AC 2009-118: SOFTWARE DEVELOPMENT FOR TEAM PROJECTS IN MANUFACTURING

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Abstract

A software package has been developed to introduce students to the integration of design criteria, material properties, mechanical properties and product cost. The software has been used in the two credit manufacturing processes course for four years and modifications have been made based upon the responses and comments of the students on the assessment questionnaires they completed. The course is required by all mechanical engineering and industrial engineering programs and is scheduled at the junior level. The overview of the typical project, results of the student questionnaires, project changes and software changes are presented.

Introduction

The basic manufacturing processes course attempts to integrate multiple design criteria, mechanical properties, material properties and manufacturing costs for a specific product. Students need interdisciplinary team projects as part of the ABET requirements and this course is one of only a few that has students from multiple engineering disciplines. The project design criteria are the load requirements and deflection limit for a simple beam structure. The manufacturing processes for the beam such as rolling and extrusion are presented in the discussions in the lectures on bulk deformation processes. The students have had the formulas for the centroid and moment of inertia in their statics and strength of materials courses for the various cross-sectional shapes such as square, rectangle, circular, triangular, I-beam and hollow box. The students must find the moment and inertia equations for an additional shape and have the model evaluate those shapes or create their own program to give the results. The additional shapes typically selected by the students are the hollow circle, T-section, C-channel or U-channel. Previous papers have been prepared on the program and this is an extension of the previous works[1-5].

The loading types available in the model are single point center load, single point end load and uniform load. The types of end supports for the beam are simply supported ends, fixed ends, and cantilever support (single fixed end). The program contains 12 materials in the data base and two materials are added to the data base during the model demonstration session. The model is e-mailed to all students in the course for their use. The students must select at least one additional material, obtain the material property, mechanical property and cost data required for the model.

The various reports were required so the students would do work throughout the 10 weeks rather than only at the last two weeks. The first three reports were 10 points each and the

last report was 70 points. In addition, the team members had to rate the performance of all team members, including them self. The performance rating was used to adjust the team project score for the individual team members. The teams were permitted to have 10 extra points to use and thus the team leader could be rated at 110 and if there were two team leaders, each could have a score of 105. The purpose was to lower the grade of those team members who did not participate fully in the project effort. Usually, only one or two teams have a problem, but it has caused a few students to receive a lower course grade. The students are told about the performance rating and shown the rating sheet during the project presentation period, but some students have difficulty in working with others. Many students have difficulties in working as a team as because of scheduling difficulties and do not know how to distribute the work load or hold team members accountable for their assignments and thus they dislike project work.

The third report was a final draft of the project report so the students could make final corrections before submitting the final report, which was the major part of the project grade. Previously there were four short reports which accounted for 15 points and the final report was 85 points, but the final report was lacking in quality. In general the new process gave a better final project, but one team decided that since they had the information in the draft report, they did not need to include it in the final report. The project represented 25 percent of the final grade in the course; only the final exam was higher at 35 percent of the final grade.

The software was used by all the student teams and was well received by the students. The software has been named "IDEAMAPS", an acronym for "Integration of Design, Economics, and Activity based Multi-disciplinary Aspects through a Project Software". The software is given to the students after they have been given the project problem, which includes a solution to the problem for two materials using the square cross-section. The project problem is gone over in detail and the critical calculations are demonstrated on the blackboard. The students are also provided with a 12 page instruction manual giving general instructions on how to enter the data for the problem to be solved, specific instructions on how to enter the equations for the moment of inertia and centroid, and how to copy graphs and tables from the program to enter into the students' report. The program was made as an Excel© program as that is available to all students and they have had experience using it. However Excel© does have some problems as the solver routine used needs a good starting point to find a solution. Since it is a team project, some students previously never used the program as they would let another team member run the software. However, the new first report required each student to run the software as they were given a specific material with unique data and it was an individual report. If a student did not do the first report, then the maximum points possible would be 90 for that student.

Four questionnaires were given to the students, one each time they handed in a report. Each questionnaire used a scale of "1" to "5", with "**1**" being "***Completely Disagree***" or

"*Definitely NO*" and "**5**" being "*Completely Agree*" or "*Definitely Yes*". The first three questionnaires were strictly rating the degree of fulfillment of an activity, but the last questionnaire had open ended questions regarding the project and software. The first questionnaire and the average response values are presented in Table 1.

In Assessment Questionnaire 1, questions A and B were to determine if the students opened the program and tried it on the example. Question D was expected to have a low response as the students did not need to do this for the first report. Questions C and E were to obtain some general feedback about the program and the team formation. The first report was an individual report rather than a team report. The number of responses to Assessment Questionnaire 1 was 39.

Table 1. Assessment Questionnaire 1 Results

Questions	Average Rating
A. You have opened the program and used it with your specific material.	4.97
B. You tried the program on the example problem and obtained the same results.	4.82
C. The program was relatively easy to understand and work with compared to other software programs you have used.	4.44
D. You did try the graphics option and were you successful.	3.38
E. The current team size of 2-5 students seems optimal for the project.	4.56

Table 2. Assessment Questionnaire 2 Results

Questions	Average Rating
A. You have opened the program and used it with your specific material.	4.97
B. You tried the program on the example problem and obtained the same results.	4.63
C. The program was relatively easy to understand and work with compared to other software programs you have used.	3.43
D. Your team has made the final selection of your added material.	4.30
E. Your team has the material, mechanical, and cost values for your added material.	4.87
F. You have made the final selection for your additional shape.	4.40
G. You have determined the expressions for the centroid and moment of inertia for your additional shape.	4.83
H. You have entered the centroid and moment of inertia equations into your computer program.	4.87
I. You have started the sensitivity analysis for your project.	2.17

The second assessment questionnaire was after the first team report. The Assessment Questionnaire 2 is in Table 2. The responses were slightly inconsistent for Question C which had a value of 4.44 on the first questionnaire and only 3.43 on the second questionnaire. Also

Question D had a response of 4.30 as to the final selection of the material but Question E had a response of 4.87 in response to the question that you have the material, mechanical, and cost values for your material . The responses to the two questions should have been the same. Question "I" had a low response as this was not required for the second report, but was included to check the validity of the responses. The number of responses for the second questionnaire was 30.

Questionnaire 3 had two main areas, the first set of questions (A through E) pertained to what should have been done and the following questions (F through K) pertained to considerations for the final report. Thirty-six responses were obtained from the students, which was over 80 percent of the class.

Table 3. Assessment Questionnaire 3 Results

Questions	Average Rating
A. The current team size of 2-5 students seems optimal for the project.	4.29
B. You have obtained all the necessary material properties and costs for the additional material.	4.75
C. You have determined the expressions for the centroid and moment of inertia for your additional shape.	4.75
D. You have entered the centroid and moment of inertia equations into your computer program.	4.88
E. You have done the sensitivity analysis (1=not started, 5 = completed)	4.13
F. You have plotted the changes in cost versus the changes in load.	2.54
G. You have plotted the changes in cost versus the changes in the deflection limit.	2.50
H. You have determined the amount you have saved (cost) over the initial square shape for the same load. (1=done nothing, 5 = completed)	2.58
I. You have determined the amount you have saved (weight) over the initial square shape for the same load. (1= done nothing, 5 = completed)	2.46
J. The required preliminary reports have helped your team better prepare your final project report.	3.96
K. You have done an ANSYS run of your final material/shape combination (although not required).	2.46

Questionnaire 4 had two types of questions, the ones similar to the first three questionnaires and then some open ended questions. The questions and average responses for the degree of fulfillment are in Table 4. Questions B through F were the same as F though J on Questionnaire 3 and the responses showed a marked increase as most of the students took the hint as what to include in the final report. There were 28 responses to the fourth questionnaire. The opened-ended questions in the fourth questionnaire are summarized in Table 5. The responses indicated the diversity of opinions by the students as some claimed it was easy to use

and another claimed it was not very user friendly. One must not take the results personally or one would be crushed and one must look for the responses that can be helpful.

Table 4. Assessment Questionnaire 4 Results

Questions	Average Rating
A. The current team size of 2-5 students seems optimal for the project.	4.62
B. You have plotted the changes in cost versus the changes in load.	4.24
C. You have plotted the changes in cost versus the changes in the deflection limit.	4.24
D. You have determined the amount you have saved (cost) over the initial square shape for the same load. (1=done nothing, 5 = completed)	3.86
E. You have determined the amount you have saved (weight) over the initial square shape for the same load. (1= done nothing, 5 = completed)	3.83
F. The required preliminary reports have helped your team better prepare your final project report.	4.52
G. The project had given you a better understanding of the integration of design, material selection, mechanical properties, and costs for product manufacturing.	4.21

It is apparent that some of the students have limited computer skills and others did not read the instructions provided. A teaching assistant summarized the comments. The importance of the responses is to find the improvements in the program and improvements in the instructions that will make the greatest favorable impact on the application of the software. In addition, the program was submitted for evaluation for a software prize, but the judges were focused on making the software prevent students from making errors by preventing them from entering negative numbers or unreasonable values. Engineers, however, must be able to analyze results to determine if they are reasonable and be careful in entering data. Many of the student improvements were to reduce the analysis of the output and to automate the cross-sectional sketches. The purpose of the software is to assist the student and not make the decisions for optimizing the design. Students need to learn to be creative and improve solutions and the software should not do the final solution. Students are not required to use the software and can write their own programs. There will always be software errors in programs that are complex as programmers cannot anticipate all the possible errors that may occur in the data entered into the program. The students also need more instructions on how to work as a team[6] rather than as a working group.

The improvements that will be attempted for the next version are:
1. Improve the instructions to change the security level to enable the macros in the program.
2. Give a specific detailed example for entering the data including inserting the moment of inertia and centroid equations.
3. Prevent the entry of negative values.
4. Explain the search procedure used to find the solution.

5. Give sample problems with the more complex shapes such as the I-beam and hollow box in the instructions.
6. Add the instructions or link to the instructions in the model.
7. Have the open-ended questions as a team response rather than as an individual response to reduce the frivolous comments.

Table 5. Open-ended Questions in Questionnaire 4 and Student Responses

H. What were the three (at least) best factors you liked about the program - please be specific

1. Easy to use
2. Done by computer/Tables and Graphs
3. Simple Input/ Fast answer

4. Able to add materials and shapes/ also several materials at once
5. Good and Detailed results
6. Several loading conditions to test

I. What were the three items (or more) you disliked most about the program - please be specific

1. Had to return for every shape/adding/dimensions/ and limitedness of shape
2. Calculations not explained/confusing results
3. Could not save information/material
4. Copying and pasting results/transferring charts from excel to word - form factor
5. Not very user friendly

J. What specific improvements would you suggest making to the program to improve its usability?

1. None
2. Layout of the input page
3. Easier to input equations for shapes/allow to calculate at same time/save additional shape
4. Show pictures of the different shapes after the program runs
5. More specific step-by-step instructions
6. Specify top two for each category (use a different color)
7. Remove copy charts button & make easier to transfer charts

8. Built in graphing/tables/more buttons
9. Show dimension inputs on output sheet
10. Possibility for user correction of the programming
11. Don't password protect so you can save
12. Show all formulas
13. Make "dm" and "md" easier to do
14. Don't erase input material

K. What additions do you have for the instructions (second set) to improve use of the model?

1. More explicit instructions
2. Good program and instructions
3. Be very specific about enabling macros

4. Instructions on how to add shapes
5. None

L. Other comments and suggestions

1. Instructor needs to clearly explain what he wants because we were never clear on it
2. Combine the project info from the syllabus and the project instructions
3. Code could be better written in Matlab©

Conclusions

Students have difficulty in working on projects as they have not learned to function as a team and typically function as a working group[6]. The development of a software package is a never ending process as improvements are always possible, and improvements require changes not only in the program but also in the instructions. The software has given insight to the students on the effects of design and material selection upon the cost of simple structures. The software developed permits the students to explore a wide variety of materials and structures in a relatively easy and rapid manner. The software permits students to compare alternatives and make a decision as to what material-shape combination best meets the design requirements.

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