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A Preliminary Classroom Survey Explains the Students' Reflections on Engineering Physics I (Mechanics) in Their Freshman Year

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Abstract

The physics course evaluations and feedback studies are extremely important at the freshman level due to several reasons. The evaluations hold students' reflections on learning outcomes which can help the instructor make necessary changes in the current practice as well as provide an engaging environment to accelerate the learning process. Teaching Engineering Physics I at the university level is always challenging and interesting since it requires an empathy with the students who have just arrived from various high schools. This paper reports the results of an independent classroom survey conducted at the end of fall 2016 and 2017. Aims of this survey are threefold: 1. To measure the course accomplishments from students' perspective 2. Compare the results between different years 3. To evaluate expectations versus performance.

1. Introduction

"There is no science in this world like physics. Nothing comes close to the precision with which physics enables you to understand the world around you. It's the laws of physics that allow us to say exactly what time the sun is going to rise. What time the eclipse is going to begin. What time the eclipse is going to end. [1]" Neil deGrasse Tyson - an American astrophysicist, author and science communicator.

Teaching physics for undergraduates, particularly at the freshmen level is challenging and exciting as it allows interacting with students at a formidable time in their lives – the transition from high school to undergraduate school. During this time, physics can become the enemy of academic growth, especially when it is seen as too difficult to understand and when students feel it is a necessary evil to endure for academic credit. This feeling is most prevalent among students who had an unqualified or un-engaging teacher or went to a school that lacked appropriate experimental facilities. There is also a big discussion among educators that the inadequacies in mathematic skills of freshmen students suppress the quality of physics education. Since 1990, the "physics first" movement [2] is working extremely hard to rebuild a strong physics curriculum at public high schools.

Our Institution is offering career focused education through seventeen bachelor degree programs together with a limited number of master degree programs. Since 2015, all engineering students at our institution have followed a common first year syllabus, taking Engineering Physics I (hereafter EP 1) in the fall of their freshman year concurrently with Calculus I, and Engineering Physics II in the spring of freshman year concurrently with Calculus II.

We believe that teachers, who demonstrate curiosity and passion about physics, will motivate students to learn at all costs. Physics is one of the subject where the theory learned in the lecture room can be complemented with real life experiments in laboratories [3,4]. Physics course evaluations and feedback studies [5-8] are extremely important at the freshmen level to provide a pleasing learning environment to our students as well as identify where shortcomings in the education process are occurring. In general, these instruments will help to rebuild and reevaluate the current teaching practices within the host institutions. Unfortunately, the study reported in this paper does not follow any standard survey models such as “Likert survey model” [9,10] and hence there is no standard to compare how “satisfaction” is defined quantitatively. Instead, we developed a perception to identify the factors limiting the students’ course accomplishments in our current classroom arrangements with a view point of enhancing the learning environment in the future. The conclusions from this study are solely determined by the course instructors in the way they feel about the statistics received through this independent in-house survey. Further comparisons of this study to the aforementioned standards will be explored in a later work.

We used the same survey questions in fall 2016 and fall 2017 without any changes except the student sample population to examine the reliability in the results. If we changed the current teaching practices in 2017 based on the students’ reflections recorded in 2016, the results obviously different between two years. However, we do not like to implement the changes to our current learning environment based on one-year study as this may lead to changes in haste. It is also worth to note that the sample size chosen in our host institution is small due to our small classroom size and the data compares between fall 2016 and fall 2017. Hence, scientifically we aware that these results should have some flaws and limitations, but, the data collected from this study may be useful for instructors who teaches the same course or for educational researchers, working closely with freshmen students.

2. Teaching Methodology

There are no prerequisites for the Engineering Physics I course outside of admittance into an engineering program. The co requisites courses include: MATH1750, Engineering Calculus I or MATH1775, Integrated Engineering Calculus I. The text book adopted for this course was “Young and Freedman, University Physics 14th Edition with online Mastering Physics, published by Pearson.

EP 1 is a four-credit course, with two 80-minutes lectures and one 110-minute lab session per week, for a total of 14 weeks. The expected course learning outcomes are defined as the students will be able to apply systematic problem-solving strategies and mathematical techniques, in particular calculus, to describe, explain, and solve problems in some or all of the following areas of physics:

- Dimensional analysis
- Unit Conversion
- Vector Addition and Multiplication
- 3D Kinematics
- Newton’s Laws
- Mechanical Equilibrium
- Work-Energy Theorem
- Momentum and Energy Conservation
- Rigid-Body Rotation
- Special Topics in Mechanics

The class materials for the course were presented in a combination of power point lecture, discussion and group problem solving. It should be noted that the course in question does not have a required recitation session as in some institutions due to a contact hour constraint. Power point lecture notes were posted electronically via course blackboard in advance. So, students can have access from anywhere at any time and also can see colorful images and diagrams without any confusion with the topics. Black and white printed copies were also distributed during the class to take their own notes next to each slide while in the lectures. Classroom and lecture materials are further explored with the readings from the text, weekly homework, end of chapter quiz assignments and laboratory experiments.

Additionally, students typically received five to six practice problems and solutions at the end of each chapter extracted from their text book. These solutions were given as an extra self-study guide to navigate their 120 minutes weekly homework assigned through online mastering physics platform. Each week's homework questions were selectively assigned as the real-world engineering applications where students were expected to use their theoretical understandings gained from the classroom. Students were encouraged to work as a team on these problems. To encourage this collaborative environment, an additional academic support and Physics Facilitated Study Groups (FSGs) were provided by the department on every Thursdays evening for three hours (but are not required for credit or completion of the course).

In order to fulfill the conceptual concepts, quizzes were provided through mastering online platform at the end of each chapter. Quizzes are multiple choice questions with numerical calculations and were open book due within a 24-hour time frame. Students do not need to finish the quiz in one sitting. Instead, they can get the help from any sources or can work as groups but need to submit on time to earn credits. In this way, each chapter was fulfilled covering engineering applications and concepts via weekly homework and quiz, respectively.

A major emphasis of the course was expected in learning through experimentation in the laboratory activities. The laboratories were aimed at discovery, practice of skills and exchange of learned material. Each lab was closely tied to the topic which was discussed in the previous week's class. Most of the labs were conducted as workshops where students worked as a group and one of the selective labs was assigned to submit a formal lab report.

The weighting of tests, laboratories and the final exam include, term exam 1: 5%, term exam 2: 15%, term exam 3: 20%, weekly homework: 20%, Laboratories: 15% and final exam: 25%. Out of the 10 weekly quizzes, the two lowest-scoring quizzes were dropped, and the averages of 8 best quizzes were considered for extra credit course activity. With the outline of the content and syllabus of the course established, we turn our attention to the data collection for this study.

3. Survey design, Data collection and Analysis

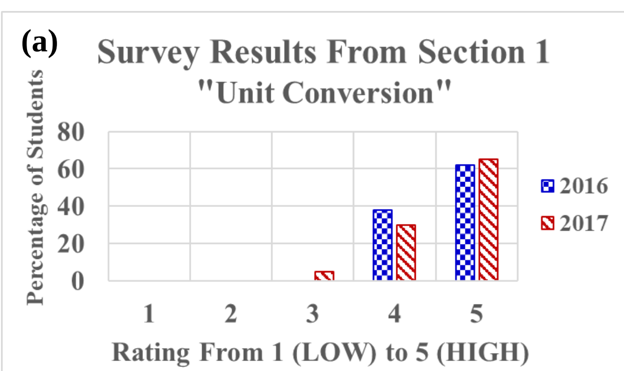
An independent classroom survey was conducted during the last day of the class, fall 2016 and 2017. The same questionnaire was given in 2017 as well, since the expectation was to see the data consistency from year to year. During both years, the statistical sample size (class size) was nearly equal due to the consistent (but small) classroom size at our host institution.

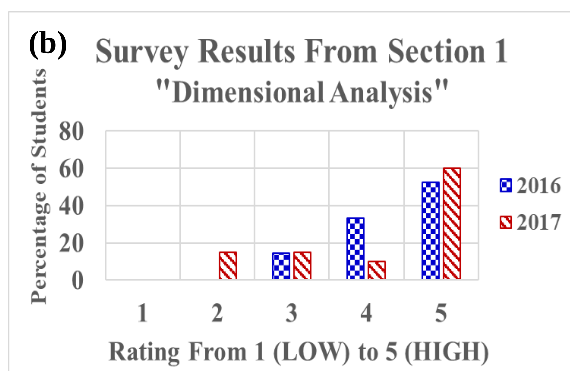
This perception survey has four sections. Section 1 was designed to measure the learning outcomes of the student with a rating of nine statements from 1 (low) to 5 (High). In section 2, ten questions were generated in five points scale to understand about the current teaching methodology from students' point of view. Namely, whether students agree with the model or disagree with that approach. Section 3 was designed with ten "YES" or "NO" type questions to learn what would potentially make students more content in the current learning environment and what makes their learning process difficult or what do they like to have in the future. In section 4, students were requested to select one challenging and one easiest chapter throughout the EP I. The idea behind this section's design is to justify students' responses with section 1. By comparing the students' responses between sections 1 and 4, it might be able to judge whether the participating student was serious about the questions or he/she completed the survey for a sake of completion.

To keep the surveys confidential, a student volunteer from the class was selected to conduct the survey. A sealed envelope with the questionnaire was given to him and the survey was conducted from the whole class without the presence of the instructor. After 15 minutes, a student volunteer collected all the questionnaires from the students and submitted to the instructor within a sealed envelope. Statistical data analysis was conducted by the instructor after the final grades had been released by the registrar.

3.1 *Section 1- Rate the following statements from 1 to 5 (1-Low and 5-High)*

The first section of the survey was designed to measure achievements in the learning outcomes of the course. The question was simply worded: "At the end of this course I can apply systematic problem-solving strategies and mathematical techniques, in particular calculus, to describe, explain, and solve problems in (1) Unit Conversion, (2) Dimensional analysis, (3) Vector Addition and Multiplication, (4) Newton's Laws, (5) Mechanical Equilibrium, (6) Work-Energy Theorem, (7) Momentum and Energy Conservation, (8) Rigid-Body Rotation and (9) 3D Kinematics". The section 1 survey results for both years are summarized in Fig.1 (a-i). In 2016, Section 1, unit conversion, received the highest students' rating of 62% (Fig.1a) and continued to stay the same in 2017 as well. Section2, dimensional analysis (Fig.1b) and section 7, momentum and energy conservation (Fig.1g) do not show any significant difference between 2016 and 2017. 71% of students rated the "vector addition and multiplication" above average in 2016 (Fig.1c) which is 6% higher than 2017.





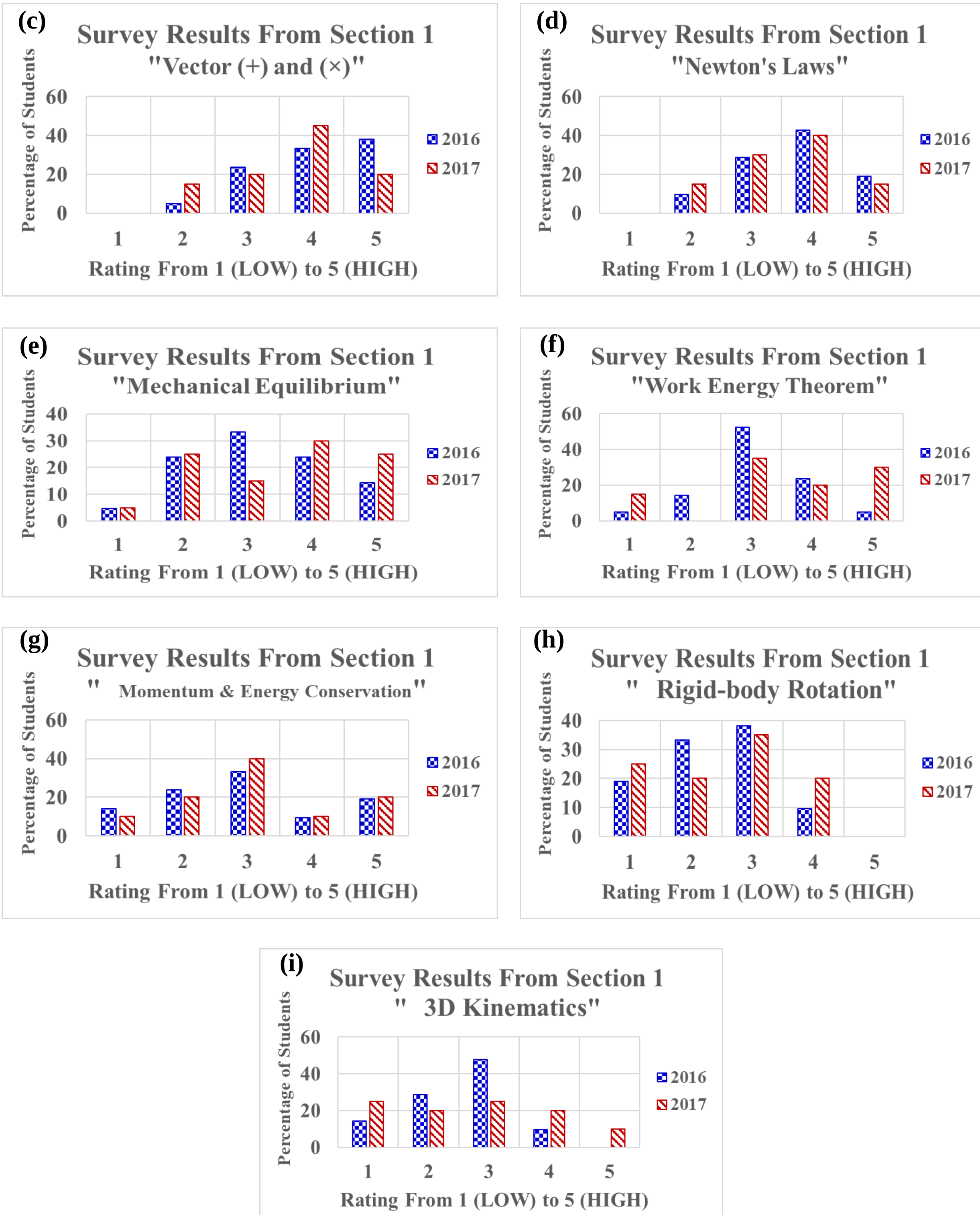


Fig.1 (a-i): *Shows the independent classroom survey results for section 1 (learning outcomes) during the fall 2016 and fall 2017.*

Newton's laws in section 4 (Fig.1d) rated as above average by 55% of students in 2017, 7% less than the previous year. In both years, 30% of the students voted below average for mechanical equilibrium (Fig.1e). "Work energy theorem" reported as above average by 29% of the class in 2016 (Fig.1f) and 50% in 2017.

Section 8, rigid body rotation (Fig.1h) received a lowest rating of 19% in 2016 and 25% in 2017. At the same time, it is rated by 10% with a score of "4" in 2016 and by 20% in 2017. However, none of the students did not rate with "5" in both years. "3D Kinematics" (Fig.1i) received a rating score of 4 and 5 by 10% of the class in 2016 which increased by 20% in 2017.

In summary, there are no significant differences between 2016 and 2017 batch of students in the measure of achievements and learning outcomes. It is also worth to note that we did not change anything in the course curriculum during these years and in both years the class sizes were chosen to survey are nearly equal. However, there is a clear consensus among students about difficulties to describe, explain and solve the problems in the rigid body rotations. Even though, students are pretty good in one and two-dimensional analysis, they had a very hard time in translating a linear coordinate "x" with an angular coordinate "θ". Their calculus knowledge is also another limiting factor in terms of understating and applying these concepts. Also, center of mass, center of gravity, moment of inertia and torque were introduced along with rigid body rotations and most of the time students could not able to identify that they need to treat the center of mass under the translational motion while the whole rigid body rotates. When we start to derive the moment of inertia of a sphere through first principles of calculus, it requires students to follow some complex integrals which they may not have encountered in their math classes yet.

3.2: *Section 2- Circle one (5-Strongly agree, 4-Agree, 3-Neutral, 2-Dis agree, 1-strongly disagree)*

In this section, we review students' response to ten questions about the current teaching methodology. Students were asked to respond to the following ten questions according to a five-point scale (5-Strongly agree, 4-Agree, 3-Neutral, 2-Disagree, 1-strongly disagree):

1. The electronic lecture handouts posted in the blackboard helped me to prepare for the class in advance.
2. The hardcopy of the lecture notes helped me to understand the course materials during the classroom lecture.
3. I am happy with the design of the lecture handouts which guided me well throughout the course.
4. The practice questions and solutions given for each chapter were very useful to further understanding of the chapters outside the classroom.
5. The practice questions and solutions given for each chapter helped me to get an idea on how to approach the homework problems.
6. The weekly homework helped me to master the application of the concepts studied in each chapter.
7. The weekly take home online quiz helped me to master the conceptual ideas studied in each chapter.

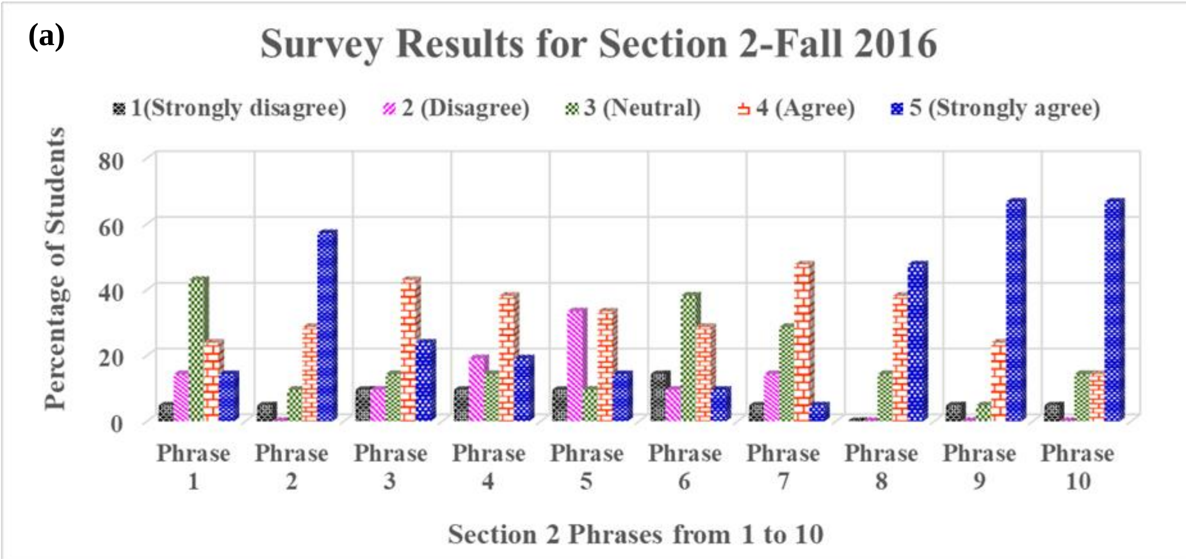
8. The labs helped me to explore the truths via careful observations or thoughtful analysis which I learned in the lecture class.
9. Two hours were enough to finish my lab experiments.
10. Two hours were enough to finish my in class closed book exams.

Referring to phrase 1 in 2016, 14% strongly agreed and 24% agreed that the "electronic lecture handouts posted in Blackboard helped them to prepare for the class in advance" (Fig. 2a). In 2017, both equally voted with 20% (Fig. 2b). As a whole, there are no significant differences in both years. Phrase 2 (Fig.2a), "the hardcopy of the lecture notes helped them to understand the course materials during the classroom lecture", was agreed by 29% and strongly agreed by 57% in 2016 which is 4% and 12% lower in 2017, respectively (Fig.2b).

Phrase 3, regarding the design of the handouts was strongly agreed by 24% in 2016 and 25% in 2017 and agreed by 43% in 2016 (Fig.2a) and 35% in 2017 (Fig.2b). "The practice questions and solutions given for each chapter were very useful to further understanding of the chapters outside the classroom" (Fig.2a) was agreed by 38% and strongly agreed by 19% which is a good sign in 2016. During 2017 (Fig.2b), 35% agreed and 10% strongly agreed. However, it is interesting to note that 10% in 2016 and 20% in 2017 strongly disagreed with this statement.

In 2016, 14% strongly agreed and 33% agreed (Fig. 2a) that the practice questions and solutions given for each chapter helped them to get an idea on how to approach the homework problems. In 2017 (Fig. 2b) only 5% strongly agreed and 30% agreed with this phrase which is 12% less as a whole compared to 2016. This fails to match with the instructor's expectation. It is worthwhile noting that 10% of students strongly agreed while 29% agreed and 38% were neutral regarding phrase 6 (Fig.2a), that the weekly homework helped them to master the application of the concepts studied in each chapter. In 2017, (Fig.2b) none of them strongly agreed but 60% agreed and 15% were neutral. This is one of our expectations from engineering students. The weekly take home online quiz helped them to master the conceptual ideas studied in each chapter is strongly agreed by 5% and agreed by 48% in 2016 (Fig 2a) which is equally selected by 20% of the students' sample in 2017 (Fig 2b).

Regarding laboratory teaching, 48% and 50% strongly agreed in 2016 (Fig.2a) and 2017 (Fig.2b), respectively that the labs helped them to explore the facts via careful observations or thoughtful analysis which they learned in the lecture class, while 38% agreed (30% in 2017) and 14% were neutral (20% in 2017), as shown in Fig.2a and b. Simultaneously, in Fig. 2a, 67% and in Fig. 2b, 80% strongly agreed that two hours were enough to finish their lab experiments. Finally, 67% strongly agreed and 14% agreed (Fig.2a) that two hours were enough to finish their in class closed book exams. However, in 2017, (Fig.2b) this is strongly agreed by 35% and agreed by 30% only. It is also worth to mention that in both years, exams were conducted in similar pattern and same number of questions with formula sheets.



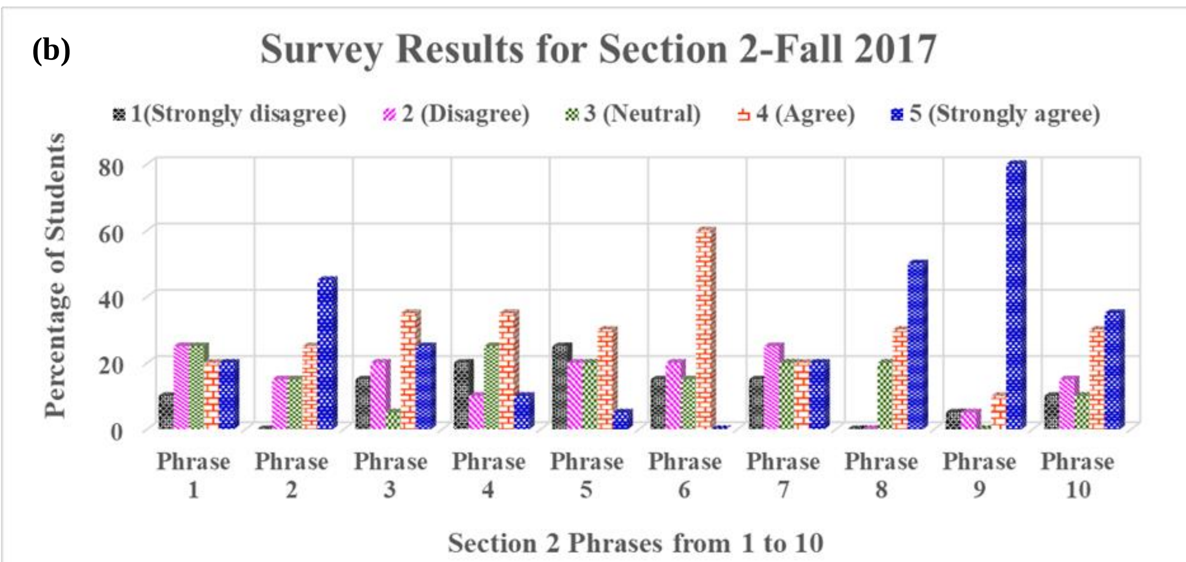


Fig. 2(a-b): *Depicts the survey results for section 2 (current teaching methodology) during the (a) fall 2016 and (b) fall 2017.*

In summary, the current teaching methodology for this course is "fairly accepted" by the sample student community (the data shows that on the average, students are fine with the course components). It is not required to do any immediate changes in this methodology but we are expecting to enhance this methodology via pre-lecture evaluation (PLE) and collaborative activities (CAs). In PLE, we will assign some reading questions which will reinforce reading from text book before the lecture class. In CAs, students have to work as a group in a round table on calculus based real life applications with the presence of their instructor and teaching assistants. We are expecting to introduce this CA once in a week for 2 hours. First 30 minutes of the seminar is the review of the last week lectures and then group problem solving for an hour and finally a closed book quiz for 30 minutes.

3.3: *Section 3- Circle one (Yes / No)*

The objective of this section of the survey was to identify what students really like to have and what they don't like during this course. Additionally, it focused on what they expect from their instructor to succeed in this course. Students were asked to respond to the following 10 questions with "Yes" or "No":

1. I would like to have a closed book quiz in the class room rather than a take home online quiz.
2. I like to do the homework manually, not through an online system.
3. I am happy to do two hours weekly homework on each chapter.
4. I like to have all the lecture materials electronically in advance to the class.
5. I like to have all the lecture materials as hardcopy during the class to take my own notes while lecturing.
6. I like to submit my own lab report.
7. I like to submit one lab report on behalf of my group.
8. I like to have extra credit questions in my exams.
9. I like the current design of the exam paper which guided me step by step on each question.
10. This class was so boring to me since I have studied all these concepts in another class or college or high school.

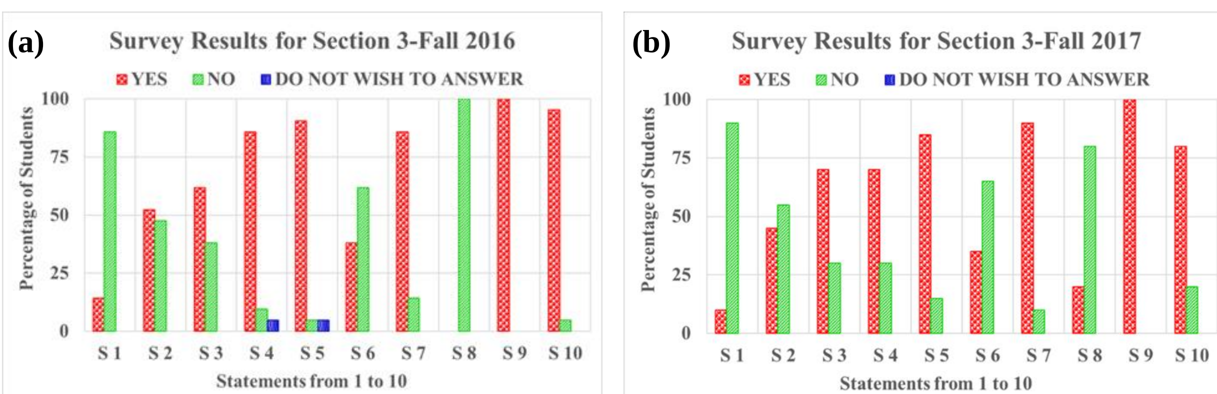


Fig 3(a-b): *Shows the survey results for section 3 (students' preferences and expectations) during (a) fall 2016 and (b) fall 2017.*

In Fig. 3a, 86% of the students in 2016 responded "NO" to having a closed book quiz in the classroom rather than a take-home online quiz. This is supported by 90% in 2017 (Fig. 3b). The take home quiz was designed to be conceptually challenging and also it had maximum of 20 multiple choice questions to be completed within 24 hours.

In 2016 (Fig. 3a), 52% students said that they wanted to do homework manually rather than regular online mastering physics which is 7% higher compared to 2017 (Fig. 3b). Always there were issues in the online platforms which lead the students under frustration. Generally, these issues involved with round off and notations that the system rejects the student's answer which is actually correct. They will not lose any points if they have submitted manually. Furthermore, Mastering Physics is expensive and must be purchased by each student, negating the possibility of buying a used textbook or one from the library.

Students responded favorably for a two hours weekly homework by 62% in 2016 (Fig. 3a) and 70% in 2017 (Fig. 3b). This is the place where students can absorb, understand and apply the theory learned in the lectures. These weekly homeworks are designed with real life day to day applications which will cover many of the engineering disciplines, namely mechanical, civil, computer, biomedical and electrical.

Students always like to have their lecture notes electronically in advance to the class. 86% and 70% voted "YES" to this statement in 2016 (Fig. 3a) and 2017 (Fig. 3b), respectively. We used to give a black and while print copy in the class to take their own notes while lecturing. However, in the electronic copy, they can see the colorful images without any confusion. If they like to take their own notes electronically, they are allowed to use electronic devices with restrictions. In the following statement, 90 % in 2016 (Fig. 3a) and 85% in 2017 (Fig. 3b) said that they really like to have a printed copy during the class for their own notes taking purpose.

Generally, students work as a group in each lab experiments. They are advised to submit one lab report on behalf of their group but everyone should attach their own data analysis at the end of the report. 62% and 65% of students' sample population said "NO" to submit individual lab reports in 2016 (Fig. 3a) and 2017 (Fig. 3b), respectively which is further supported by the following statement "I like to submit one lab report on behalf of my group". This statement was strongly supported by 86% in 2016 (Fig. 3a) and 90% in 2017 (Fig. 3b).

There could be a possible argument that writing reports take lot of time during the semester since each student is taking 16-20 credit units, but based on instructors' prospect, we encourage this approach for a team work practice, which is an essential skill for engineers. Students strongly rejected to have extra credit questions in the exam paper in both years. This is very surprising to us. We could not able to predict the reason behind this selection.

All 5 extra credit questions were designed as multiple-choice questions (MCQs) with 4 answers. Most of the time, we, instructors saw that they never select an answer to these questions. Even though they did not know the right answer, they can select at least one answer per question. They will not lose anything by selecting a wrong answer. However, most of the time, they left those questions as un answered. Someone may argue that they may run out of time to read those questions. The answer is “NO”. Their exam is 2 hours and most of the time they finished no later than 90 minutes. As instructors, we observed that they are not very much interested in MCQs. This is one of the reasons why we introduce an open book quiz with only MCQs, to reinforce as a part of the course. In future, we are planning to give an extra credit question as a regular type of structure question to verify this statement. In both years, 100% of students’ sample population strongly supported the design of the exam paper (Fig.3a &b) which was guiding them from one step to another toward the final target variable. This approach was completely opposite to their weekly homework design in the mastering physics where most of the time; they did not know where to start the problem. In these situations, they had to follow through available publisher’s hints which are considered as an adoptive study guides.

The last statement is very important to this survey which was worded as “This class was so boring to me since I have studied all these concepts in another class or college or high school”. 95% said “YES-IT IS BORING” in 2016 (Fig. 3a) and 80% in 2017 (Fig. 3b). Now the question is, if they understood these concepts in high school or some other places, they should perform well in this class. The section 1 survey results measured their learning goals which are not very favorable and contradict with this answer. At the same time, the question was prepared very carefully because, it means that the class is boring since I knew the content earlier, not because of the teacher or lack of teacher’s enthusiasm in the subject or in the class. The one factor we found to support this discussion is their poor skills in calculus, geometry and algebra knowledge. On the other hand, if they took AP physics credits they can simply use that credit to skip EP I, but they are advised to take this EP I again in this university means that their previous performances were not satisfactory with the expectations.

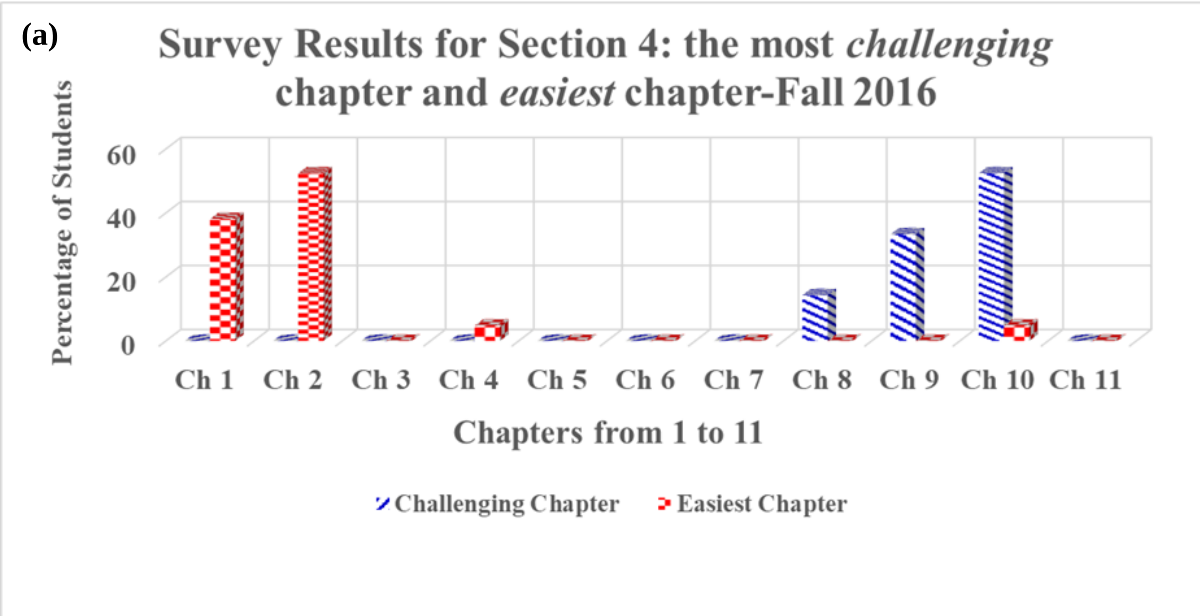
3.4: *Section 4- Select clearly only one answer*

Finally, we evaluated the degree of difficulty as experienced by the student for each of the chapters covered in the course. Students were asked to select one answer only for the following two questions:

1. The most challenging chapter for me
2. The easiest chapter for me

Chapter 1: Units, Physical Quantities and Vectors
Chapter 2: Motion along a Straight Line
Chapter 3: Motion in Two or Three Dimensions
Chapter 4: Newton’s Laws of Motion
Chapter 5: Applying Newton’s Laws
Chapter 6: Work and Kinetic Energy
Chapter 7: P.E and Energy Conservation

Chapter 8: Momentum, Impulse and Collisions
Chapter 9: Rotation of Rigid Bodies
Chapter 10: Dynamics of Rotational Motion



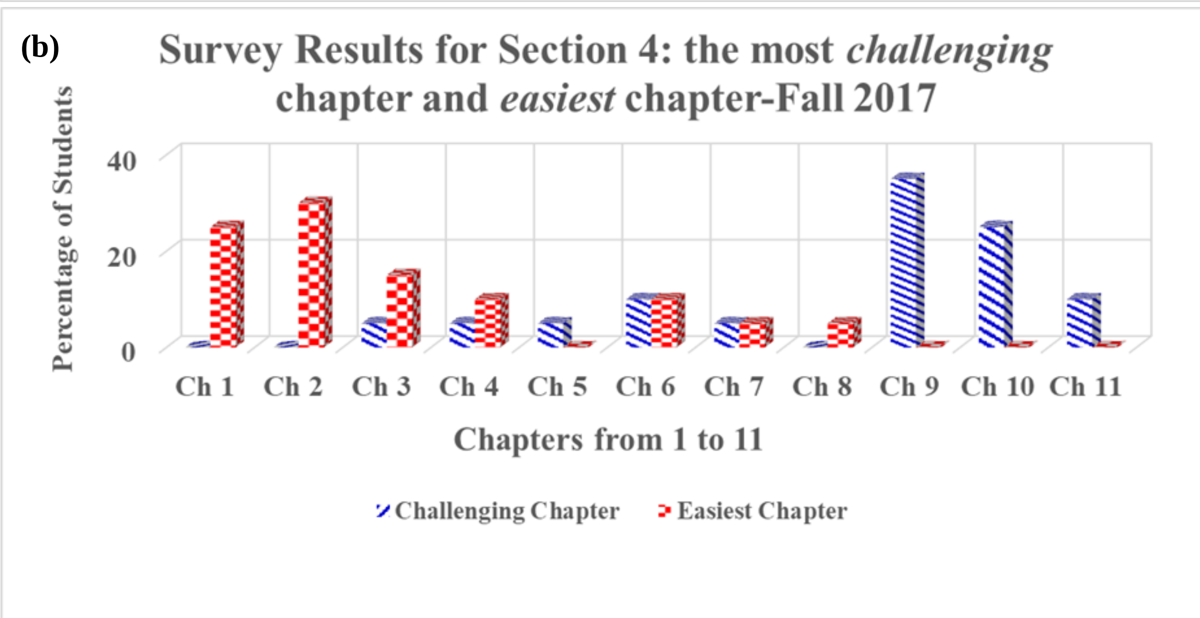


Figure 4(a-b): *Exhibits the survey results for section 4 (challenging versus easiest chapter) during the (a) fall 2016 and (b) fall 2017.*

The goal of this section was to check the consistency with the results reported in section 1, "measuring the learning outcomes". None of the students rated "Rigid body rotation" with 5 in section 1 indicating that learning outcome in this particular topic is relatively poor in both years.

This was very consistent and in agreement with section 4 where chapters 9 (Rotation of rigid bodies) and 10 (Dynamics of rotational motion) were selected as the most challenging chapters by 85% of the student sample population in 2016 (Fig. 4a) and by 60% in 2017 (Fig.4b). Chapters 1 and 2 remained the easiest during both years which is also in good agreement with the results recorded in section 1.

4. Conclusions

In summary, there is no significant difference in the leaning outcomes between 2016 and 2017. Expectations versus performances in the learning outcome were not remarkable in the section 1. It always makes us wonder whether students are struggling with the conceptual sides of the physics or do they have a barrier with their mathematics skills to apply the principles. From our experiences over the years, we found that the mathematical skills play a major role than the physics concepts. This is a two-way process which needs to be rectified with their math professors as well.

Based on the section 2 results, our teaching methodology does not require any immediate changes but with time, we are planning to introduce PLE and CAs to strengthen the course curriculum and to improve the learning goals as we discussed above. Section 3 results reveal that students like to do an open book quiz rather than a closed one. The quiz is not considered as an exam and the goal is to encourage them to learn as much as possible outside the classroom. This is in line with the instructor's expectations. At some point students like to the old method meaning that they strongly supported for having a printed copy of the lecture notes during the class. This is quite surprising because rapid development of technologies and students' addiction towards it made us to think that students may like electronic note taking instead on manual one. More importantly students strongly rejected the online homework system and expressed their opinion to do manual homework. As instructors, we also like to go with manual homework assignments even though it is little work load for us in terms of grading. The reason is that students can easily use other online resources to complete online homework just for earning credits only. Moreover, in the manual system we can provide partial credits for the right approaches with wrong answers.

Finally, section 4 results were consistent with the section 1. Rigid body rotations and dynamics of the rotational motion are noted as more challenging topics and their learning outcome clearly reflecting this fact as well. Overall, it is clear that the course requires some fillings and shaping to improve the students learning experiences. At the same time, further studies require in collaboration with the students' mathematics instructors to identify the factors limiting the physics leaning outcomes. In the future, we will continue to collect this data and deploy this self-study to other sections within our host institution. After the data set is larger, more conclusive comparisons to standard results will be discussed in a future work.

5. Acknowledgements

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