a voice-over to be distracting. On the technical side, movies with audio narration are on the order of 10-20 times larger than non-audio movies, making them much slower to use over the Internet and less reliable in operation. These factors led to a decision to defer audio content until Internet delivery technology (e.g., modem speeds) is faster.
## MecMovies: Instructional Software for Mechanics of Materials

Multimedia elements are clearly labeled… | MecMovies animations and illustrations generally begin with a broad context before focusing on a specific aspect of theory. This approach has proven successful in helping the learner to visualize theoretical considerations in a larger context.
---|---
The software has multimedia elements that…are interactive… | See Combined Loadings>Gen Combined Loads>Up periscope and Combined Loadings>Axial Bending Shear>Beams bending about two axes as examples of user interactivity with three-dimensional graphics.

### 1.6 Instructional Use/Adaptability: The software can be used in a variety of settings.

| Part 1 | The intended use is not so narrowly defined that only a select few could use this software. | While the software primarily focuses on the Mechanics of Materials course, portions of MecMovies have been used to supplement Statics classes (see Games and Tools>Section Properties>The Centroids Game and Games and Tools>Section Properties>The Moment of Inertia Game). MecMovies may also be used to supplement the Machine Design course.
|---|---|
| There are suggestions in the instructors’ guide or mechanisms in the software to assess learning. | Roughly half of the movies in the software include some sort of interactive exercise in which learners are asked to respond to questions or to perform a calculation. In all cases, a printable report form is included that can be turned in to the instructor. (While an automated grade recording and reporting database approach could be incorporated into MecMovies, a conscious decision was made to keep MecMovies “low-tech” in this regard at this time so that the widest possible variety of schools and institutions, both domestically and internationally, could begin using MecMovies without the overhead of login accounts, database records, and other problems associated with using software based on another institution’s servers.)

### Part 2

| The software provides different use levels… | MecMovies does not have explicit user levels.
| Help functions and guides are provided. | Instructions are provided within each movie as necessary.
| There are instructor configurable software settings. | MecMovies is packaged in a form that permits it to be installed locally on an institution’s web site. Instructors may configure the sequence of topics (i.e., the gold menu buttons in the left frame) as desired. Additionally, instructors can prepare specific assignment sheets (see the gold menu button labeled Assignments) for their classes.
| …suggestions for alternate uses | Suggestions are offered in the instructors’ guide.
| This software has potential to improve the way instructors spend their time. | The individualized drill-and-feedback on foundational concepts and skills provided to learners by MecMovies can and has altered the way that instructors spend their classroom time. The percentage of classroom time devoted to elementary concepts (and sometimes remedial work) has been reduced, which allows more time for the instructor to focus on higher-order thinking and problem-solving skills.

### SOFTWARE DESIGN

#### 2.1 Engagement: The software holds the interest of a diversity of learners.

| Part 1 | Software is stimulating and challenging. | Student feedback has been overwhelmingly positive.
| Software does not contain stereotypes. | Stereotypes are not present in MecMovies.
| Speed of software is satisfactory. | Considering that the software is delivered over the Internet, the software speed is excellent. Every effort has been made to keep individual movie sizes small.
| The software is visually appealing and attractive… | MecMovies is very attractive and professional in appearance.
| The learner would use it more than once. | Feedback and tracking data show that learners do use the software more than once.

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http://web.umr.edu/~mecmovie/index.html
Learner-tailorable interface settings… | There are no learner-tailorable interface settings.
---|---
Consideration for learners with physical impairments. | With regard to motor impairment, most movies require only simple mouse clicks to navigate and use. There has been no provision for visually impaired users.
The software promotes diversity and gender equity. | While MecMovies does not promote diversity and gender equity, these issues generally do not arise in the consideration of Mechanics of Materials problems. Formative assessment studies reveal no significant differences in learner performance or learner opinions according to either gender or race.

## 2.2 Learner Interface and Navigation: The software is easy to use.

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<tr>
<td>The software is consistent in its design and response to learner actions.</td>
<td>The software is consistent in its design for all example problems and theory presentations. Learning games have been intentionally developed in different styles (i.e., fonts, color palettes, etc.) to provide more interest, variety, and fun.</td>
</tr>
<tr>
<td>The learner will not get confused about how to proceed.</td>
<td>The software is very easy to use and simple to navigate. In fact, the table of contents (which appears after a gold menu button is clicked) mimics the Scene Selection option incorporated in all commercial DVD movie disks.</td>
</tr>
<tr>
<td>The learner can form a mental map…</td>
<td>MecMovies is simple to navigate and the main menu is always present in the left frame.</td>
</tr>
<tr>
<td>…graphical symbols are clear and unambiguous.</td>
<td>Symbols are clear and consistent with traditional course usage.</td>
</tr>
<tr>
<td>There are multiple forms of navigation (e.g., table of contents, next/previous, index, and search).</td>
<td>There are multiple forms of navigation. A menu of primary topics is always present in the left frame. Within each topic, there are several subtopics. Available movies for each topic and subtopic are clearly identified by a screenshot picture, a movie title, features found in the movie, and a brief description of the movie purpose. Within each movie, both linear and non-linear navigation is provided. Next/previous/continue buttons are provided at the bottom of each movie scene. In the upper right hand corner, a drop-down menu can be accessed to allow users to proceed directly to specific scenes.</td>
</tr>
<tr>
<td>Screens can be viewed without scrolling.</td>
<td>Screens do not require scrolling.</td>
</tr>
<tr>
<td>Text on screens is appropriately scaled and cannot be erased.</td>
<td>Font sizes and styles have been chosen for easy readability. On-screen text cannot be erased.</td>
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## 2.3 Technical Reliability: The software is free from technical problems.

<table>
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<tbody>
<tr>
<td>There are no obvious software bugs.</td>
<td>Entire classes of students have successfully used MecMovies for several semesters.</td>
</tr>
<tr>
<td>There are no interface problems…</td>
<td>The MecMovies interface is attractive yet simple, functional, and easy to use.</td>
</tr>
<tr>
<td>Software crashes occur very rarely, if at all.</td>
<td>Software reliability has been excellent. The software is written in Macromedia Flash, which has an excellent performance history.</td>
</tr>
<tr>
<td>Screens can be viewed without scrolling.</td>
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## ENGINEERING CONTENT

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COMPREHENSIVE EVALUATION OF ANIMATED INSTRUCTIONAL SOFTWARE FOR MECHANICS OF MATERIALS

Timothy A. Philpot and Richard H. Hall

Abstract - During the past three years, the Basic Engineering Department at the University of Missouri – Rolla has been developing a second-generation suite of instructional software called MecMovies for the Mechanics of Materials course. In the Fall 2003 semester, MecMovies was integrated into assignments throughout the entire semester for one of the six UMR Mechanics of Materials sections. This paper presents a comparison of student performance in the experimental section with student performance in five control sections along with discussion of student qualitative ratings and comments.

Index Terms – animations, assessment, instructional software, mechanics of materials.

INTRODUCTION

The Mechanics of Materials course, one of the core courses for students in a number of engineering and engineering-related disciplines is usually taken in the sophomore or junior year. The course introduces students to fundamental principles involved in designing typical components found in machines and structures such as drive shafts; floor beams, pressure tanks, and bolted connections. The course explores various common structural components, teaching students how to analyze the effects of forces and loads on the internal stresses and deformations in the components.

While these components are three-dimensional objects, students are generally taught about these objects through static, two-dimensional illustrations in textbooks and on the classroom board. As educators, we have an understanding of the components and processes that constitute our discipline…we can visualize these things in our mind’s eye. One of the initial challenges we face is conveying our visual understanding to our students. Once this foundation is laid, we can proceed to establish an understanding of the relevant theory and to develop the problem-solving skills needed to become proficient in specific topic areas.

Computer-based instruction offers new capabilities that can enhance the student’s understanding of mechanics of materials. With three-dimensional (3d) modeling and rendering software, it is possible to create photo-realistic images of various components and to easily show these components from various viewpoints. Animation software allows objects or processes to be shown in motion. By combining these two capabilities, a fuller description of a physical object can be presented to the student. Better images can facilitate the mental visualization that is so necessary to understanding and solving engineering problems in this subject area.

Animation also offers a medium for a new generation of computer-based learning tools. The traditional instructional device – example problems – can be greatly enhanced through animation to emphasize and illustrate desired problem solving thought processes in a more memorable and engaging way. Animation can also be used to create interactive tools that focus on specific skills students need to become proficient problem-solvers. These computer-based tools can provide not only the correct solution but also a detailed visual and verbal explanation of the process needed to arrive at the solution. Since these learning tools are available on the Internet, students have easy access to them. They can use them at times that suit their study habits, and they can work with the learning tools without external pressure until they feel comfortable with their understanding of a topic.

Students generally respond favorably to instructional software; however, much of data that has been gathered to assess the effectiveness of this type of instructional software has been anecdotal. The method by which instructional software is incorporated into the engineering class is partly responsible for this lack of systematic evaluation. Often, software packages have been implemented in the classroom as supplemental material – recommended but not required.

During the past three years, the Basic Engineering Department at the University of Missouri – Rolla (UMR) has been developing a second-generation suite of instructional software called MecMovies targeting the Statics, Dynamics, and Mechanics of Materials courses. For the Mechanics of Materials course, the MecMovies software suite consists of over 100 animated example problems, drill-and-practice games, and interactive exercises. In the Fall 2003 semester, MecMovies was integrated thoroughly into the course assignments for one of the six UMR Mechanics of Materials sections. Four professors were involved in the study, and student performance in the experimental MecMovies section was compared to performance in the other five control sections throughout the semester by means of common problems included on the four mid-course exams and through a common final exam. At the end of the semester, students who used the MecMovies software also completed a survey questionnaire consisting of a number of subjective rating items. This paper presents a comparison of student performance in five control sections along with discussion of student qualitative ratings and comments.

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final exam performance in the experimental and control sections along with discussion of student qualitative ratings and comments.

**MecMovies**

Use of the computer as a medium for instruction provides many capabilities that cannot be readily duplicated within the traditional lecture format. The motion and deformation of common engineering objects can be realistically depicted with animation. Sophisticated graphics including photorealistic, rendered, three-dimensional solids can greatly improve visual communication. Concepts that are difficult for the student to visualize based solely on static, two-dimensional images become much more understandable when computer graphics are combined with animation techniques. Desired mental processes such as problem-solving methodology are demonstrated and reinforced through animation and repetition. Altogether, computer-based materials can provide instruction that capably addresses many of the visual and verbal needs of learners. Effective software can become a tool that students use to attain proficiency in the subject area.

A large number of animated example problems are included in MecMovies. These example problems offer several advantages over traditional static, two-dimensional presentations. A number of topics discussed in Mechanics of Materials involve three-dimensional geometry and loading. Such topics are difficult to adequately describe to students using hand-drawn illustrations in class. For these types of topics, three-dimensional rendering and animation software can be quite effective in presenting a clearer explanation of the concepts involved. A MecMovies example that utilizes 3d rendering and animation is shown in Figure 1.

Animation is also used to clearly demonstrate concepts. An example involving beam flexure is shown in Figure 2. In this example, the effects of positive and negative bending moments acting on a small beam length are graphically demonstrated. The image of the deformation in motion often fosters greater understanding of the concepts.

The Mechanics of Materials course is a problem-solving course, and many of the MecMovies animations seek to more clearly and more memorably explain the procedure required to solve various problems. An example involving a moment of inertia calculation of a shape comprised of standard steel shapes is shown in Figure 3.

The computer as an educational medium provides a wide array of possibilities for interaction between the student and the software. A number of MecMovies animations include a feature called “concept checkpoints.” The purpose of concept checkpoints is to encourage students to immediately apply the concepts and procedures presented in the animations.

For some topics, a simple multiple-choice format can be effective. Most Mechanics of Materials topics, however, are better suited by a numeric response format (Figure 4). In these cases, a problem is presented to the student that requires only a few basic calculations to answer. After the
student enters their calculation results, the software indicates whether the answer is correct or incorrect. Should the student enter an incorrect value, the software will, in many instances, provide a brief explanation of the correct solution procedure (Figure 5).

It is often assumed that repetition leads to proficiency; however, few students relish working dozens of problems on a particular topic. To make the learning process more enjoyable, repetition and drill on a specific topic can be encapsulated in a game context. Through the challenge of the game, the student can receive the benefits of repetition without the sense of labor that they might feel otherwise. A game context provides students with a structure for learning and permits students to develop their skills at their own pace in a non-judgmental but competitive and often fun environment. Since the computer is a medium that is well suited for repetitive processes and for numeric calculations, computer-based games focused on specific calculation processes offer great potential as a new (or perhaps updated) type of learning tool for engineering mechanics courses. An example image taken from the Moment of Inertia Game: Starting from Square One game is shown in Figure 6. Several games such as this one are included in MecMovies. They are focused on fundamental calculations such as centroids, moments of inertia, and Mohr’s circle transformations that are building blocks employed to solve problems and develop designs in a variety of situations.

INCORPORATING MECMOVIES INTO CLASS

Experience has shown that students will generally not begin to take advantage of instructional software unless they are required to do so in some manner. In the 2003 Fall Semester, students in one section of the Mechanics of Materials course were given approximately 25 MecMovies assignments. Generally, these assignments replaced one regular homework problem with a comparable assignment consisting of a concept checkpoint or a game. In each MecMovies assignment, a summary form incorporated in the movie was printed out and turned in for homework credit by the student.

As an instructional medium, the computer is very well suited to repetitive tasks while it is less well suited for topics requiring intuition, experience, or other less quantifiable reasoning. The MecMovies homework assignments focused on introductory concepts, fundamental calculation skills, and areas that have consistently been difficult for students to master. The concept checkpoints features usually consist of 4-10 questions, and early in the semester, it was made clear to students that they should continue working with these assignments until they achieved a perfect or near-perfect score. Students were free to work with the software modules at their own pace, repeating the concept checkpoints and the games until they attained proficiency. The educational objective for assignments of this type was to establish a firm conceptual basis in the fundamentals outside of class so that the limited class time could be devoted to the higher-order thinking skills and the more difficult calculation procedures.
ASSessment of MecMovies

During the 2003 Fall Semester at UMR, four professors taught six Mechanics of Materials sections to 167 students. For the assessment, one section consisting of 29 students was the experimental group and the remaining five sections served as the control group. A common final exam is given for the UMR Mechanics of Materials course, and this final exam score served as a quantitative measure in comparing the performance of the experimental and control groups. The experimental group was also asked to complete a questionnaire in which they gave quantitative ratings and comments to a number of statements concerning MecMovies, and as a basis for comparison, the course textbook and the course lectures.

Comparison of Final Exam Performance

In order to compare the exam scores for students in the section that included MecMovies with those in sections that did not, an Analysis of Covariance was computed with section (experimental vs. control) as the independent variable, exam score as the dependent variable, and grade point average (GPA) as a covariate. (Using GPA as a covariate removes variance for GPA and adjusts the statistical-significance-probability estimate and means based on the relationship between GPA and exam scores).

A perfect score on the final exam was 200 points. The GPA-adjusted mean score for students in the experimental section was 161.88 while the GPA-adjusted mean score for the control group was 154.04, a difference that translates into a 4% higher mean final exam score for students in the experimental group. This Analysis of Variance was statistically significant $F(2, 164) = 5.62, p < 0.05, \eta^2 = 0.03$.

To examine the mediational effect of students’ GPA, a 2-way between-subjects analysis of variance was performed. Group (experimental vs. control) and GPA group (based on a median, high vs. low split) served as independent variables and exam scores served as the dependent variable. There were no non-redundant statistically significant effects.

Student Ratings for Experimental Group

At the end of the Fall semester, students in the experimental group were asked to complete a questionnaire in which they responded to Likert-type statements using a 9-point scale where 1 = “strongly disagree” and 9 = “strongly agree.” To provide a basis for comparison within the group, students were presented with five similar statements for each of three modes of instruction: (a) classroom lectures, (b) course textbook and textbook homework assignments, and (c) the animated movies. These three instructional components are subsequently referred to as instructional modalities. A portion of the questionnaire used in assessing the effectiveness of MecMovies as used throughout the semester is shown below. Mean values for the student ratings are summarized in Table I.

1. The (modality a, b, or c) were very important in helping me to become proficient in the problem-solving techniques needed for Mechanics of Materials.
2. The (modality a, b, or c) helped me visualize Mechanics of Materials concepts.
3. The (modality a, b, or c) increased my confidence about Mechanics of Materials.
4. The (modality a, b, or c) helped me clearly identify the things I know well and the things I need to work on concerning Mechanics of Materials topics.
5. I thought the time spent on (modality a, b, or c) was a worthwhile use of my study time.

To examine differences among students’ ratings of the three instructional modalities, a series of five within-subjects analyses of variance were computed, one each for the five sets of questions that referred to a comparison of these modalities. In each of these analyses, instructional modality served as the independent variable (lectures vs. textbook assignments vs. MecMovies) and students ratings served as the dependent variable in each ANOVA.

The ANOVA that used the questions regarding visualization was statistically significant $F(2, 46) = 4.79, p < 0.05, \eta^2 = 0.18$. Tukey post hoc tests indicated that the mean for the MecMovies rating was significantly higher than the textbook assignments rating. Although the MecMovies ratings were also higher on three of the four other ratings sets, these effects were not significantly different nor were the effect sizes beyond a medium level.

<table>
<thead>
<tr>
<th>Questionnaire Statement</th>
<th>Modality</th>
<th>Classroom Lectures</th>
<th>Textbook Assignments</th>
<th>MecMovies Assignments</th>
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</thead>
<tbody>
<tr>
<td>1. Problem-solving techniques</td>
<td></td>
<td>7.38</td>
<td>7.42</td>
<td>7.17</td>
</tr>
<tr>
<td>2. Visualization*</td>
<td></td>
<td>7.17</td>
<td>6.63</td>
<td>7.96</td>
</tr>
<tr>
<td>3. Confidence</td>
<td></td>
<td>7.17</td>
<td>6.88</td>
<td>7.42</td>
</tr>
<tr>
<td>4. Identify things I know well (metacognition)</td>
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<td>6.89</td>
<td>6.75</td>
<td>6.92</td>
</tr>
<tr>
<td>5. Worthwhile use of study time.</td>
<td></td>
<td>7.29</td>
<td>7.54</td>
<td>7.46</td>
</tr>
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</table>

*p < 0.05

To examine the mediational effect of students’ GPA in these ratings, a series of five 2-way, mixed analyses of variance were performed. Modality (lecture vs. textbook vs. MecMovies) again served as a within subjects’ independent variable and GPA group (based on a median, high vs. low split) served as a between-subject independent variable. Student ratings for each of the categories of comparison again served as the dependent variable.
There were no statistically significant, non-redundant effects. However, the interaction between ratings of how worthwhile the modality was and GPA was marginally significant, and the effect size was medium to large based on Cohen’s (1969) criteria – $F (2, 44) = 2.90, p = 0.07$, $\eta^2 = 0.12$. The means associated with this interaction are displayed in Table II.

### Table II

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<th>Modality</th>
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<td>High</td>
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<td>Classroom Lectures</td>
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<td>Textbook and textbook</td>
<td>8.17</td>
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<tr>
<td>MecMovies assignments</td>
<td>6.92</td>
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Further investigation on a student-by-student basis for the five questionnaire statements reveals additional insights. For each student, the difference between their numeric ratings for the MecMovies and textbook assignments was noted for each of the five questionnaire statements. (The textbook assignments modality was used as a benchmark since these types of homework assignments are nearly universal in Mechanics of Materials courses.) Using this measure, a positive difference could be interpreted as an indication of student approval or endorsement of the new MecMovies assignments in regard to the questionnaire statement. (In other words, a positive difference indicates that the student thought MecMovies was somewhat more effective than the traditional textbook-based assignment.)

Approximately two-thirds of the experimental group indicated that MecMovies was helpful regarding visualization (Table III). Approximately half of the class rated MecMovies higher than the textbook assignments in the problem-solving proficiency, course confidence, and worthwhile study time questionnaire statements.

Approximately 40% of the experimental group rated the textbook-based assignments higher than MecMovies in regards to problem-solving proficiency and metacognition. Such findings are not surprising. By the time they reach the university level, students have often developed study habits that work relatively well for them. For example, further examination of the problem-solving ratings revealed that five of the nine students who rated the textbook assignments higher than the MecMovies assignments (i.e., 21% of the experimental group) had a GPA greater than 3.50. Our assessments occasionally come across very successful students who are strongly disinclined to experiment or try out innovations such as those being developed in the MecMovies project, preferring instead to stick with the techniques that they know work well for them.

As a broad generalization, a majority of the students in the experimental group rated MecMovies higher than the traditional assignments while a smaller number of students rated MecMovies lower – often markedly lower – than the traditional assignments. This dichotomy is not readily apparent from a cursory comparison of mean ratings values. Additional insights can also be found in the student comments (presented below).

### MecMovies Impact on Student Attitudes

Two additional statements were included on the questionnaire to investigate possible effects on student attitudes concerning the Mechanics of Materials course.

6. The animated movies helped me to be more interested in Mech of Materials than I would have been otherwise.

7. The animated movies helped me to like Mechanics of Materials more than I would have otherwise.

A histogram showing the frequency of student ratings for these two questionnaire statements as well as the ratings for MecMovies statement 3 (i.e., the animated movies increased my confidence about Mechanics of Materials) is presented in Figure 7. In the histogram, ratings are grouped according to strength of agreement with the questionnaire statement, where weak agreement is defined as a student rating of 1, 2, or 3 for a questionnaire statement, moderate agreement is a rating of 4, 5, or 6, and strong agreement is a rating of 7, 8, or 9. From this histogram, it is evident that approximately two-thirds of the experimental group strongly agreed that MecMovies increased their confidence and interest in the Mechanics of Materials course and that the software helped them to like the course more than they probably would have otherwise. The histogram helps to further illustrate the dichotomy in student response to MecMovies: most students were very positive about the software, but a smaller number were lukewarm or negative (preferring the familiar textbook-based instructional format). Nevertheless, most students in the experimental group felt that the software improved their course experience over what they had expected it to be before the start of the semester. Although difficult to quantify, one could suppose that improved student attitude about the course was a contributing factor in the superior performance exhibited by the experimental group on the common final exam.
On the questionnaire, students were also asked to comment on their overall evaluation of the animated movies. The following are representative comments concerning the overall software package as an addition to the course:

- They explained the material thoroughly and could be accessed at anytime of the day. They helped answer my questions and reinforce an understanding of the topic.
- They allow the student to go over difficult concepts and understand them better than the lecture alone. They were the most useful tools for me when studying for a test.
- I liked the fact that each movie was different. It helped keep me interested.
- The software was, by far, the best possible thing for me. I enjoyed it and learned a lot.
- Animation better than pictures for Mech of Matl concepts. Done well.

A number of students commented on visualization:

- Loved the movies, went through all of them. They really help you visualize what effect the forces/moments will have and to see what process you should go through in finding a solution.
- The movies were great at showing what went on in a certain problem better than a textbook ever could
- Very good at helping me visualize the concepts
- Helped to visualize things tremendously.
- Better visualization that just a problem on paper.

Students also liked the pedagogical style used in the movies.

- I thought that software was just awesome. I really like how it would start out with a multi-step process and really concentrate on the first step, then after awhile move on to the next.
- I really like how it would pound in the first step of a process before moving on to a following step. I really think it just did a great job, too, to further explain certain aspects.

There were also some minor complaints:

- The movies could get a little long sometimes.
- Some of the topics aren't detailed enough
- Some of the text describing the process was long. I know if I started skimming over it, others did too.

Students who were not particularly fond of the software had these explanations.

- …for me, the textbook problems were just more valuable, but the movies may have been more so for other people
- More like a chore than a learning experience. I did enjoy the Q game. Learned from that one.
- They were very thorough, yet that wasn't the way I learn best.
- I did not use the animated movies often because it is usually easier for me to learn by trying to work the problems and then asking questions.

**CONCLUSIONS**

The MecMovies instructional software was fully integrated into the course assignments for one of the six sections of Mechanics of Materials offered at UMR in the Fall 2003 semester. Scores on a common final exam given to all six sections (167 students total) were used to compare the performance of the experimental group with the five other sections. Statistical analysis of the data, corrected to account for student ability as indicated by cumulative GPA, revealed that there was a statistically significant difference between students who used MecMovies and those who did not. Student opinions of MecMovies, as indicated by subjective quantitative ratings and comments, were very positive. Students generally found the software to be very helpful, particularly with regard to visualization of Mechanics of Materials concepts. In addition to measurable performance improvements, student reported that using the software throughout the semester helped them to feel more confident about their understanding of course concepts, to become more interested in the course, and to enjoy the course more than they would have expected.

**ACKNOWLEDGMENT**

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**REFERENCES**

Using Games to Teach Statics Calculation Procedures: Application and Assessment

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Abstract
Computers afford opportunities for creative instructional activities that are not possible in the traditional lecture-and-textbook class format. Two computer-based interactive games for engineering statics are described in this paper. These games are designed to foster proficiency and confidence in narrowly defined but essential topics through the use of repetition and carefully constructed levels of difficulty. The game format provides students with a learning structure and an incentive to develop skills at their own pace in a non-judgmental but competitive and often fun environment. Quantitative and qualitative assessments of both games revealed that: (a) students’ quantitative ratings and comments were consistently positive; (b) students who used the games scored significantly higher on quizzes over the subject material than those who learned via traditional lecture; and (c) students rated the games as significantly more effective than the textbook as an aid for learning the material.

I. Introduction
Engineering mechanics courses such as Statics seek to develop the student’s ability to analyze basic engineering machines, mechanisms, and structures and to determine the information necessary to properly design these configurations. Fundamental calculations such as centroids and area moments of inertia are building blocks that students must employ to solve problems and develop designs in a variety of situations. Accordingly, the likelihood of a student’s success in the Statics course and in their subsequent coursework is enhanced by mastery of these fundamentals.

It is often assumed that repetition leads to proficiency; however, few students relish working dozens of problems on a particular topic. To make the learning process more enjoyable, repetition and drill on a specific topic can be encapsulated in a game context. Games have been found to be an effective method of increasing motivation, enjoyment and learning for many math and science topics that may otherwise seem boring to students (Smith, 1999; Jih, 2001; Westbrook & Braithwaite, 2001; Amory, 2002). There is evidence that such tools can be a particularly powerful for learning engineering concepts where visualization is important, such as engineering graphics (Crown, 1999). Through the challenge of the game, the student can receive the benefits of repetition without the sense of labor that they might feel otherwise. A game context provides students with a structure for learning and permits students to develop their skills at their own pace in a non-judgmental but competitive and often fun environment. Since the computer is a medium that is well suited for repetitive processes and for numeric calculations, computer-based games focused on specific calculation processes offer great potential as a new (or perhaps updated) type of learning tool for engineering mechanics courses. In this paper, games pertaining to two fundamental calculation skills – centroids and area moments of inertia – are described, and student response to these games is discussed.

II. Rationale
The procedure required to calculate the centroid location and the area moment of inertia for a composite shape is a very repetitive process. The procedure begins by subdividing an area into a collection of simple shapes such as rectangles, triangles, or circles (Figure 1). For each of the sub-areas, several values must be determined, including the area, selected distances from reference positions, and others quantities. Although the calculations required for each sub-area are elementary, the proper distances and dimensions must be used for each calculation. Students are typically exposed to several examples problems worked by the lecturer in the classroom and several more problems as part of homework assignments. However, the typical student needs to apply the centroid and area moment of inertia calculations in a greater variety of situations to become proficient.
Within the constraints of a traditional Statics course, there is generally not enough time to devote such extra attention to these topics.

The game format is well suited as a teaching tool for calculations of this type. Within the game, multiple levels of difficulty can be constructed to permit the student to build up their skills one step at a time. This compels the student to attain competency in each step of the solution process before proceeding to the next level. The game provides instant feedback, allowing the student to immediately repeat a level in order to apply the procedures correctly. Since only selected aspects are targeted in each level, the student is not overly burdened if a variety of shapes are used in each level. The games generally require 25-50 minutes to complete, and in the course of the game, the student might make computations pertaining to 30 different shape variations, many more than would typically be addressed in the traditional lecture and homework format. This variety is very important because applying calculation procedures in a number of different situations helps to develop proficiency.

The game format is also a form of active learning, and it has been successfully used at the University of Missouri – Rolla as a replacement for the traditional lecture on these topics. Rather than passively watching a lecturer perform calculations, students in a computer classroom immediately begin to perform calculations within the carefully constructed levels of the game. By awarding points for each response, games tap into the competitive nature of students to excel, and the progressive character of the game encourages their success. Furthermore, the game format removes the fear of failure. Students can make a mistake, immediately learn from their error, and rectify the mistake with no penalty other than the brief time required to repeat a level. At the completion of a games class period, students leave the computer classroom certain that they have mastered the day’s topic.

Two games developed and used at the University of Missouri – Rolla to teach centroid and area moment of inertia calculation procedures are discussed in this paper. The Centroids Game – Learning the Ropes teaches centroid calculation procedures and The Moment of Inertia Game – Starting from Square One teaches procedures for computing the area moment of inertia. Both games focus on composite shapes consisting of rectangles. Details of these games are presented below.

III. The Centroids Game

The Centroids Game was developed to help students improve their proficiency in centroid calculations. This game is constructed in multiple levels (termed rounds), designed to lead the student from recognition of a proper calculation to the ability to correctly perform the calculation.

The Centroids Game – Learning the Ropes (Figure 2) consists of six rounds. In Round 1 (Figure 2a), the student is presented with a series of shapes comprised of rectangles. A target centroidal axis is superimposed on each shape in an incorrect location. The student is asked to decide whether the true centroidal location is above or below this axis. The purpose of this round is to try to develop a student’s intuitive understanding of centroids so that they develop a sense of where the centroid should be located before they begin the calculation, rather than performing a calculation and blindly accepting whatever number they obtain. For each question in the round, students receive immediate feedback whether they answer correctly or incorrectly, and points are awarded for correct answers. After responding to all shapes in Round 1, students are shown a scorecard that indicates the points scored and the possible points in the round. At this juncture, a student may elect to repeat Round 1 to improve their score. If they do repeat the round, the game randomly shuffles the target centroidal axes so that the student sees a slightly different problem. The student may elect to repeat the round as many times as they wish before moving on to Round 2.

For Round 2, a centroid calculation presented in a tabular format is shown for a shape (Figure 2b). One of the terms in the calculation table is purposefully made incorrect, and the student is asked to identify the incorrect term. The student receives full points if they identify the incorrect term on the first attempt, but the available points are successively reduced for each unsuccessful attempt. A student could opt to randomly guess, but the odds of gaining full points for each question are not favorable. After completing Round 2, the scoreboard is again shown and the student is given the chance to repeat the round. The student may repeat only the most
recent round; therefore, a student could not opt to repeat Round 1 at this point. If the student elects to repeat the round, the questions are again randomly shuffled, and thus, students will encounter a slightly different problem each time they repeat the round.

For Round 3, a centroid calculation is presented in a tabular format; however, one area term and one distance term are left blank (Figure 2c). In Round 4, all of the distance terms are omitted (Figure 2d), and in Round 5, all of the terms are left blank (Figure 2e). In each of these rounds, the student receives points for each correct term that they enter, and as they advance through the game, the points increase with each round. The game provides feedback immediately after the student submits an answer. At the close of each round, the student is allowed to repeat the round with the problems randomly shuffled for each attempt.

In the final round, the student is presented with a dimensioned shape but no other information. The student is asked to compute the correct centroid for the shape (Figure 2f). After submitting an answer, the student is shown the correct calculation. The possible point total for this last question is set very high so that the student cannot get a good score for the entire game unless they successfully answer the Round 6 question.

IV. The Moment of Inertia Game – Starting from Square One

The Moment of Inertia Game – Starting from Square One was developed to teach students area moment of inertia calculation procedures. Similar to The Centroid Game, this game is constructed with multiple rounds that are designed to lead the student from recognition of a proper calculation to the ability to correctly perform the calculation. Points are awarded for each correct answer, and the correct values are revealed immediately after an incorrect response. Each round can be repeated as many times as desired before moving to the next round. Shapes, orientations, and values are randomly shuffled prior to the start of each round so the student will be presented with a different problem when a round is repeated.

The Moment of Inertia Game begins with a single rectangle shape (Figure 3a). The student is simply asked for the base and height dimensions needed to compute the area moment of inertia about either the horizontal or vertical centroidal axis. The intent of this first round is to emphasize the dependency of the calculation on the axis being considered. In the second round, composite shapes comprised of three rectangles are considered (Figure 3b). A tabular calculation is presented with three values omitted – one base dimension, one height dimension, and one moment of inertia value – and the student is asked to fill in the missing values. With the example provided by the table as a guide, students can deduce the correct value for the missing terms.

After the second round, the parallel-axis theorem is introduced. This calculation procedure is essential to determine the area moment of inertia for most common shapes, and it is the proper application of the parallel-axis theorem that often poses the biggest challenge in mastering the moment of inertia calculation. After a brief explanation of the theorem, the game proceeds to Round 3 where the student must use the parallel-axis theorem to compute the area moment of inertia of a single rectangle about an arbitrary set of axes (Figure 3c).

Round 4 presents composite shapes (consisting of two or three rectangles) that require the use of the parallel-axis theorem for solution (Figure 3d). A tabular computation is shown in which one value has been intentionally set to a plausible but incorrect value, and the student must select the erroneous term. To discourage guessing, the possible points for each problem are reduced for incorrect responses. In Round 5, a blank table is shown and the student must fill in the correct values for composite shapes consisting of two rectangles. Points are awarded for each correct response, and the correct values are noted for incorrect responses. In Round 6, the student must fill in the correct values for composite shapes consisting of three rectangles (Figure 3e). In all three of these rounds, the centroidal axis – either vertical or horizontal – about which the calculation should be made is alternated.

In the final round, the student must perform the complete area moment of inertia for a three-rectangle compound shape about both the horizontal and vertical centroidal axes (Figure 3f). After the response is entered, the correct values for all terms in the computation table are revealed. The point values for Round 7 are much
greater than those in previous rounds. Therefore, the student must demonstrate the ability to perform the complete area moment of inertia calculation in order to get a good score for the game.

**V. Assessment of The Centroids Game – Learning the Ropes**

In the 2002 academic year, the effectiveness of *The Centroids Game – Learning the Ropes* as a teaching tool was assessed with two undergraduate Statics classes at the University of Missouri – Rolla. Instead of the normal lecture period, students were taken to a computer lab where a computer was available for each student. During the preceding class period, students had been introduced to the topic of centroids and the process of determining centroids by integration. At the start of the assessment class period, students were given a two-minute introduction to the procedure for calculating centroids in composite bodies. They were then given 40 minutes to play the game at their own pace. An instructor was present in the computer lab to answer questions about centroids and to clarify game procedures.

The Tuesday/Thursday class period is 75 minutes long; therefore, students were allowed 60 minutes to play the game before stopping to complete a questionnaire and a post-test quiz. All students completed the game within 50 minutes with the fastest students finishing in about 20 minutes. Of the 23 students who played the game, ten achieved a perfect game score while the remaining 13 students scored 94% or better.

**Student Ratings of Effectiveness**

After playing the game, students completed a questionnaire, responding to the following Likert-type statements using a 9 point scale where 1 = “strongly disagree” and 9 = “strongly agree”.

1. After using *The Centroids Game*, I felt confident in my ability to calculate centroids for composite bodies.
2. After using *The Centroids Game*, I was able to visualize the procedure for calculating centroids.
3. After using *The Centroids Game*, I understood which cross-sectional dimensions to include in my calculations when working a centroids problem.
4. *The Centroids Game* helped me to recognize how much I know and don’t know about the procedure for calculating centroids.
5. I found *The Centroids Game* to be motivational concerning the procedure for calculating centroids.
6. I liked playing a game to help me get better at calculating centroids.
7. I learned a great deal about the procedure for calculating centroids from *The Centroids Game*.
8. I learned a great deal about the procedure for calculating centroids from my Statics textbook (Spring 2003 only).
9. I thought the time spent playing *The Centroids Game* was a worthwhile use of my study time.
10. The procedure for playing *The Centroids Game* was easy to understand.
11. The number of questions and the number of rounds used in *The Centroids Game* seemed about right to me.
12. Give your overall evaluation of *The Centroids Game* on the procedure for calculating Centroids, using the 1…9 scale, with 1 being very poor and 9 being outstanding.

The survey results for both Fall and Spring Statics classes are summarized in Table 1. (The table also includes results from *The Moments of Inertia Game* survey, which are discussed below). Mean values for responses to each of the survey questions listed above are shown in the table. These results show uniformly strong agreement with the survey statements for both classes, indicating that students felt that *The Centroids Game* was helpful, both in clarifying procedures used in centroid calculations and in fostering calculation proficiency. They also enjoyed playing the game and felt that *The Centroids Game* was a worthwhile use of their study time.
Students were also asked to comment on their overall evaluation of *The Centroids Game*, and their comments were consistently positive, as characterized by representative comments such as:

- “I think it's a much easier way to do homework and I did 10 times as many problems as I normally do. I have this concept down very well.”
- “Easy to understand. Helps to teach by progression…easy-to-hard.”
- “It showed me everything I didn't know and allowed me to learn.”
- “Most fun I've had while learning in a long time.”

To compare student ratings of *The Centroids Game* with their textbook, survey statement 8 was added to the Spring 2003 questionnaire. The responses to statement 7 were compared with the responses to statement 8, using a within-subjects t-test. This test indicates whether or not the mean response to one of the statements differs significantly from the other. This test was statistically significant \(t(22) = 10.098, p < .001\). On a scale of 9, students’ agreement with the statement that they learned a great deal from the game was more than two times higher (Mean = 7.35) than their rating of the same statement for the textbook (Mean = 3.17).

### Impact of Game on Learning
In the Spring 2003 assessment experiment, a single-problem quiz was administered to students at the end of the class period following completion of *The Centroids Game* exercise. To serve as a control group, students in four additional Statics sections were also given the same quiz. None of the students in the control groups had exposure to *The Centroids Game*. Students in the control group took the quiz either one class period or two class periods after the topic of centroids of composite areas had been discussed in lecture. Students in the control group, therefore, had some opportunity to review notes and work assigned homework problems in the
days following their in-class exposure to this topic. Students in both the experimental and control groups, however, were not told about the quiz before the class period in which it was administered.

The quiz question is shown in Figure 4. Students were asked to compute the vertical location of the centroid for a double-tee shape. Quizzes were marked correct if the student reported the centroid location as 60 mm from the top or 120 mm from the bottom of the shape. For the purposes of this study, any other response was counted as incorrect. The results of the quiz are shown in Table 2.

<table>
<thead>
<tr>
<th>The Centroids Game Quiz Results</th>
<th>Total Number of Students</th>
<th>Correct Responses</th>
<th>Incorrect Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students who played The Centroids Game</td>
<td>23</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>Students in control group</td>
<td>91</td>
<td>55</td>
<td>36</td>
</tr>
</tbody>
</table>

\[ \chi^2(1) = 10.50, \ p < .01 \]

An analysis was conducted to compare problem scores for students in the test group with those in the control group. Since these data consisted of dichotomous data, a Pearson Chi-Square was computed to test for significant differences in the distribution of correct and incorrect responses between the groups (test vs. control). This test was statistically significant, indicating that those in the centroids game group performed significantly better on the quiz problem than those in the control group.

VI. Assessment of The Moment of Inertia Game – Starting from Square One

The quantitative results from the Spring 2003 Centroids Game assessment were very encouraging. In fact, the results seemed too good to be true. There was some question as to whether students in the test group performed better on the quiz because the quiz was administered immediately after completing the game exercise. To investigate further, a similar game was developed to teach the area moment of inertia calculation procedure for composite areas. Similar to the centroids procedure, the area moment of inertia calculation procedure is very repetitive; however, more calculations are required and the calculations are a bit more complicated.

An experimental procedure similar to The Centroids Game was used to assess The Moment of Inertia Game, and the same Spring 2003 Statics class was used in the study. During the class period before the assessment experiment, students had been introduced to the topic of area moments of inertia and the process of determining this property by integration. On the day of the assessment, students were taken to a computer lab where a computer was available for each student. The students were given a two-minute introduction to the procedure for calculating moments of inertia in composite bodies and then allowed to start the game. As before, an instructor was present in the computer lab to answer questions about moments of inertia and to clarify game procedures.

The Tuesday/Thursday class period is 75 minutes long; therefore, students were allowed 65 minutes to play the game before stopping to complete a questionnaire similar to the centroids questionnaire. All students completed the game in this period with the fastest students finishing in about 40 minutes. Of the 23 students who played the game, 11 achieved a perfect game score, 8 more scored above 95%, and the remaining four students scored between 81% and 87%. Students completed a quiz over the material at the beginning of the next class session.

Student Ratings of Effectiveness

After playing the game, students completed a questionnaire similar to that used for The Centroids Game, responding to Likert-type statements using a 9 point scale where 1 = “strongly disagree” and 9 = “strongly agree”. The survey results are included in Table 1. Mean values for responses to each of the survey questions
are shown in the table. These results are very similar to those obtained from The Centroids Game. Student ratings were uniformly near the top of the scale, indicating that they thought the game was useful, they enjoyed playing the game, and they felt it was a worthwhile use of their time.

To compare student ratings of The Moment of Inertia Game with their textbook, the responses to statement 7 were compared with the responses to statement 8, using a within-subjects t-test. This test indicates whether or not the mean response to one of the questions differs significantly from the other. This test was statistically significant t(22) = 6.86, p < .001. On a scale of 9, students’ agreement with the statement that they learned a great deal from the game was almost four times as high (Mean = 7.87) as their rating of the same statement for the textbook (Mean = 2.17).

Two open-ended questions were included in The Moment of Inertia Game questionnaire to explore students’ perceptions of instructional software in general, particularly after having just had an experience with the game.

- Are there things you really dislike about instructional software? Do you think software is a waste of time or just no-good? What really bugs you about this stuff?
- Are there things that you really like about instructional software? Have you tried instructional software? Are there any programs that you think are really good?

Students’ responses to these open-ended questions were combined and categorized according to themes. Two themes that emerged from students’ comments and some representative student comments are presented below:

**Theme 1.** Students felt very positive about instructional technology in general and The Moment of Inertia Game in particular. The principle advantages cited were (a) immediate feedback, (b) aid in visualization, and (c) increase in motivation and enjoyment.

(a) Immediate Feedback
- “It's a great way to do homework and it gives you the correct answers right away – that way I KNOW I'm doing it right, every time.”
- “I enjoyed…the instant results, right or wrong.”
- “Working lots of problems and getting immediate feedback is the only way to learn this stuff.”

(b) Aid in Visualization
- “If it is good visually and outlines steps, it can be very helpful.”
- “Easy to see what's going on.”

(c) Increase motivation and enjoyment
- “I like instructional software and think it's fun.”
- “I enjoyed it thoroughly. I like the competitive view, try to get the better score.”
- “I really like it. It taught me and I learned fast.”
- “Can do problems at my own pace.”

(d) The Moments of Inertia Game in Particular
- “This was one of the better instructional programs I have used. Really covered material well. Usually, instructional software is long, impersonal, and hard to understand.”
- “I really like the software. It helps you understand the problems without all the number crunching.”
- “It was an interesting approach to this topic.”

**Theme 2.** It is important that instructional software is integrated with the class and instructor.
- “I like it in class if the prof is walking around helping.”
- “I think it (instructional technology) is a good idea, but must be assigned in class.”
- “Needs to be promoted, maybe not required”
- “I think it is good but I probably wouldn't use it if I didn't have to.”
Impact of Game on Learning
To compare students who used *The Moment of Inertia Game* to those who learned in a traditional lecture, the test class was compared with a control group of three Statics classes that had not used the game. Students in both the test group and the control group were given a brief quiz at the beginning of the class period after moments of inertia for composite areas had been presented, either by the game or in a lecture. Students in both groups, therefore, had some opportunity to review notes and work assigned homework problems in the two days following their in-class exposure to this topic. This assessment differed from *The Centroids Game* assessment in that students in both the test and control groups were told in advance about the upcoming quiz.

The quiz question is shown in Figure 5. Students were asked to compute the area moments of inertia $I_x$ and $I_y$ for a tee-shape about both the horizontal and vertical centroidal axes, respectively. The vertical location of the centroid was explicitly given. Quizzes were graded and grouped into three categories: 100% correct if the student correctly determined both $I_x$ and $I_y$, partially correct if the student correctly determined either $I_x$ or $I_y$ or if they simply made a calculation error while performing the correct procedure, or 100% incorrect if the student did not demonstrate understanding of the proper calculation procedure. The results of the quiz are shown in Table 3.

<table>
<thead>
<tr>
<th>Moment of Inertia Quiz Results</th>
<th>Total Number of Students</th>
<th>100% Correct Responses</th>
<th>Partially Correct</th>
<th>100% Incorrect Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students who played <em>The Moment of Inertia Game</em></td>
<td>23</td>
<td>20 (87%)</td>
<td>2 (9%)</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Students in control group</td>
<td>55</td>
<td>26 (47%)</td>
<td>14 (25%)</td>
<td>15 (27%)</td>
</tr>
</tbody>
</table>

$\chi^2(2) = 10.71$, $p < .01$

Since these are categorical data, a Pearson Chi-square analysis was again used to test for statistical significance between the distributions of scores for those in the test group versus those in the control group. The Chi square test was statistically significant $\chi^2(2) = 10.71$, $p < .01$. The frequencies displayed in Table 3 indicate that the significant Chi square was due to the fact that virtually all of the students in the test group scored 100% correct on the quiz while over half of the students in the control group received partially correct or 100% incorrect.

VII. Conclusions
Two simple, computer-based games have been developed to help engineering students develop proficiency and confidence in narrowly defined but essential topic areas. The games use repetition and carefully constructed levels of difficulty to lead students toward improved skills. The game format provides students with a learning structure and an incentive to develop skills at their own pace in a non-judgmental but competitive and often fun environment. Student response to these games has been consistently positive.

The assessments conducted for the games discussed in this paper were particularly positive indicating that students perceived the game as very effective, and this perception was consistent with objective learning outcomes. More specifically, students rated the games as significantly more effective than the textbook as an aid in learning the material. Most importantly, student learning of these specific topics was significantly higher when the course subject material was presented in a game format rather than a traditional lecture.

Games appear to be an effective teaching tool for fundamental engineering topics that require repetition or practice to master. Games seem to work in this context for several reasons. A game can be used to partition a somewhat complicated procedure into a series of skills necessary to master the topic, thus providing a learning outline for students. Students can freely repeat portions of the game as many times as necessary without penalty.
and with instant feedback at every stage so that they become aware of what they know and what they don’t know, which is very motivating for students. Computer-based games offer possibilities for animation and realistic rendering that can help to communicate concepts visually to students. The game exercise, if conducted as a class session in a computer laboratory, provides an opportunity for the lecturer to become a coach who can provide individualized instruction as needed. Compared to students who learned about centroids and area moments of inertia in the traditional lecture setting, students who used these games demonstrated proficiency much more rapidly, and what’s more, they enjoyed the learning method.

VIII. Acknowledgement
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IX. References


Web Address
Materials presented in this paper are available via the Internet at: http://web.umr.edu/~bestmech/preview_mechmatl.html

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Figure 2 – The Centroids Game: Learning the Ropes
Figure 3 – The Moment of Inertia Game: Starting from Square One
Compute the location of the centroid in the vertical direction for the shape shown.

(a) Compute the moment of inertia of the shaded area with respect to the x-axis.

(b) Compute the moment of inertia of the shaded area with respect to the y-axis.
Links to Papers Published on the Internet

http://www.ijee.dit.ie/OnlinePapers/Interactive/Philpot/philpot_media_mm.htm

http://imej.wfu.edu/articles/2003/1/04/index.asp
List of Publications Pertaining to the Project

Refereed Publications


Peer-Reviewed Conference Publications


MecMovies: Instructional Software for Mechanics of Materials


Non-Refereed Publications

Questionnaire Description:

On the questionnaire that follows, you will be asked to answer questions that will help us to evaluate instructional media currently being developed at UMR for topics in undergraduate Basic Engineering classes. Your responses will be completely confidential. Neither your instructor nor those scoring the data will see your name associated with your responses.

I, ___________________________ (please print your name), have read the above statement regarding the nature of this experiment and give the researchers permission to use data collected during this experiment. I understand that all of these data are completely confidential. I also understand that I am free to withdraw from this experiment at any time.

Signed

____________________________________

Student number

____________________________________

Background

A group of UMR professors and staff in the Basic Engineering Department is currently working on a project to develop computer-based instructional materials for the Statics, Dynamics, and Mechanics of Materials courses. This multi-year project is funded by the U.S. Department of Education, and it is intended that the materials developed in this project will be used by students such as you in universities throughout the United States and in many countries around the world. Our purpose in developing this software is to do a better job of explaining topics from the Statics, Dynamics, and Mechanics of Materials courses and to provide you with example problems, games, learning tools, or other software applications that will help you to become more successful in these courses. To help guide us in our project, we are trying to understand what a typical student might want and use. Questionnaires such as this help us to improve our software, and we sincerely appreciate your patience and participation in studies such as this one.
Comparison of Instructional Components used in BE 110

December 12, 2003

Please use the scale below to respond to each of the statements and explain your answers in the space provided.
Thanks for your participation, your suggestions, and most of all, your patience.

Strongly Disagree  1 … 2 … 3 … 4 … 5 … 6 … 7 … 8 … 9    Strongly Agree

Section A – Class Lectures

_____ 1. The class lectures were very important in helping me to become proficient in the problem-solving techniques needed for Mechanics of Materials.
Comments:

_____ 2. The class lectures helped me visualize Mechanics of Materials concepts.
Comments:

_____ 3. The class lectures increased my confidence about Mechanics of Materials.
Comments:

_____ 4. The class lectures helped me clearly identify the things I know well and the things I need to work on concerning Mechanics of Materials topics.
Comments:

_____ 5. I thought the time spent on class lectures was a worthwhile use of my study time.
Comments:

Section B – Textbook and textbook homework assignments

_____ 6. The textbook and textbook homework assignments were very important in helping me to become proficient in the problem-solving techniques needed for Mechanics of Materials.
Comments:

_____ 7. The textbook and textbook homework assignments helped me visualize Mechanics of Materials concepts.
Comments:

_____ 8. The textbook and textbook homework assignments increased my confidence about Mechanics of Materials.
Comments:

_____ 9. The textbook and textbook homework assignments helped me clearly identify the things I know well and the things I need to work on concerning Mechanics of Materials topics.
Comments:
10. I thought the time spent on textbook homework assignments was a worthwhile use of my study time.
   Comments:

Section C – Animated movies (not including MDSolids)

11. The animated movies were very important in helping me to become proficient in the problem-solving techniques needed for Mechanics of Materials.
   Comments:

12. The animated movies helped me visualize Mechanics of Materials concepts.
   Comments:

13. The animated movies increased my confidence about Mechanics of Materials.
   Comments:

14. The animated movies helped me clearly identify the things I know well and the things I need to work on concerning Mechanics of Materials topics.
   Comments:

15. I thought the time spent on the animated movies was a worthwhile use of my study time.
   Comments:

16. The animated movies in this course helped me to be more interested in Mechanics of Materials more than I would have been otherwise.
   Comments:

17. The animated movies in this course helped me to like Mechanics of Materials more than I would have otherwise.
   Comments:

Section D – MDSolids homework assignments

18. The MDSolids homework assignments were very important in helping me to become proficient in the problem-solving techniques needed for Mechanics of Materials.
   Comments:

   Comments:
20. The MDSolids homework assignments increased my confidence about Mechanics of Materials.
   Comments:

21. The MDSolids homework assignments helped me clearly identify the things I know well and the things I need to work on concerning Mechanics of Materials topics.
   Comments:

22. I thought the time spent on the MDSolids homework assignments was a worthwhile use of my study time.
   Comments:

23. The MDSolids homework assignments in this course to be more interested in Mechanics of Materials more than I would have been otherwise.
   Comments:

24. The MDSolids homework assignments in this course helped me to like Mechanics of Materials more than I would have otherwise.
   Comments:

Section E – Help me with future development directions for animated movies

25. Please list what you consider to be strengths of the animated movies for Mechanics of Materials.

26. Please list what you consider to be weaknesses of the animated movies for Mechanics of Materials.

27. What suggestions could you offer for improving the animated movies for Mechanics of Materials?
28. In your opinion, what would be the best way of incorporating the animated movies into the Mechanics of Materials course?

29. Would you please list any movies that you thought were exceptionally helpful, useful, or out-of-the-ordinary (in a good way)?

30. Would you please list any movies that you thought were exceptionally confusing, pointless, or otherwise a complete waste of time?

31. Have you got any ideas or suggestions for movies that I should develop?

32. Considering all of the course topics, which topics were the easiest for you to understand?

33. Considering all of the course topics, which topics were the most difficult for you to understand?

34. Now that you’ve completed the entire course, are there any topics about which you might say, “I still don’t know why we learned that” or “I still don’t know why a person would ever need to know that?”
The Centroids Game: Learning the Ropes

March 6, 2003

Questionnaire Description:

On the questionnaire that follows, you will be asked to answer questions that will help us to evaluate instructional media currently being developed at UMR for topics in undergraduate Basic Engineering classes. Your responses will be completely confidential. Neither your instructor nor those scoring the data will see your name associated with your responses.

I ______________________ have read the above statement regarding the nature of this experiment and give the researchers permission to use data collected during this experiment. I understand that all of these data are completely confidential. I also understand that I am free to withdraw from this experiment at any time.

Signed

_____________________________

Student number

_____________________________

Background

A group of UMR professors and staff in the Basic Engineering Department is currently working on a project to develop computer-based instructional materials for the Statics, Dynamics, and Mechanics of Materials courses. This multi-year project is funded by the U.S. Department of Education, and it is intended that the materials developed in this project will be used by students such as you in universities throughout the United States and in many countries around the world. Our purpose in developing this software is to do a better job of explaining topics from the Statics, Dynamics, and Mechanics of Materials courses and to provide you with example problems, games, learning tools, or other software applications that will help you to become more successful in these courses. To help guide us in our project, we are trying to understand what a typical student might want and use. Questionnaires such as this help us to improve our software, and we sincerely appreciate your patience and participation in studies such as this one.
Please use the scale below to respond to each of the statements and explain your answers in the space provided. Thanks for your participation, your suggestions, and most of all, your patience.

Strongly Disagree  1 … 2 … 3 … 4 … 5 … 6 … 7 … 8 … 9  Strongly Agree

_____ 1. After using The Centroids Game, I felt confident in my ability to calculate centroids for composite bodies.
   Comments:

_____ 2. After using The Centroids Game, I was able to visualize the procedure for calculating centroids.
   Comments:

_____ 3. After using The Centroids Game, I understood which cross-sectional dimensions to include in my calculations when working a centroids problem.
   Comments:

_____ 4. The Centroids Game helped me to recognize how much I know and don't know about the procedure for calculating centroids.
   Comments:

_____ 5. I found The Centroids Game to be motivational concerning the procedure for calculating centroids.
   Comments:

_____ 6. I liked playing a game to help me get better at calculating centroids.
   Comments:
7. I learned a great deal about the procedure for calculating centroids from *The Centroids Game*.  
   **Comments:**

8. I learned a great deal about the procedure for calculating centroids from my Statics textbook.  
   **Comments:**

9. I thought the time spent playing *The Centroids Game* was a worthwhile use of my time.  
   **Comments:**

10. The procedure for playing *The Centroids Game* was easy to understand.  
    **Comments:**

11. The number of questions and the number of rounds used in *The Centroids Game* seemed about right to me.  
    **Comments:**

12. Technical problems with my computer or unexpected software behavior caused me to dislike *The Centroids Game* assignment.  
    **Comments:**

13. Give your overall evaluation of *The Centroids Game* on the procedure for calculating centroids, using the 1.....9 scale, with 1 = very poor and 9 = outstanding.  
    **Comments:**
14. The only way that I would use computer-based instructional materials such as *The Centroids Game* outside of class was if it was required by my professor.

Comments:

15. How do you like to study? Please rate your study habits (outside the classroom), using the 1…9 scale, with 1 = *never* and 9 = *always*.

   When I’m trying to learn Statics topics, I typically…
   a. Study alone
   b. Study with one other person
   c. Study with a group of people

16. Please rank the following study habits (outside the classroom) in order of importance to you, with 1 = *most important* to 8 = *least important*.

   When I’m trying to learn Statics topics, I typically…
   a. Study the example problems in the textbook
   b. Study my class notes
   c. Attend the Statics Learning Center
   d. Go to my professor outside of class
   e. Study old exams
   f. Work problems from the textbook in addition to the assigned problems
   g. Study the Statics Online problems and examples
   h. Other. *Please explain.*

17. Here’s an open-ended question. Are there things that you really dislike about instructional software? Do you think software is a waste of time or just no-good? What really bugs you about this stuff?

Comments:

18. Here’s another open-ended question. Are there things that you really like about instructional software? Have you tried instructional software? Are there any programs that you think are really good?

Comments:
The Centroids Game - Learning the Ropes

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<th>round</th>
<th>your score</th>
<th>points possible</th>
</tr>
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Game Over

Please enter your name:

[Field]

Game Over

The Centroids Game - Master of the Realm

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Game Over

Please enter your name:

[Field]
Quiz (10 points)

Compute the location of the centroid in the vertical direction for the shape below.
Links to MecMovies Modules and Questionnaires
Used in Fall 2003 Dissemination Study

MecMovies modules and the survey instruments can be accessed online at:

Stress transformation and Mohr’s circle stress transformations:
http://web.umr.edu/~bestmech/stress.htm

Section properties:
Instructor’s Guide
http://web.umr.edu/~mecmovie/toc/MasterList.htm

Contents:
- Suggestions for classroom implementation
- Instructions for customizing MecMovies
  - Using MecMovies on your own Web Page
  - Course sequence customization
  - Custom classroom assignment sheets