

# The Role of MDSolids in International Mechanics of Materials Education\*

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*MDSolids is educational software intended primarily for students in the Mechanics of Materials course. MDSolids has been available free-of-charge to the engineering education community since 1997, and it has been provided to hundreds of schools and universities around the world. Although MDSolids has been widely used, there has not been a formal study of its role in Mechanics of Materials education. To gather information on its use, a survey was conducted to gather information about (1) the types of learners who use MDSolids, (2) student attitudes about using the software, (3) information about how professors utilize MDSolids in their teaching, and (4) effects of MDSolids on student performance in selected topics as perceived by professors. The survey results show that MDSolids is used in all types of settings in a variety of ways. Professors note that MDSolids serves to help motivate students and that it seems to be a factor in the noticeable improvement in their students' performance in several topic areas.*

## INTRODUCTION

MDSolids is educational software intended primarily for students in the Mechanics of Materials course. The software consists of 12 modules that correspond to major topics included in the course (see Table 1). While the software performs a wide variety of calculations, it provides much more feedback to the user than simply the numerical result. Pictures, graphs, free-body diagrams, stress distributions, and animations are included throughout the software to provide visual information to the student. In many instances, a dynamic, text-based explanation is generated to explain the calculation procedure, show the equations used in the calculation, and describe the proper problem-solving approach to students. MDSolids is a *learning tool* that students can employ to develop proficiency in many fundamental aspects of the Mechanics of Materials course. There is no prescribed sequence that the student must follow in using the software, and the software is versatile enough to be used as a supplement to any textbook.

MDSolids has been available to the engineering education community since 1997. In 1998, MDSolids was a winner of the Premier Award for Excellence in Engineering Education Courseware by the National Engineering Education Delivery System (NEEDS). The software is provided free-of-charge to any educational institution for use on their campus computing facilities, and since 1997, it has been provided to hundreds of schools and universities around the world. MDSolids also appears in the textbook *Mechanics of Materials*, 2nd Ed. by Roy R. Craig, Jr.

## RATIONALE

Although MDSolids has been widely used, there has not been a formal study of its role in Mechanics of Materials education. To gather information on its use, a survey was conducted in the fall of 2002. The survey was designed to gather information about (1) the types of learners who use MDSolids, (2) student attitudes about using the software, (3) information about how professors utilize MDSolids in their teaching, and (4) effects of MDSolids on student performance in selected topics as perceived by professors. Approximately 400 professors who had previously asked for the free registration code for MDSolids were contacted by e-mail and asked to complete an online survey. Of this number, 120 professors completed the survey. Since all of the professors who were surveyed use MDSolids, there is an obvious bias in the survey. Presumably, professors who use MDSolids are likely to view MDSolids very favorably and perceive some utility and value in the software or else they would not have chosen to include MDSolids in their teaching. Also, student attitudes about MDSolids are not measured directly. The survey can only report on student attitudes as perceived by the professor. Questions included in the survey are presented in Table 2.

## DEMOGRAPHICS OF RESPONDENTS

Professors from many regions of the world participated in the survey (Fig. 7). As one might expect, the largest percentage was from North America (59%), with 48% of respondents from the United States and 11% from Canada and

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Table 1. Features of MDSolids software.

MDSolids Module	Function and Features
Problem Library	Common introductory problems used to teach stress concepts. Uses animations to illustrate concepts (for example, Fig. 1).
Trusses	Determinate truss analysis using simple drag-and-draw input (Figures 2 and 3).
Indeterminate Axial Structures	Common indeterminate axial structure configurations subjected to forces, temperature effects, gaps, and misfits.
Torsion	Simple torsion, power transmission, shafts with multiple torques, and indeterminate torsion members (with animated explanation).
Determinate Beams	Simply supported and cantilever beams. Loadings include concentrated force, concentrated moment, uniform load, linearly varying distributed load (Figure 4). Draws shear force, bending moment, slope, and deflection diagrams (Figure 5). Singularity functions.
Flexure	Computes axial, shear, and bending stresses for user defined cross sections. Stress distribution plots. Uses three-dimensional rendering to illustrate beam deformation. Other features perform beam design, determine maximum allowable beam loading, and determine stresses produced by unsymmetrical bending.
Section Properties	Common cross-sectional shapes that the user can customize with dimensions to calculate centroid location, moments of inertia, and other properties. Define and compute section properties for cross sections composed of two different materials. Includes extensive database of standard U.S. steel shapes, aluminum shapes, and timber shapes.
Mohr's Circle Transformations	Mohr's circle for stress, strain, strain rosettes, and moments of inertia (Figure 6).
Combined Loadings	Common combined loading configurations with animated explanations and three-dimensional illustrations.
Pressure Vessels	Spherical and cylindrical pressure vessels.
Columns	Euler buckling calculations with various end conditions. Several design code column equations for steel, aluminum, and wood. Column design capability.
General Analysis	General analysis routine for statically determinate or indeterminate axial structures, torsion structures, and beams.

Mexico. Countries represented in the survey are summarized in Table 3.

The types of educational institutions represented in the survey are summarized in Table 4. MDSolids is installed on the campus computing facilities at 75% of these programs. The number of students exposed to MDSolids each year in these programs is summarized in Table 5. Counting all survey respondents, roughly 8,400 students per year are exposed to MDSolids in the 120 institutions included in the survey data.

### COMPARATIVE ANALYSES

Quantitative analyses were carried out in order to examine the following questions:

1. Based on professors' perceptions, what types of learners benefit most from MDSolids?
2. Based on professors' perceptions, in what areas has student performance improved as a result of incorporating MDSolids into teaching activities?
3. How do faculty from different types of schools differ in their perception of the usefulness of MDSolids?
4. How do United States professors compare to professors in other countries in the way in which they perceive MDSolids?

To address questions one and two above, two repeated measures analyses of variance were computed with questionnaire ratings (i.e., agree/disagree) serving as the dependent measure. In the first analysis, questions 1—4 on the survey

Table 2. MDSolids survey statements.

Statement	Number
Survey Statement	(1 = strongly disagree; 9 = strongly agree)
1	I find that the students most likely to use MDSolids are . . .
2	<i>higher-ability students.</i>
3	<i>highly motivated students.</i>
4	<i>visual learners.</i>
5	<i>sequential learners.</i>
6	Students react very positively to MDSolids.
7	I require students to use MDSolids for specific assignments.
8	I have observed a noticeable improvement in the performance of my students in . . .
9	<i>truss analysis.</i>
10	<i>shear force and bending moment diagrams.</i>
11	<i>centroid and moment of inertia calculations.</i>
12	<i>beam flexural and transverse shear stress calculations.</i>
	<i>Mohr's Circle transformations.</i>
	There are activities that I now use with my students that I could not have done otherwise without MDSolids.

Table 3. Countries represented by the survey participants.

Geographic Region	Countries Represented by the Survey Respondents	
North America	United States	
	Canada	
	Mexico	
South America	Brazil	
	Columbia	
	Venezuela	
Europe	Croatia	Portugal
	France	Romania
	Greece	Russian
	Ireland	Federation
	Netherlands	Spain
	Norway	United Kingdom
Asia	Australia	Pakistan
	India	Singapore
	Indonesia	South Korea
	Malaysia	Taiwan
	New Zealand	
Africa/Middle East	Oman	
	Saudi Arabia	
	Turkey	
	United Arab Emirates	
	Zimbabwe	

Table 4. Types of Educational Institutions Represented by the Survey Participants.

Type of Educational Institution	Percentage
University	65%
College	15%
Community College	18%
K-12 Schools	2%

Table 5. Number of Students Per Year Exposed to MDSolids at Each Educational Institution

Number of Students Per Year Exposed to MDSolids At Each Educational Institution	
Mean	73
Median	60
Standard Deviation	57
Coefficient of Variation (COV)	0.79

Table 6. Types of learners perceived to benefit from MDSolids.

Types of Learners	High			
	Ability	Motivated	Visual	Sequential
Mean Value of Professor Ratings	6.36	7.54	7.55	6.36

Scale: 1 = strongly disagree; 9 = strongly agree.

• Overall effect of learners was statistically significant:  $F(3, 342) = 18.52, p < .001$ .

• Subsequent post hoc tests indicated that the means for Motivated & Visual learners were significantly higher than the means for High Ability & Sequential learners.

instrument (see Table 2), which asked professors to rate the degree to which different types of learners benefit from MDSolids, served as a within-subject independent variable. In the second analysis, questions 7–11, which asked professors to rate the effectiveness of different concepts, served as a within-subject independent variable.

Both of these analyses were statistically significant, and the means are presented in Tables 6 and 7. Following these, Post Hoc tests were computed to determine specifically which means scores significantly differed from one another. In the case of learners, faculty rated the students who were most motivated and spatial learners significantly higher in the degree to which they benefited from MDSolids than they did the high ability and sequential learners. (However, note that all ratings were quite high). In the case of the different topics, professors perceived that students improved in 'shear force and bending moment diagrams' significantly more than from 'truss analysis', 'centroid and moment of inertia calculations', or 'beam flexural and transverse shear stress calculations'. (All ratings were again quite high). No other mean comparisons were significantly different for either of these ANOVAs.

To address the third comparative question above, the comparison of different types of educational institutions, thirteen one-way between-subjects ANOVAs were computed with school (University vs. College vs. Community College) serving as the independent variable and responses to the different questionnaire items serving as the dependent variables. (Although K-12 was also an option for type of school, there were too few K-12 respondents to include K-12 in this analysis). The means for the ANOVAs are presented in Table 8. The only significant difference was for the number of students who use MDSolids. Post Hoc tests indicated that the University professors reported exposing significantly more students per year to MDSolids than the College or Community College Professors. In addition, the effect for the rating of the degree to which high ability students benefited from MDSolids was marginally significant (i.e., not statistically significant, but very close). The means indicate that this effect appears to be due to particularly low ratings for those in Colleges compared to University or Community College Instructors.

To answer the final comparative question posed above, a series of thirteen between subjects t-tests were computed with country (United States vs. World) serving as the independent variable and the different ratings serving as the dependent variable. The means associated with these analyses are displayed in Table 9. Again, only one of these comparisons was statistically significant although all ratings for both the US and World groups were very high. United States professors rated the positive reaction of their students to MDSolids as significantly higher than non-US professors. This result may be attributable, in part, to issues

Table 7: Students improvement on topics as a result of MDSolids

Course Topics	Truss Analysis	Shear and Moment Diagrams	Centroid and Moments of Inertia	Beam Stress Calculations	Mohr's Circle
Mean Value of Professor Rating***	7.05	7.92	7.02	7.10	7.41

Scale: 1 = strongly disagree; 9 = strongly agree.

• Overall effect for course topics was statistically significant:  $F(4, 356) = 6.46, p < .001$ .

• Post Hoc tests indicated that the mean for Shear and Moments Diagrams was significantly higher than the other three means, which did not significantly differ from each other.

Table 8. Questionnaire responses as a function of school type

Survey Statement	University	College	Community College	Post hoc
Students most likely to use MDSolids are . . .				
1. Higher-ability learners (*)	6.44	5.31	6.67	-
2. Highly motivated learners	7.45	7.63	7.52	-
3. Visual learners	7.52	7.47	7.52	-
4. Sequential learners	6.41	6.00	6.15	-
5. Students react very positively	8.82	8.21	9.05	-
6. Require MDSolids for assignments	6.77	6.24	7.00	-
7. Truss analysis	7.06	6.76	7.06	-
8. Shear and moment diagrams	7.79	7.89	8.32	-
9. Centroid and moment of inertia calculations	7.10	6.94	6.61	-
10. Beam stress calculations	7.24	6.39	7.10	-
11. Mohr's Circle transform	8.30	7.97	7.52	-
12. Activities that could not have done otherwise	7.71	7.33	8.35	-
Number of Students*	88.86	44.05	37.04	U > C&CC

\* Statistically Significant (probability of occurring by chance is less than 5%).

(\*) Marginally Significant (probability of occurring by chance is less than 10%).

Table 9. Questionnaire responses as a function of country.

Survey Statement	United States	World
Students most likely to use MDSolids are . . .		
1. Higher-ability learners	6.21	6.50
2. Highly motivated learners	7.37	7.69
3. Visual learners	7.72	7.40
4. Sequential learners	6.15	6.54
5. Students react very positively*	9.07	8.52
6. Require MDSolids for assignments	7.11	6.40
Noticeable improvement in student performance in . . .		
7. Truss analysis	7.04	7.05
8. Shear and moment diagrams	8.11	7.75
9. Centroid and moment of inertia calculations (*)	6.62	7.34
10. Beam stress calculations	6.96	7.23
11. Mohr's Circle transform	7.43	7.39
12. Activities that could not have done otherwise	7.00	6.75
Number of Students	69.75	73.65

\* Statistically Significant (probability of occurring by chance is less than 5%).

(\*) Marginally Significant (probability of occurring by chance is less than 10%).

of language since MDSolids is only available in English. In addition, a marginally significant effect was found with respect to the degree to which professors perceived that students improved in their performance with 'centroid and moment of inertia calculations.' Non-US professors rated this item substantially higher than the professors from the United States did.

### QUALITATIVE SURVEY RESULTS

The first four statements in the survey were intended to characterize the students most likely

to use MDSolids as a part of their studies. Typical comments from professors related to each statement are presented below.

*Statement 1: I find that the students most likely to use MDSolids are higher-ability students*

Professors report that students of all ability levels benefit from MDSolids, although students differ in how they use MDSolids. For the more capable students, MDSolids is used to dig deeper into the subject material:

- All the top students tend to 'explore' MDSolids.
- Although nearly all use the tool to aid in 'finding

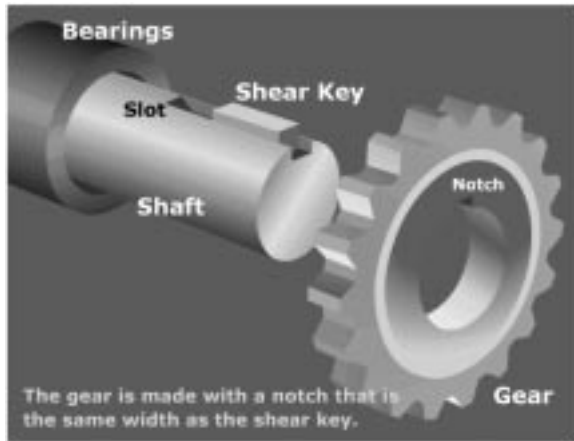


Fig. 1. Example of Animated Explanation of Basic Stress Concept.

the answer' to a specific problem, the students using it to understand 'what if' scenarios are definitely the higher-ability and highly motivated students.

Professors also observe that MDSolids is helpful to students who are less proficient in the subject matter:

- Often students with moderate ability find MDSolids very helpful and understandable.

- Even the limited ability and less motivated students liked tinkering with the program. It appears that they appreciated being freed from the need to perform calculations and concentrate more on concepts and acquiring a gut feeling about forces and stresses involved.
- I think many students who like MDSolids are those who are not strong in calculations and so for them, it is good to try solving a problem and get a correct answer immediately, for example, drawing shear force and bending moment diagrams.
- I would not have called myself a higher ability student 15 years ago, but if we'd had MDSolids to use, it would have given us a far better understanding of the material.
- Lower-ability students try to use MDSolids to involve minimum effort when they need to find a solution. Finding answers on the computer gives them the excitement similar to that of solving computer game puzzles. I consider that this may eventually encourage them to look for the theoretical background and to solve assigned problems long hand.
- I've had student's using MDSolids that aren't particularly talented, just dedicated.
- For the most part this is true, but I also have several students who are not performing well and they use the software as a tutorial.

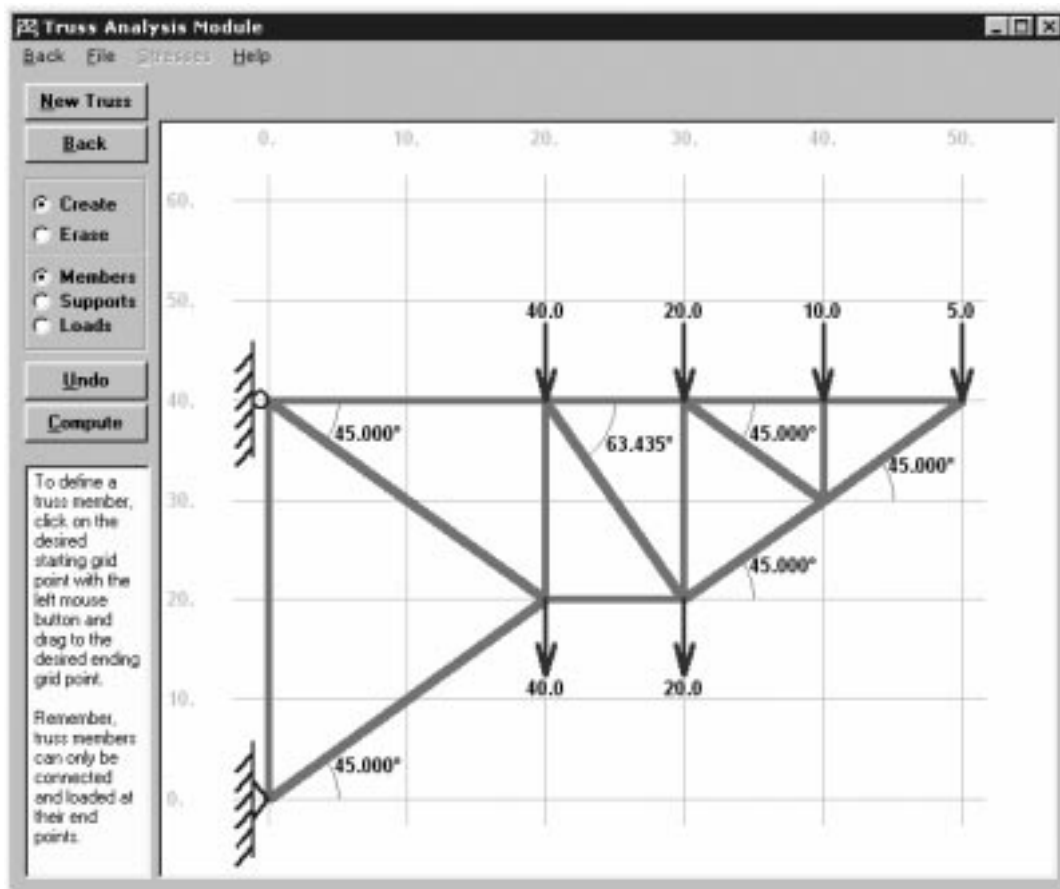


Fig. 2. Truss Module—Definition of Members, Supports, and Loads.

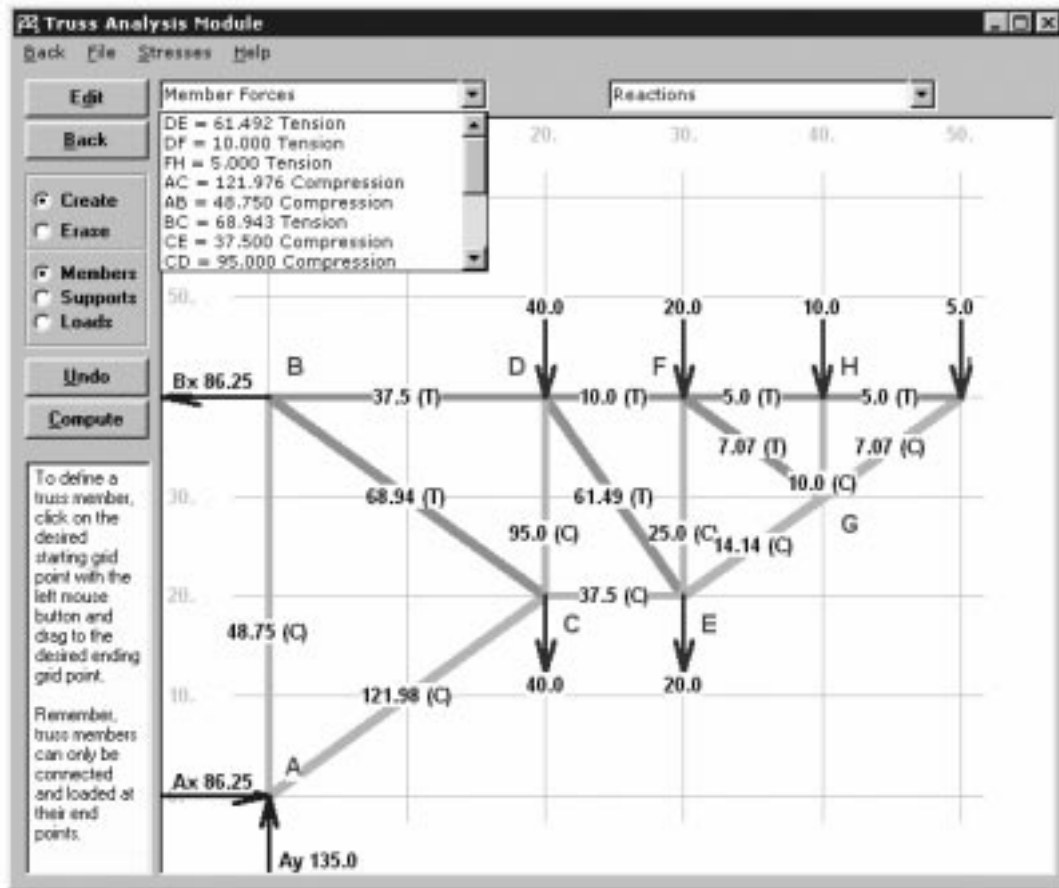


Fig. 3. Truss Module—Analysis Results.

Statement 2: I find that the students most likely to use MDSolids are highly motivated students

- Highly motivated students are normally able to handle the problems from the first principle, but they like to check they answers with the use of

this program. It also gives them satisfaction to find confirmation of their solutions, which in turn encourages them to take greater interest in the subject. Students of lower motivation, however, would like to use the program as a computer game. It seems to be advantageous—eventually they may develop greater interest in the theoretical background.

- I am inclined to say that a motivated student is one who will tackle additional problems outside the required course work and is interested in learning the principals rather than just get by. MDSolids would allow such a student to perform ‘what if’ scenarios.
- The highly motivated students are more likely to use it in other courses.
- Even our students with moderate motivation get interested in MDSolids.
- It does take some time to be proficient at using some of the applications; those that can’t be bothered to do an excellent job are less likely to use the software.

A number of professors also commented that MDSolids served to help motivate students:

- I think the option to use such a tool, in a first year [freshman] course *excites* many students and in turn motivates them—that is WHY I use it!



Fig. 4. Determinate Beam Module—Load Definition Input Form.

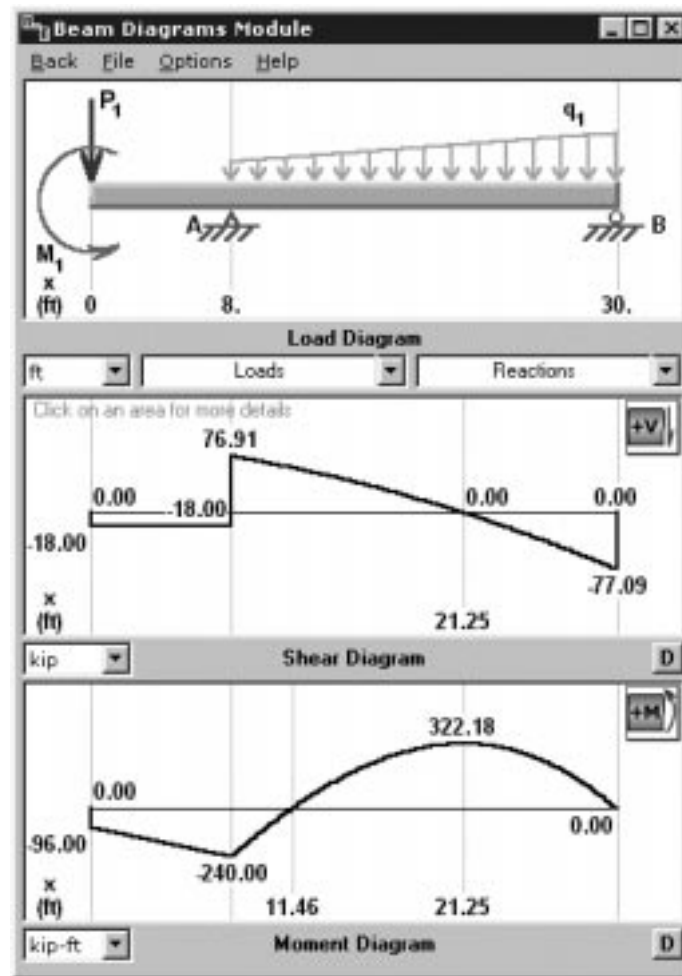


Fig. 5. Determinate Beam Module—Shear Force and Bending Moment Diagrams.

- In fact, I think the software helps to motivate the student to explore certain issues, say for example, trusses, and how different loads might affect similar configurations.
- I have used MDSolids to get students motivated.
- The main source of motivation is without a doubt, the class instructor. If you show the students how to take advantage of MDSolids to solve problems or class projects they will use it.

*Statement 3: I find that the students most likely to use MDSolids are visual learners*

In general, visual learners get more information from visual images (pictures, graphs, illustrations, sketches, etc.) than from verbal material (written and spoken words and mathematical formulas). One of the design objectives in developing MDSolids was to utilize pictures and images to convey an understanding of the Mechanics of Materials topics. Rather than simply stating the numerical result for a particular calculation, the software was designed to give, wherever possible, a visual context for the result. Since visual feedback is a unique advantage that MDSolids offers, the survey asked professors whether they had noticed that

students whose learning style was visual responded more favorably to MDSolids:

- I am not fully aware of whether or not a particular student is a visual learner or not. I do however feel that engineering is taught more effectively when visual techniques are incorporated.
- I think that all of us are visual learners, and we have to develop abstraction capacity to get verbal material.
- I've gotten positive feedback from both visual and verbal learners.
- During the past three years, I've taught several students who had failed the course on a previous attempt with another professor. When they come into my class and see the pictures and particularly the animations in MDSolids, a light seems to go off in their heads. It's like the pictures and the animations supply the missing piece that they need to make sense of the course topics.

While there was no clear consensus about visual learners, professors did agree that the visual presentations in MDSolids were very useful for their students.

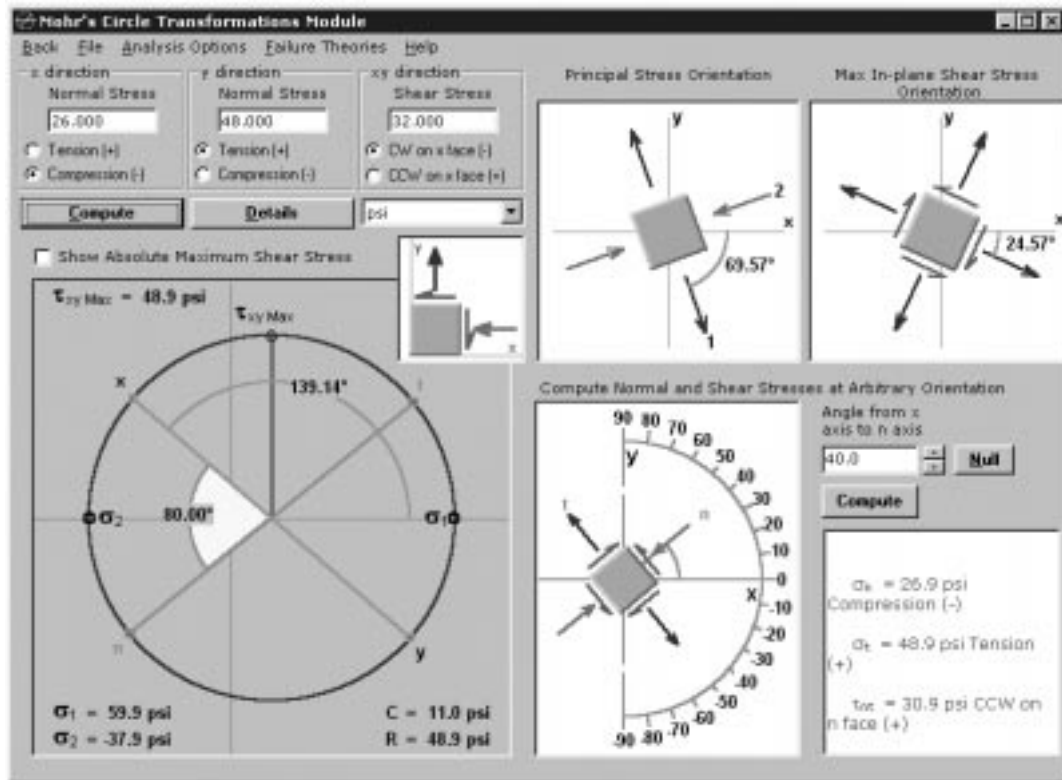


Fig. 6. Mohr's Circle Transformation Module—Plane Stress.

- The visual aspect helps their understanding significantly.
- Every user has commented on ease of use and value. They seem to appreciate the visuals, especially because it makes the software easier to use. Visuals also make concepts easier to remember.
- I found the students grasp the concepts more quickly and have the ability to apply mathematics to the problems with greater understanding.
- The visual aspect, especially shear and moment diagrams, are why I like MDSolids.
- The 'pictorial' approach seems very intuitive to the students, thus reinforcing their need for visual references.
- The animations are very good for learning.
- Yes, they learn a lot from seeing the displays that graph the load and stress. Many times, there is only so much you can say before you need an example like MDSolids to help put all the theory together so it makes sense.
- I know this visual approach works for me. I use MDSolids to learn more about the areas that I have never understood that well.

*Statement 4: I find that the students most likely to use MDSolids are sequential learners*

Another aspect of learning style is described as sequential versus global learning. As a general definition, one could say that sequential learners acquire understanding of material in small,

connected chunks while global learners take in information in seemingly unconnected fragments and achieve understanding in large holistic leaps. Sequential learners can solve problems with incomplete understanding of the material and their solutions are generally orderly and easy to follow, but they may lack a grasp of the big picture. Global learners may do poorly on homework and tests until they grasp the total picture such as how the material being presented relates to their prior knowledge.

- The sequential-learners benefit from this program, but the program presentation helps mostly the global-learners as they can grasp the total picture and quickly arrange the material in an orderly fashion. They like to plough through step by step and the program is helping. I find that even greater benefit are provided to global students who can use the program to assemble the fragments of material into one picture that they can understand easily.
- Many of my Strength of Materials students feel that they must completely understand a topic before continuing. These students do like the help MDSolids gives to solve problems one piece at a time.
- I think that it is used by all but more likely by the global learner—it helps fill in those fragments. They can't be bothered with (or understand) free body diagrams so this allows them to grasp the total picture more effectively.
- I haven't noticed a bias of student types, but I



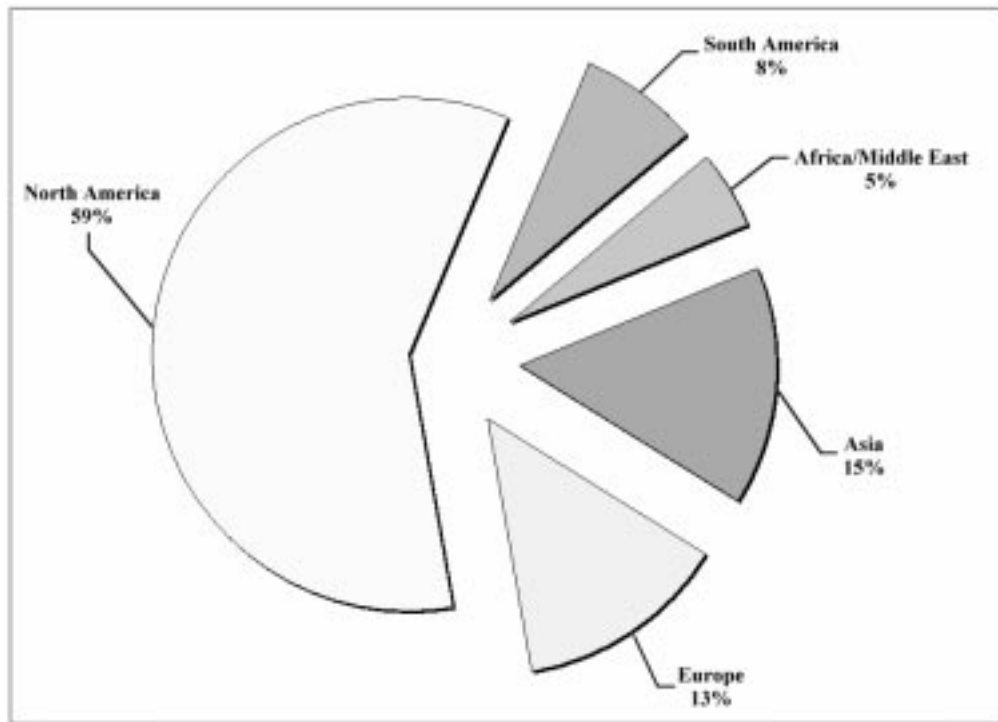


Fig. 7. Geographic Distribution of Survey Respondents.

have noticed that comments become more numerous when the questions are more global.

- I found the program helps global learners to achieve understanding sooner. Sequential learners develop their learning faster due to the structure of the program.

*Statement 5: Students react very positively to MDSolids*

There was a very strong consensus that students respond positively to MDSolids. Comments include:

- We have had excellent experience with MDSolids.
- Using MDSolids gives the students a sense of satisfaction—actually applying their book knowledge to a more real situation. They can also solve problems that are more difficult using MDSolids. If they had to work on these problems without the software, they would become confused and have a more difficult time . . . There's something about applying the theory in a real world setting using MDSolids that builds confidence. Once they feel confident, they can do much more than they thought they could do.
- I use MDSolids mainly during lectures and I find students more interested and willing to try their abilities harder in finding their own solutions. Whatever their motive, they all are getting to it with great interest. I am convinced that the program, when introduced, will have very positive effect on students' progress
- I observed that a minority of the students embraces MDSolids (and a minority do well generally), but those that do really appreciate it.

- They (and myself) feel it is one of the best written technical software tools available in education, and that it is a good value.
- I find students working on extra, unassigned problems just to test theory. I find them pushing beyond where I would expect them to be after a first year course.

*Statement 6: I require students to use MDSolids for specific assignment*

- I want the students to have the confidence to use MDSolids so as engineers they feel confident to solve problems using advanced software tools. Using MDSolids helps the student understand concepts that are difficult to explain in class.
- Anyway they do their problems its fine with me but there comes a time when I encourage them to use some learning aids as it would help them to develop a sense of being resourceful and not expect to get everything from only the lecture.
- Our typical homework assignment is three or four problems per day. For assignments during the first half of the semester, I pick out one problem per assignment and require that students work it by hand and with MDSolids. I have them turn in an MDSolids printout of that selected problem along with their hand calcs. I tell them that their hand calcs have to match the MDSolids answer in order to get credit for the problem, but if the answers match, I give them double credit. My students won't even try MDSolids if I make it voluntary, but once I prod them a little by making them use MDSolids during the first half of the course, I find that they will continue to use it and benefit from it.

I've gotten very favorable student evaluation comments since I started this approach.

- . . . Also, I have given them group projects—MDSolids proved to be invaluable in their work.
- Students are given options for which tools to use. MDSolids is one of them, but is the most popular one.

Survey statements 7–11 were intended to gauge the effectiveness of MDSolids on the performance of students in specific topics. Of these topics, truss analysis, shear force and bending moment diagrams, and Mohr's Circle Transformations seem to be the topics in which MDSolids has the most notable effect:

*Statement 7: Since I've started including MDSolids in my teaching activities, I have observed a noticeable improvement in the performance of my students in **truss analysis***

- Great for varying the truss and seeing how the forces change.
- The ability to present changes from tension to compression and from compression to tension is very helpful. The flexibility of graphical presentation is most useful. Easy presentation of changing effects of forces on truss members
- I have observed little change in class performance, but significant change in individual performance.
- I emphasize the 'what if' scenarios in solving problems. MDSolids is instrumental in implementing this approach.
- By far, the usefulness of the tool for truss analysis is cited most often in end of term comments.
- The truss section of MDSolids is great. This semester, we are going to design a bridge using the truss analysis section. This will be a fun project that they can build for extra credit.

*Statement 8: Since I've started including MDSolids in my teaching activities, I have observed a noticeable improvement in the performance of my students in **shear force and bending moment diagrams***

- Drawing shear and bending moment diagrams is a cumbersome task. If a mistake is made early in the problem, the whole solution is incorrect. MDSolids removes this problem and the students don't mind performing iterations in a design.
- The students learn more by using MDSolids because they can experiment with different loading configurations and see the effects. Then, they can think about it and get a better feel for the theory.
- We started using the program last year and we saw significant changes in how a good number of students understood Shear and Bending.
- We can now spend more time in analyzing the results
- This, with trusses, is one of the best parts of

MDSolids for giving students an intuitive feel for what to expect for homework answers.

- Probably more from me using the software in the classroom showing quickly how loads affect the diagrams.
- My steel design students like to use it as a check of their diagrams which helps them become more proficient in drawing them on their own.

*Statement 11: Since I've started including MDSolids in my teaching activities, I have observed a noticeable improvement in the performance of my students in **Mohr's Circle transformations***

- Invaluable—by experimenting with combinations of inputs, students gain an intuitive feel for the answer, which is helpful in the topic of combined stress.
- The ability to visualize the changes in stress states helps the student to understand the concepts more readily.
- The whole Mohr's circle subject is much easier to teach and understand using MDSolids.
- The Mohr's Circle section is really nice. This gives the students a chance to quickly check their work and stimulates their interest in the Mohr's Circle section.

*Statement 12: There are activities that I now use with my students that I could not have done otherwise without MDSolids*

With the availability of MDSolids, professors note their ability to pose more complex questions to their students:

- While they always developed the ability to solve problems before, I find using MDSolids allows for greater complexity of problems and more exposure to different types of problems.
- The 'what if' capabilities allow a multitude of variables to be changed which could not be possible if performing the calculations manually.
- I assign projects and offer MDSolids as a tool to investigate designs. Though we can do without, I rely on MDSolids as a design tool.
- As mentioned in an earlier question, iterations in the design problems is something that students would try to avoid in the past. They do not mind digging further into a problem to find a more correct solution now.

Many professors also commented on the usefulness of MDSolids as a tool that they use in preparing class lectures and during class lectures, both for its visual presentation and for the ability it provides to quickly examine various configurations and loadings:

- The program enables more attractive presentation, saves lecture preparation time and reduces the use of white-board drawing during lectures. Students show greater interest and become more

assertive. The program allows me to reduce the time for preparation of lectures. Presentation is very interesting for students, and the use of sketches on the white-board during classes is reduced. A very good tool for lecturing.

- The graphical part of the program is great to illustrate concepts.
- It mostly has to do with demonstrating many more examples in the classroom than was possible through a 'chalk' talk.
- I would have to do more 'chalk talk' without the program or give more handouts so MDSolids makes things easier but it does not let me do things I could not do other ways.
- I use MDSolids to quickly and easily test different material sizes/materials/shapes when designing for different types of loading conditions in Machine Design applications. This has been an extremely useful tool for both me as an instructor and the students as designers.
- Demonstrating sensitivity of design to changes is easy to do in class, with instant feedback
- I use MDSolids in class. I use a projector in the class to explain things that would be difficult to get through by using the chalkboard. I like using MDSolids because it lets the students work on problems in the class while I walk around explaining what they are seeing. Sometimes they get off on the wrong track, but that's good, because then we better understand the mistake we made. It is difficult for students to work in class doing a problem in a short time without MDSolids. I split the class up between lecture and lab. Without MDSolids, the class would get boring. The students always look forward to applying what we have talked about in class.
- I spend a lot more time studying truss behavior using MDSolids than I would using traditional methods of truss analysis.

I am able to spend more time on beam design and truss analysis.

## CONCLUSIONS

Largely through word-of-mouth, MDSolids has become a valued component in Mechanics of Materials education in countries around the world. Professors report that students of all ability levels benefit from MDSolids in their studies and that students respond positively to MDSolids. In the opinion of the professors participating in the survey, highly motivated learners and spatial learners respond particularly positively to the software. Furthermore, a number of professors commented that MDSolids served to help motivate students. Professors noted that MDSolids seemed to be a factor in the noticeable improvement in their students' performance in several topic areas but especially in the construction of shear force and bending moment diagrams. The survey revealed that professors from different types of schools don't differ significantly in their perception of the usefulness of MDSolids. Moreover, professors both in the United States and in countries around the world report similar student reaction and performance as a result of MDSolids usage in their classes. With the availability of MDSolids, professors note their ability to pose more complex questions that encourage students to dig deeper into the subject material. Many professors also commented on the utility of MDSolids as a tool in preparing class lectures and during class lectures, both for its visual presentation and for the ability it provides to quickly examine various configurations and loadings. Taken as a whole, professors from a wide variety of schools and countries have found that MDSolids is a very useful addition to their teaching effort for Mechanics of Materials.

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