AC 2012-5341: IMPROVING STUDENT ENGAGEMENT: AN APPROACH USED IN KINEMATICS AND DYNAMICS OF MACHINERY

Dr. Claire Yu Yan, University of British Columbia

Claire Yan is an instructor in the School of Engineering at the Okanagan campus of the University of British Columbia. She received her B.A.Sc. and M.A.Sc. degrees in mechanical engineering from Xi'an Jiaotong University, China, and Ph.D. degree in mechanical engineering from the University of Strathclyde, U.K. She is a registered Professional Engineer.

Dr. Carolyn Labun, University of British Columbia

Improving Student Engagement - An Approach Used in Kinematics and Dynamics of Machinery

Abstract

Instructors frequently ask themselves "What are the best ways for an instructor to support student learning? How can we assist students in engaging in deep learning? How can we help them bridge the divide between theory and practice?

This paper discusses efforts to address these issues in a course on Kinematics and Dynamics of Machinery. Kinematics and Dynamics of Machinery is a core course in the mechanical engineering curriculum. One of the challenges in this course is to make students fully appreciate mechanism design by integrating the principles of kinematics and dynamics in real world design practice. To assist with this goal, students were encouraged, early in the term, to discover real life examples of mechanisms with an aim to promote curiosity and foster interest in learning. Throughout the term, a design project was introduced which required students not only to apply fundamentals of kinematics and dynamics, but also to exercise skills in teamwork, collaborative learning and communication. A student survey was conducted at the end of the course and the efficacy of the approach was assessed.

Introduction

The University of British Columbia's Okanagan campus was established in 2005 in Kelowna, British Columbia. The School of Engineering offers three undergraduate programs: Civil Engineering, Electrical Engineering and Mechanical Engineering. In 2010, the School of Engineering received its first accreditation from the Canadian Engineering Accreditation Board (CEAB).

The creation of a new School of Engineering offered an exciting opportunity to stress integration and design from the outset. During the first two years, which are common to all three disciplines, all students study together, in an effort to both teach and show students the integration of engineering concepts desired by industry and recognized by many as ideal. In addition to taking traditional engineering courses, students (in both first and second year, and again in the fourth year capstone design course) work in multi-disciplinary teams on major design projects that integrate technical knowledge and metaskills. As noted by researchers in engineering education, both technical knowledge and metaskills (such as critical thinking and problem solving skills, the ability to innovate, the ability to work in a team, and the ability to communicate effectively), are of great importance in today's workplace. In order to graduate engineers with such skills, instruction must take all aspects of learning into consideration[1,2,3]. Consequently, instructors face challenges such as

- How to engage students in deep learning?
- How to strengthen the link between theory and practice?

- How to encourage critical thinking, problem solving and teamwork skills within the context of a solid technical foundation?

There is no simple answer to these questions. As instructors, we and our colleagues continually work to adapt our assignments and teaching practices to respond to our students' and industry's needs. One important aspect is to create "authentic" assignments that "interweave" theoretical and practical elements[4]. This paper focuses on one such attempt situated in the third year of study.

In Kinematics and Dynamics of Machinery, an active learning activity was introduced early in the term in an attempt to engage students and foster their interest in the course concepts. As noted by Felder and Brent (2004), "people learn new material most effectively when they perceive a clear need to know it in order to solve a problem or meet a challenge." [5] In addition, students were required to complete an open-ended design project at the end of the term. Traditional assignments that stress concept coverage through activities that privilege calculating, explaining and proving were retained for reasons explained below. The implementation of different learning activities was intended to encourage students to move from knowledge to comprehension to application of course concepts. The variety of assignments and learning methods also offered students an opportunity to practice self-learning, active collaboration, and critical thinking skills, while ensuring that fundamentals were covered. A survey was conducted at the end of the term to determine students' views of the effectiveness of the different assignments and learning methods.

Course Goals and Instructional Methods

Kinematics and Dynamics of Machinery covers fundamental principles in analysing and synthesising mechanisms and is a foundation to the broader subject of machine design. The objectives of this course are 1) to develop students' essential technical knowledge in machinery, 2) to develop their ability to implement classroom learning through solving real-life design problems, and 3) to encourage technical communication, problem-solving, critical thinking, and teamwork skills.

In order to achieve these objectives, this course (in Term 1 of 2011-2012) was taught by combining active learning elements, for example, real-life examples and design projects, with traditional instructional methods such as formal lectures, tutorials and exams. Lectures and tutorials remain an important part of the course. Many students find that structured lectures and tutorials help them learn by highlighting and emphasizing key skills in a logical and coherent manner. On the other hand, lecturing on its own is usually not sufficient and effective since people rarely learn by just listening and/or following. As an ancient Chinese proverb says, "When I hear, I forget; when I see, I remember; when I do, I understand." In engineering education, it is important that students are given opportunities to discover, analyze, and solve problems, and to exercise their creativity in conjunction with a grounding in fundamentals. Thus, this course retained its lecture component in order to ensure that students understood the core engineering principles, while offering opportunities for students to identify, record, and share their observations of real-world applications of those principles.

Assignments

In this course, six assignments and one design project were given during the term. Table 1 lists these assignments and their different focuses.

Table 1: Course Assignments

Assignment	Concepts covered
1	Applications of mechanism, kinematic diagram, mobility
2	The Grashof condition, position vector, displacement, graphical position analysis, analytical position analysis: vector loop method
3	Graphical and analytical velocity and acceleration analysis
4	Dynamics fundamentals, dynamic force analysis, balancing
5	Gear trains
6	Cams

The first assignment was designed specifically to foster students' interest in the course subject and to help them experience a wide application of kinematics devices. In this assignment, "Discovery of mechanisms in real life", students were asked to 1) find one or more real-life examples of mechanisms and take photos and/or make videos of these examples, 2) describe the motions of each mechanism, draw kinematic diagrams and calculate their mobility, and 3) write a brief report to document their findings. After the first assignment was submitted, an online library was created to store all photos and videos on WebCT Vista. This library was then made accessible to the whole class to practice kinematics fundamentals. Students were also given an opportunity to present their mechanisms in class. During this exercise, students discovered a wide range of applications, from industrial equipment such as aircraft landing gear to consumer products such as snowmobiles, bicycles, and nail clippers. Appendix 1 lists the types of mechanisms found by students through this assignment.

The other five assignments included close-ended textbook questions given to students to practice theories and concepts taught in class.

Design project

In the design project, students were divided into teams of four to five students. Each team was asked to choose one project from the 33 projects outlined in chapter 3 of *Design of Machinery*[6], and to design a mechanism to solve the problem of their choice. All of the design projects were open-ended and unstructured problems. Examples of projects chosen by students include:

- A mechanical walking device to test army boots for durability
- A wheelchair lift to raise a wheelchair and a person 3 feet from the garage floor to the level of the first floor of a house
- An attachment for a conventional wheelchair, which allows the wheelchair to get up over a curb
- A lift mechanism to automatically move a boat from a cradle on land to the water
- A mini-dumpster attachment for pickup trucks
- A mechanism to simulate the motion of a rocking chair

- A boat launcher attached to a trailer to help the trailer stay dry during launching

The project was conducted in two stages. In the first stage, students were required to write a project proposal, which consisted of background research, a synopsis of the problem, a clear goal statement, a list of performance specifications, and a breakdown of labour and meetings. Students were required to discuss their preliminary design ideas with the course instructor in a formal meeting.

In the second stage, students performed a detailed analysis, calculations, and optimization. In this process, students used computer software, such as Solidworks and ADAMS to visualize and optimize their designs. Students practiced lifelong learning skills through identifying and locating new information and learning new concepts. In addition, students were encouraged to leverage each team member's expertise in order to complete the project successfully. The deliverable was a formal report, which documented details of their design solutions.

Results and assessment

An anonymous survey was conducted at the end of the term to collect data from students attending the course in order to assess the effectiveness of the different teaching methods in student learning. The survey was designed by the instructor, submitted for ethics approval, and then posted on WebCT Vista by the University's Centre for Teaching and Learning. In total, 53 students were surveyed and 39 responses (74%) were received. A copy of the survey is included in Appendix 2.

Comparison of assignments, projects, lectures, tutorials and exams

The first group of questions focused on the value students gave to different teaching methods. Students were asked to identify which instructional methods, assignments, project, lectures, tutorials, and exams, best supported their mastery of the material. The importance of each method was represented on a Likert scale of 1-5 from "very helpful" to "not helpful at all." Table 2 summarizes student responses regarding this group of questions.

Table 2. Student responses to questions 1-7 in the survey

	Number of Responses					
	Very helpful	Helpful	Moderately helpful	Rarely helpful	Not helpful at all	Not answered
Assignments	16	18	3	1	0	1
Project	1	10	20	3	4	1
Lectures	13	18	7	0	0	1
Tutorials	9	10	11	6	2	1
Exams	4	15	12	5	2	1

The majority of students found lectures and tutorials/assignments were most helpful in their learning; 87% indicated that assignments were helpful or very helpful, 79% found lectures were helpful or very helpful, and 49% indicated that tutorials and exams were helpful or very helpful.

Interestingly, only 28% of responses indicated the project was very helpful or helpful. Here are some student comments taken from the survey:

"I found that the project took away from studying time so I found myself less prepared (for exams) than I had hoped to be. It did not contribute to the learning I did in the class."

"The assignments and tutorials were helpful in that they provided many practice problems."

"Group size for project is almost too big, as we are only working on one design with 5 people sometimes I was left with no work to do."

"I previously had mentioned that I felt the assignments were more important than the project in understanding the course content. However, I feel there were parts of the project that I found to be very practical."

"Tutorials that reflect examination questions and show a complete step by step approach to solutions."

These comments revealed two key factors affecting the rating of the project. The first factor relates to time management issues. Third-year engineering students typically take 6 courses per term, with transfer students from other institutions taking 7 courses. Many of these courses have term projects. Quite often, students find they lack time to concentrate on their projects due to assignment deadlines, exams, and laboratory assignments. Time management thus becomes a significant concern, as it affects the outcome of their design projects.

The second factor relates to student perspectives on what is meant by "helpfulness." It seems that students found that traditional assignments and tutorials were more helpful to their learning. One reason might be that traditional assignments and tutorials provide immediate feedback on how well students understand the course materials, and students find this information to be immediately helpful. Another reason might be that traditional assignments relate more directly to exams. Many students find that they can usually achieve satisfactory marks on an exam if they have invested more time and done well on the related assignments. This work can be done independently, and as such, provides efficient, significant and quite prompt feedback, as well as fairly immediate returns for students in terms of marks. In comparison, projects require time-consuming collaboration between team members, and the value of the metaskills thus developed is not immediately apparent to students, as these skills mature gradually and are much more difficult to measure. This may be one reason that students tend not to appreciate the elements designed to foster metaskills embedded in a design project. It remains challenging for instructors 1) to organize projects in a feasible timeframe that fits into students' busy schedule, and 2) to introduce assignments that assess and reward the improvement of metaskills.

Comparison of interactive assignment and traditional assignments

The second group of questions surveyed the first assignment (interactive assignment) and the five remaining traditional assignments given in the term. Students were asked, "At the beginning of the term, you were given the first assignment 'Discovery of mechanisms in real life'. This assignment asked you to find examples of common mechanisms in real life. How helpful was this assignment in sparking your interest in the course?"

Overall, 44% responses indicated very helpful or helpful, 31% moderately helpful, 21% rarely helpful or not helpful at all. Fully 90% of students indicated that they would or might recommend assignments similar to the first assignment be given to students taking this course in the future. This finding suggests that an introduction of interactive assignments at an early stage of a course can help motivate student's interest in course subjects.

A following question asked students to identify how helpful the first assignment was in developing their understanding of the engineering concepts subsequently taught in the course. Student responses (Figure 1) show that the interactive assignment introduced in this term was helpful in their learning of engineering concepts.

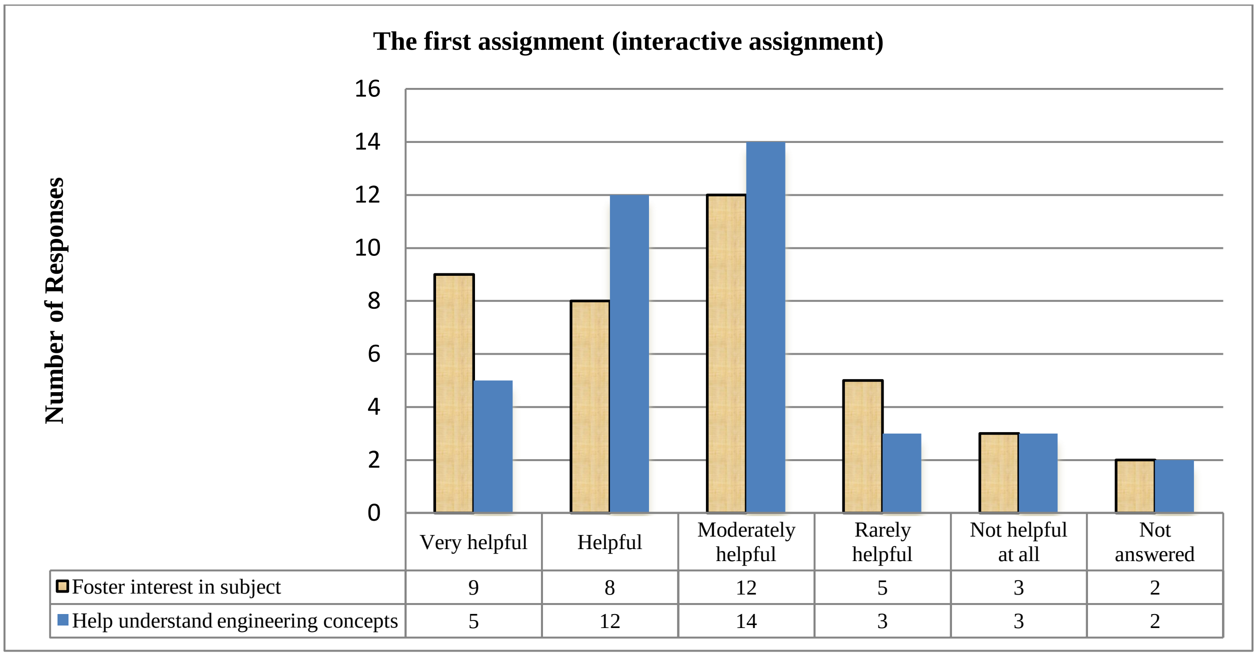


Figure 1 Student responses to the effectiveness of the first assignment

Figure 2 shows a comparison of students' perspective on the interactive assignment and the traditional textbook assignments. On one hand, this data may be biased since we compared one assignment with five assignments, and the first assignment covered relatively simple concepts compared to the other assignments, which were given later in the term. On the other hand, this data emphasizes the importance of assignments, whether interactive or traditional, as opposed to lectures.

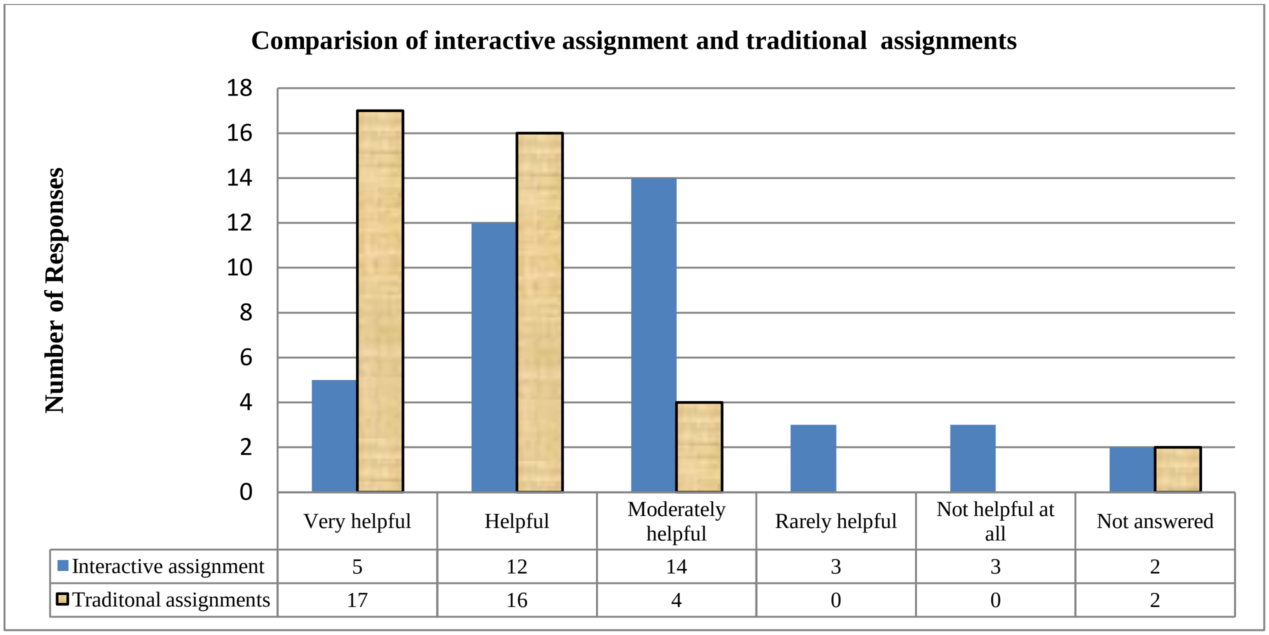


Figure 2 Student responses to all assignments

Presentation

As part of the first assignment, students were offered opportunities to make a brief presentation in class on the mechanisms that they had found and documented. Only two students volunteered to make such a presentation. Survey questions 10 and 11 revealed the main reasons that students were reluctant to make a presentation (listed from top ranked to bottom ranked): 1) lack of time, 2) not worth marks, 3) uncomfortable in the public, and 4) not confident with the ability to explain the relevant concepts. Again, the main issue here was one of time management. It would seem that demands on students' time have a significant effect on their academic decision-making. It seems that students expect to receive marks for participating in class activities. The question is: How can we help students see value in activities that are not rewarded by immediately measurable mechanisms such as marks?

Conclusions

The overall design and delivery of the Kinematics and Dynamics of Machinery course achieved the goal of more student engagement and involvement in learning. The range of assignments presented to the students was well received and succeeded in meeting the learning needs of the majority of the students. The first assignment, which asked students to locate and document a real-life example, was especially satisfactory in helping to engage students in the course material they were about to explore. Ninety percent of students indicated via the survey that they would recommend it be included in this course in the future. This finding confirmed our theory that introducing interactive elements at an early stage of a course can boost student interest in technical concepts. Data from the survey suggest that assignments, whether interactive or of a traditional type, contribute to students' learning experience, and therefore to their engagement.

The feedback received on projects is worth further research and investigation. Going forward, we intend to focus on how we can help students appreciate the value of activities that do not yield immediate results and may not be rewarded by measurable mechanisms such as marks. Another area to explore is to develop assignments that assist students in realizing the value of metaskills such as collaboration, communication, and lifelong learning. We look forward to continuing to work together to design ways to integrate active learning and communication more closely into the course assignments.

References

1. Felder, R. M., Woods, D. R., Stice, J. E., & Rugarcia, A. 2000. The Future of Engineering Education: II. Teaching Methods That Work. *Chemical Engineering Education*, 34(1), 26–39.
2. Engineers Canada. Accreditation Criteria. *Canadian Engineering Accreditation Board Accreditation Criteria and Procedures.* http://www.ccpe.ca/e/files/Accreditation_Criteria_Procedures_2010.pdf
3. Accreditation Board for Engineering and Technology (ABET). General Criterion 3: Student Outcomes. *Criteria for Accrediting Applied Science Programs, 2012 – 2013* http://www.abet.org/asac-criteria-2012-201
4. Templeman, E. & Pilot, A. 2010. Strengthening the Link between Theory and Practice in Teaching Design Engineering: An Empirical Study on a New Approach. *The International Journal of Technology and Design Education* (*21*), 261-275.
5. Felder, R.M., Brent, R., 2004. The ABC's of Engineering Education: ABET, Bloom's Taxonomy, Cooperative Learning and so on. *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*
6. *Design of Machinery*, R.L. Norton, McGraw Hill, 5th edition, 2011

Acknowledgement

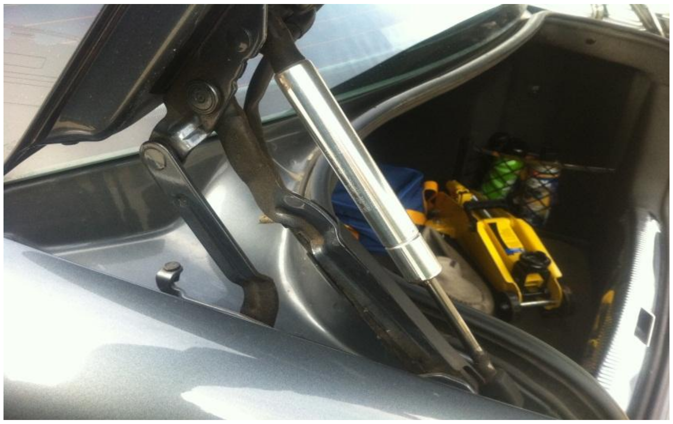
The authors would like to thank all students in the School of Engineering, University of British Columbia's Okanagan campus, who participated in this study. The authors would also like to thank Vania Chan in the Centre for Teaching and Learning in the University of British Columbia's Okanagan campus for helping with the survey on WebCT Vista.

Appendix 1
Examples of mechanisms found by students through the first assignment

Category	Examples
Gym equipment	Leg press machine in a multi-gym unit Bench
Automobiles and transportation	Automobile trunk hinge Dirt bike suspension linkage V-Twin engine in a motorcycle Bicycle with a full suspension Opposed Piston Opposed Cylinder (OPOC) 2-stroke diesel engine Airbus landing gear Sandbox backhoe
Tools	Foldable saw table Wire cutter Drilling arm Vise grips Car/trolley lifting jack
Consumer product	Snowmobile suspension Camera tri-pod Toy tractor Foldable reclining chairs Hinges in cabinet and closet-door Guitar mount Bolt action rifle Painting easel Nail clipper Scissor Step ladder Window and garage door openers Carabiner


Leg press machine in a multi-gym unit


Camera tri-pod


Automobile Trunk Hinge

Vise grips

Appendix 2

Survey on ENGR 381 Kinematics and Dynamics of Machinery

Instructions

This survey will be used to help us understand how students learn. Your answers will help instructors understand which types of assignments students find most helpful in assisting their learning. This survey is anonymous and will not affect your evaluation in the course ENGR 381. It will take approximately 10-15 minutes to complete. Your participation in this survey will be highly appreciated.

1-7 In this term, we have implemented different instructional tools/methods. Which of the following instructional methods supported your mastery of the material the most?

1. Assignments

- 1. Very helpful
- 2. Helpful
- 3. Moderately helpful
- 4. Rarely helpful
- 5. Not helpful at all

Save Answer

2. Project

- 1. Very helpful
- 2. Helpful
- 3. Moderately helpful
- 4. Rarely helpful
- 5. Not helpful at all

Save Answer

3. Lectures

- 1. Very helpful
- 2. Helpful
- 3. Moderately helpful
- 4. Rarely helpful
- 5. Not helpful at all

Save Answer

4. Tutorials

- 1. Very helpful
- 2. Helpful
- 3. Moderately helpful
- 4. Rarely helpful
- 5. Not helpful at all

Save Answer

5. Exams

- 1. Very helpful
- 2. Helpful
- 3. Moderately helpful
- 4. Rarely helpful
- 5. Not helpful at all

Save Answer

6. If you were to choose two most helpful instructional tools from the above list, i.e., Assignments, Project, Lectures, Tutorials, Exams, what would they be?

Paragraph

New Insert equation

Save Answer

7. Please share any comments you may have that would help the instructors understand your preferences.

Paragraph

New Insert equation

Save Answer

8-15 About the first assignment

8. At the beginning of the term, you were given the first assignment "Discovery of mechanisms in real life". This assignment asked you to find examples of common mechanisms in real life. How helpful was this assignment in sparking your interest in the course?

- 1. Very helpful
- 2. Helpful
- 3. Moderately helpful
- 4. Rarely helpful
- 5. Not helpful at all

Save Answer

9. Would you recommend assignments similar to the first assignment you had in this term be given to students taking this course in the future?

- 1. Yes
- 2. Maybe
- 3. No

Save Answer

10. As part of the first assignment, you had an opportunity to present your photo or video in class. Did you offer to present your photo or video?

- 1. Yes
- 2. No

Save Answer

11. If you answered "No" to question 10, which of the following prevented you from presenting? Please check all that apply.

- 1. Lack of time
- 2. Not worth marks
- 3. Uncomfortable in the public
- 4. Not confident with the ability to explain the relevant concepts
- 5. N/A
- 6. Other (please specify the reason in the next question)

Save Answer

12. If you chose "Other" in question 11, please specify the reason.

Paragraph
New Insert equation

Save Answer

13. An online library of mechanisms was created from the first assignment, where the videos and photos you took can be viewed by the class. Did you offer to post your photo or video?

- 1. Yes
- 2. No

Save Answer

14. If you did NOT offer to post your videos and/or photos, which of the following prevented you from doing so? Please check all that apply.

- 1. Not worth marks
- 2. Not confident with your own work
- 3. Do not think it is necessary to set up such a library of mechanism
- 4. N/A
- 5. Other (please specify the reason in the next question)

Save Answer

15. If you chose "Other" in question 14, please specify the reason.

Paragraph
New Insert equation

Save Answer

16-17 Except for the first assignment, all other assignments in this course were traditional textbook assignments. Which type of assignments best helped you understand engineering concepts?

16. Non-traditional, interactive assignments (e.g., Assignment 1)

- 1. Very helpful
- 2. Helpful
- 3. Moderately helpful
- 4. Rarely helpful
- 5. Not helpful at all

Save Answer

17. Traditional textbook assignments (e.g., Assignments 2-6)

- 1. Very helpful
- 2. Helpful
- 3. Moderately helpful
- 4. Rarely helpful
- 5. Not helpful at all

Save Answer

18-20 The software ADAMS was recommended to the class as an optional tool to assist your design projects during the term. We are exploring the possibility to purchase a full license of ADAMS and make it a mandatory component in this course. Your experience as a user will be very valuable.

18. Did you use ADAMS in this term? Check one answer.

- 1. Tried it just for practice
- 2. Used it in the project
- 3. Not at all

Save Answer

19. If you did NOT try ADAMS at all, why? Check all that apply.

- 1. Lack of time
- 2. Not worth marks
- 3. Not interested in it
- 4. Technical difficulty
- 5. Other (please specify the reason in the next question)

Save Answer

20. If you chose "Other" in question 19, please specify the reason.

Paragraph

New Insert equation

Save Answer

21. Please share any comments you may have on your learning experience with ENGR 381.