Two Aspects of Mastery Practice:
An Analysis of Inquiry Based Learning and the Solution Manual Use of
Undergraduate Dynamics Students

A thesis presented in partial fulfillment of the
requirements for the degree of Master of Science in
Mechanical Engineering

By

Rachel L. Cao

Dr. Eric L. Wang/Thesis Advisor

December 2015
We recommend that the thesis prepared under our supervision by

RACHEL L. CAO

Entitled

Two Aspects Of Mastery Practice: An Analysis Of Inquiry Based Learning And The Solution Manual Use Of Undergraduate Dynamics Students

be accepted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Eric L. Wang, Ph.D., Advisor

Emil J. Geiger, Ph.D., Committee Member

Keri L. Ryan, Ph.D., Graduate School Representative

David W. Zeh, Ph.D., Dean, Graduate School

December, 2015
Abstract

This thesis is an analysis of student learning in an undergraduate engineering mechanics course. The two mastery goal and performance goal outcomes of student learning are based on learning with the interactive inquiry-based learning activity (IBLA) and learning of concepts through homework completion and solution manual usage. The learning outcomes for the activities were analyzed using IBLAs involving weight-pulley systems, rolling-cylinder work-energy problems, and spool-friction rigid body motion. The IBLA showed mixed results in terms of the impact of the IBLAs on student performance on the final exam. However, the IBLAs were shown to broaden schema content for students, potentially increasing persistence and learning.

The learning outcomes of students’ solution manual use were analyzed through comparisons of traditional textbook homework questions and novel homework questions. The results showed that the majority of students not only use solution manuals, but that they use them in ways that do not promote the practice of problem solving.
# Table of Contents

List of Tables ........................................................................................................... v

List of Figures ........................................................................................................... vii

**Chapter 1 Introduction to the Thesis** ................................................................. 1

1.1 Motivation ......................................................................................................... 3

1.2 Approach to the Study ..................................................................................... 5

1.3 Organization of the Thesis ............................................................................... 6

**Chapter 2 Analysis of the Inquiry-Based Learning Activities IBLAs** ............... 8

2.1 Motivation for the IBLA study ......................................................................... 8

2.1.1 Introduction to the IBLA Study ................................................................ 10

2.1.2 Case Format of the IBLA ........................................................................ 12

2.1.3 Approach to the IBLA Study .................................................................... 28

2.1.4 Model for Activities in Previous Semesters ............................................ 28

2.1.5 Model for Newly added IBLAs ................................................................. 29

2.2 Background Information about Learning Activities ...................................... 30

2.2.1 Classroom Learning Processes .................................................................. 30

2.2.2 Metacognitive Analysis of Activities ....................................................... 31

2.2.3 Assessment of Learning .......................................................................... 34

2.2.4 Student Self-Assessment of Learning ...................................................... 34

2.3 Assessment Methods for the Application of Learning Activities ................... 34

2.3.1 What is an Inquiry-Based Learning Activity? .......................................... 34

2.3.2 Case Format for the Inquiry-Based Learning Activity ......................... 35

2.3.3 Survey Format for the Inquiry-Based Learning Activity ..................... 35
2.4 Results and Discussion for the Inquiry-Based Learning Activity ........................................36
  2.4.1 Mastery Assessments ........................................................................................................36
  2.4.2 Data Analysis for the Inquiry-Based Learning Activity .......................................................36
  2.4.3 Survey Results for the Inquiry-Based Learning Activity .....................................................55
  2.4.4 Limits of the Results ............................................................................................................56

2.5 Summary and Conclusion of Student Learning Outcomes ................................................57
  2.5.1 Effects of Environmental Learning ..................................................................................59
  2.5.2 Student Learning Outcomes ............................................................................................60
  2.5.3 Future Research ................................................................................................................60

Chapter 3 Solution Manual Analysis .......................................................................................62

3.1 Introduction and Background ...............................................................................................62
  3.1.1 Motivation ..........................................................................................................................62
  3.1.2 Introduction ........................................................................................................................62
  3.1.3 Approach to the Study .......................................................................................................67

3.2 Background Student Solution Manual Applications ..........................................................67
  3.2.1 Student Learning with Solution Manuals ..........................................................................68
  3.2.2 Student Assessment with Solution Manuals ......................................................................71

Chapter 3.3 Methods for Surveying Usage of Solution Manuals ..........................................71
  3.3.1 Survey Background ............................................................................................................71

3.4 Results and Discussion of Student Surveys and Grades ..................................................72
  3.4.1 Student Output Implications for Using Solution Manuals .................................................72
  3.4.2 Survey Results ....................................................................................................................73
  3.4.3 Discussion of Survey Results .............................................................................................79
3.4.4 Comparison Between Textbook Problems and Novel Homework Problems ........81

3.4.5 Comparison Between Textbook Problems and Novel Homework Problems
Discussion ........................................................................................................................................85

Section 3.5 Summary and Conclusion to Solution Manual Use .............................................88

3.5.1 Student Learning Outcomes ..............................................................................................88

3.5.2 Future Research ..................................................................................................................89

Chapter 4 Summary and Conclusions .........................................................................................91

4.1 Summary of Information on IBLAs .......................................................................................91

4.2 Summary of Information on Solution Manual Use ...............................................................93

4.3 Student Learning Outcomes ................................................................................................95

4.4 Future Work ..........................................................................................................................97

References ....................................................................................................................................100

Appendix A.1 Weight and Pulley IBLA Worksheet .................................................................103

Appendix A.2 Rolling Cylinder IBLA Worksheet .....................................................................110

Appendix A.3 Spool IBLA Worksheet .........................................................................................116

Appendix A.4 Final Exam Questions Related to IBLAs ............................................................123

Appendix B.1 ME242 Spring 2014 Survey End of Semester Survey .......................................129

Appendix B.2 ME242 Fall 2014 Optional Online Webcampus Survey ..................................132

Appendix B.3 ME242 Fall 2014 End of Semester In-Class Survey .........................................133

Appendix B.4 ME242 Spring 2015 End of Semester In-Class Survey ..................................136

Appendix B.5 ME242 Course Weighted Grade Percentages .....................................................139
List of Tables
Table 1. Fall 2014 Weight-Pulley IBLA results. ..............................................................37
Table 2. Fall 2014 weight-pulley IBLA confidence levels. ..............................................38
Table 3. Fall 2014 Rolling Cylinder Activity Results ..........................................................40
Table 4. Fall 2014 final exam question results. .................................................................42
Table 5. Dynamics Concept Inventory Pre-Activity Scores. .............................................43
Table 6. Spring 2015 Weight-Pulley IBLA Results. .............................................................44
Table 7. Spring 2015 Weight-Pulley IBLA confidence levels. ..........................................44
Table 8. Spring 2015 Final Exam Weight-Pulley Results. ...............................................45
Table 9. Spring 2015 Final Exam Weight-Pulley Results. ...............................................46
Table 10. Spring 2015 Final Exam Weight-Pulley Results. ..............................................47
Table 11. Spring 2015 Results from Reed High School and McQueen High School
Physics Courses. ..................................................................................................................48
Table 12. Spring 2015 Rolling Cylinder IBLA Results. ......................................................49
Table 13. Spring 2015 Rolling Cylinder IBLA Case 1 and Case 2 Questions. .................50
Table 14. Spring 2015 Final Exam Rolling Cylinder Comparison Question Results. .......51
Table 15. Spring 2015 spool IBLA results. ...........................................................................53
Table 16. Spring 2015 final exam results. ..........................................................................54
Table 17. In-class IBLA survey results. ...............................................................................56
Table 18. Combined final exam scores related to IBLAs ....................................................56
Table 19. Spring 2015 percentage of student attendance to IBLAs. .................................57
Table 20. Survey results of the level of satisfaction of course preparedness ..................73
Table 21. Survey results for class awareness of solution manuals. ..................................74
Table 22. Survey results of how a student obtained a solutions manual. ..........................74
Table 23. Survey results relating the number of weekly homework sets a solutions manual was used by a student. ......................................................................................................75
Table 24. Survey results pertaining to the number of problems in a homework set a solutions manual was used by a student. ..................................................................................76
Table 25. Survey results pertaining to the main uses of a solution manual by a student. 77
Table 26. Survey results on a student's opinion on the usefulness of a solutions manual. 78
Table 27. Survey results of difficulty of homework problems out of the book compared to the novel homework problems. ..........................................................................................78
Table 28. Spring 2015 paper and online homework scores. ..................................................79
Table 29. Fall 2014 WebCampus data including traditional homework questions not found in a solutions manual. ..............................................................83
Table 30. Spring 2015 Webcampus data including traditional homework questions not found in a solutions manual. ..............................................................84
Table 31. Fall 2014 WebCampus data including traditional homework questions not found in a solution manual..............................................................87
Table 32. Spring 2015 Webcampus data including traditional homework questions not found in a solution manual..............................................................87
**List of Figures**

Figure 1. Difference between mastery goals and performance goals. Reproduced from Ames and Archer, 1998. ..........................................................4

Figure 2. Instructional layout of each IBLA Case. ..................................................12

Figure 3. Weight-pulley IBLA Case 1 individual worksheet. ..........................................13

Figure 4. Weight-pulley IBLA team worksheet. ..........................................................14

Figure 5. Weight-pulley IBLA Case 2 individual worksheet. .........................................15

Figure 6. Case 3 of the weight-pulley IBLA ..............................................................16

Figure 7. Case 4 of the weight-pulley IBLA ..............................................................17

Figure 8. Rolling-cylinder IBLA follow-up questions. ..................................................18

Figure 9. Case 1 rolling-cylinder IBLA team questions. ...............................................20

Figure 10. Case 2 rolling-cylinder IBLA team questions. ..............................................21

Figure 11. Case 3 rolling-cylinder IBLA team questions. .............................................22

Figure 12 Case 4 rolling-cylinder IBLA team questions. ............................................23

Figure 13. Spool-friction IBLA Case 1 individual worksheet. .......................................24

Figure 14. Spool-friction IBLA Case 2 individual worksheet. .......................................25

Figure 15. Spool-friction IBLA Case 3 individual worksheet. .......................................26

Figure 16. Spool-friction IBLA Case 4 individual worksheet. .......................................27

Figure 17. A description of the modeling method. Reproduced from Hestenes, 1997.....33

Figure 18. Cases 1 and 2. These representations are meant to test student understanding of net force and acceleration. .................................................................37

Figure 19. Cases 3 and 4. These representations are meant to test student understanding of mass and acceleration. .................................................................37
Figure 20. Experimental Set-up of the Rolling Cylinder IBLA ........................................39
Figure 21. Case 1 of the IBLA. Solid Cylinder vs. Hollow Cylinder. ..........................39
Figure 22. Case 2 of the IBLA. Small Solid Cylinder vs. Large Solid Cylinder .........39
Figure 23. Case 3 of the IBLA. Small Solid Cylinder vs. Larger Hollow Cylinder ......39
Figure 24. Case 4 of the IBLA. Small vs. Medium vs. Large Hollow Cylinders ........39
Figure 25. Fall 2014 Final Exam Question. This question was given to the Fall 2014
undergraduate dynamics class. ..................................................................................42
Figure 26. Spring 2015 weight-pulley pre-activity question. ....................................43
Figure 27. Spring 2015 Final Exam Weight-Pulley Question. This question was given to
Spring 2015 class section one. ....................................................................................45
Figure 28. Spring 2015 Final Exam Weight-Pulley Question. This question was given to
Spring 2015 class Section two. ..................................................................................46
Figure 29. Spring 2015 Final Exam Weight-Pulley Question. This question was given to
the Spring 2015 class section three. ..........................................................................47
Figure 30. Spring 2015 Rolling Cylinder IBLA. (A) case 1: cylinder vs. pipe. (B) case 2:
small vs. big cylinder. (C) small cylinder vs. big pipe. (D) small plastic pipe vs. big
plastic pipe vs. small metal pipe. ..............................................................................49
Figure 31. Spring 2015 Final Exam Rolling Cylinder Comparison Question. This
Question was given to Spring 2015 class section 1. .................................................53
Figure 32. Case 1 of the IBLA. Pull to the right. .........................................................53
Figure 33. Case 2 of the IBLA. Pull upward. .................................................................53
Figure 34. Case 3 of the IBLA. Pull downward. ............................................................53
Figure 35. Case 4 of the IBLA. Inner diameter pull to the right. ...............................53
Figure 36. Spring 2015 final exam direction of friction question. This question was given to section one and section two of the Spring 2015 class. ..........................................................54

Figure 37. Mastery goals. Reproduced from J. Reeve, *Understanding Motivation and Emotion*. ......................................................................................................................................70
Chapter 1 Introduction

This thesis is about the influence of different teaching aspects on the development of mastery goals for Newtonian mechanics concepts at the undergraduate level. The class in which this study was developed was undergraduate dynamics (ME 242) at the University of Nevada, Reno (UNR) over the Fall 2013 to Spring 2015 semesters. It has been shown that the direct outcomes of students who had experienced interactive learning through the inquiry-based learning activities (IBLA) had a greater amount of competency in the subject area of the activity (Adam, Self et al. 2015, Self, Widmann et al. 2013, Baheej Nabeel James Saoud 2015) and to test this theory, IBLAs have been added to the UNR undergraduate dynamics curriculum over the past years. It has also been shown from student outcomes that dynamics concepts are not always intuitive to a student (Adam, Self et al. 2015); this is because although a student may be able to complete a task on paper, there is a tangible experience that may be missing from a student’s concept of the idea (Georgette 2013). In the act of working with a concept, something like an abstract idea, such as kinetic energy, inertia, mass, force, moment, or angular acceleration, may become more clear and relatable for a student. In helping a student broaden their schema of the subject instructors are more able to improve student mastery motivations of that subject (Shapiro 2004). In order to test the ability of the IBLA to improve student knowledge of a concept, pre-activity tests were given to students before some of the learning activities, activities were done in class with instructors and teaching assistants present and in-class activity sheets were filled out by the students, and later at the end of the semester scores on the final exam questions which were related to each of the
activities were analyzed. The relationships between the pre-activity, in activity, and post-activity answers to questions were analyzed to show the effectiveness of these IBLAs in the undergraduate dynamics course.

Another area in this thesis where mastery levels were studied was in the practice of homework. There are many instances in which students use solution manuals to complete their homework; surveys were given to students to find out the effectiveness of solution manual use in relation to the undergraduate dynamics course ME 242. A copy of the surveys can be found in Appendix B of this document. It has been shown that many students in higher education all over the nation are using solution manuals as a homework aid with little remorse about this loss of opportunity in study habits (Lipson and McGavern 1993, Jordan 2001, Passow, Mayhew et al. 2006). In exit surveys, it has been expressed by students that solution manuals are useful when you “use the manual in the correct way.” One way to lessen student use of solution manuals is to change the way in which students view their usage of said manuals (Nuss 1984, Harding 2000, Harding, Carpenter et al. 2001, Jensen, Arnett et al. 2002, Harding, Carpenter et al. 2003, Passow, Mayhew et al. 2006). To encourage student autonomy in solving homework problems, weekly problems with unavailable solutions were given in addition to the homework sets that are traditionally given in the class. To test the effectiveness of this approach towards homework problems a comparison of student’s homework grades over the Fall 2013 to Spring 2015 semesters were analyzed. The analysis that was done used the online Blackboard tool Webcampus. Using the Webcampus platform the following information was analyzed: student grades on homework, the number of student attempts on individual
homework problems, the amount of correct submissions for a homework problem, and the grades that students received on paper copies for turned in homework. Although acts of academic dishonesty like cheating on class assignments and on exams has been shown to lead to unethical actions in other aspects of a students’ career (Nuss 1984, Jordan 2001, Jensen, Arnett et al. 2002, Passow, Mayhew et al. 2006), it has been shown that in the case of engineering courses there was a minimal difference in student learning outcomes when students used a homework solution manuals as a class aid (Lipson and McGavern 1993, McCabe 1997, Widmann and Shollenberger 2006, Widmann, Shollenberger et al. 2007). These surveys and analyses were done as assessments for student use of solutions manuals to complete homework problems and to learn about student habits for reaching mastery and performance goals in the process of learning the basics of Newtonian mechanics.

1.1 Motivation

Mastery skills are an important part of being successful in any field of study. If mastery goals can be found within an individual student, that student will have the ability to learn concepts well with a drive for life long knowledge. Anecdotally, instructors tend to focus on mastery goals while students tend to focus on performance goals, but a goal of the instructor is to help aid students in focusing more on mastery goals. Figure 1 shows how Ames describes the differences between a mastery goal and a performance goal in terms of achievement goals in the classroom (Ames and Archer 1988).
From a pedagogical perspective teachers ask, “How can students achieve a mastery level of learning within the allotted time of a single semester in any subject area?” A mastery level requires a very large knowledge base of the subject material and positive reinforcement of that material with a working understanding of the physical world as well as a conceptual understanding of a large number of possible situations in which those concepts could occur. Undergraduate dynamics is a course in which a vast amount of information is taught and (hopefully) learned. There are many crucial concepts that are explained and taught in class, but these concepts are not necessarily efficiently positively reinforced. A reason for this could be from a range of possibilities, such as student allotment of time in the subject area or stress over the subject material.

In my own personal observations as a grader and teaching assistant of the undergraduate dynamics course (ME 242) at the University of Nevada, Reno (UNR), I have found anecdotal evidence suggesting that students rely on solution manuals to complete homework and there is a lack of hands-on experience with the subject material. These are factors in unbalanced learning and can cause changes in motivation from the intrinsic to the extrinsic (i.e. performance goals rather than mastery goals).
To remedy the lack of hands-on experience, inquiry-based learning activities were introduced to the Fall 2014 and Spring 2015 undergraduate dynamics curricula. Furthermore, to change behavior of solution manual use, a novel set of weekly questions (those without student access to a solution manual) were introduced to the Fall 2014 and Spring 2015 curricula.

1.2 Approach to the Study

In order to study the area of inquiry-based learning activities it is necessary to compare and contrast the traditional lecture model of teaching to that of a more student based inquisitive learning style (Hestenes 1997, Laws, Sokoloff et al. 1999). To test the effectiveness of the learning activities this study compares student assessments given during the in-class activities to the end of semester exams. These exam questions are modeled from the Dynamics Concept Inventory (DCI) (Evans, Gray et al. 2003, Self and Widmann 2009). The reason for this comparison of environmental learning to traditional lecture based learning is to gain insight in student knowledge on different concepts and how different types of learning may affect student retention of subject materials.

The student based learning style is based more on the environmental learning of the student rather than the output learning of instructor knowledge and (Hillocks Jr 1981), therefore, it is necessary to gauge a student’s impulse reaction to the activity with a survey. Questions on the survey for the in-class inquiry-based learning activity included a Likert based scale from Strongly Disagree to Strongly Agree, topics that compared the
activities to lectures, compared the activity to a homework problem, and compared the amount of motivation that the activity inspired in the student. In contrast to the Fall 2014 undergraduate dynamics course offering, the “flipped classroom” instructional approach was used in the Spring 2015 semester of the course. This thesis only looks at the individual inquiry-based learning activities and post-activity final exam scores; an analysis of the affect of the flipped classroom approach is beyond the scope of this research.

The second objective of this research was to examine the affects of solution manual use on student learning of course materials. This analysis was based on how students approach, attempt, and feel about the difficulty of homework problems and their reasoning(s) behind using an outside source, like a solutions manual, for guidance in the homework to learn subject material.

1.3 Organization of the Thesis

Chapter two of this thesis consists of an analysis of three different types of inquiry-based learning activities: the first being the weight-pulley inquiry-based learning activity (IBLA), the second being the rolling cylinder IBLA, and the third being the spool and friction IBLA. For each activity a general overview of each activity will be given, followed by an analysis of in-activity worksheets, and questions from the final exam that related to the IBLAs with their exam outcomes. Handouts used for these activities and the final exam questions can be found in Appendix A.
Chapter three of this thesis consists of an analysis of student use of solution manuals. The surveys were designed to assess a student’s level of perceived difficulty towards different tasks throughout the semester and solution manual usage. The relationship between the quality of work done by students in their homework and usage of the solution manual were analyzed with data from the Fall 2014 and Spring 2015 semesters. Data taken from UNR’s learning management system (LMS) allowed the comparison of homework questions that can be found in the solution manual to questions that are not found in the solution manual.

Chapter four is a summary and conclusion of the research related to the undergraduate dynamics course at the University of Nevada, Reno. The chapter also includes suggestions for future research.
Chapter 2 Analysis of the Inquiry-Based Learning Activities (IBLAs)

2.1 Motivation for the IBLA Study

In an attempt to improve student success and mastery of concepts presented in a second year engineering mechanics course (dynamics), IBLAs were implemented during the Fall 2014 and Spring 2015 semesters at UNR. The IBLA approach to teaching a new concept is designed to reveal insights into prior knowledge that students have and to correct any misconceptions that students may have in the subject area. Student inquiry on the material is important for comprehension of knowledge towards the intrinsic relationship of a concept to the individual and to the way in which the concept is being taught. Learning does not follow teaching. Rather, learning follows having one’s interests identified, facilitated, and supported (Reeve 2008). In comparison to the traditional lecture, an IBLA allows a teacher to become the facilitator of an idea (Hillocks Jr 1981).

Conceptual learning can be a difficult part of the undergraduate dynamics curriculum. To help students reach a higher level of knowledge in the subject area learning activities based on inquiry are being developed in the field of dynamics. In collaboration with the California Polytechnic University, San Luis Obispo (Cal Poly), UNR has incorporated IBLAs into its curriculum. With the use of IBLAs, concepts can be taught with a greater source of environmental motivation and with a higher tolerance for failure in the subject matter. Through an IBLA, direct feedback on the concept is given to the student through the use of an experimental set-up as the physical example, the professor, and
supplemental instructors. The direct feedback of information about the given concept helps students gain hands-on experience with an abstract idea about the physical world and at the same time expresses to the instructors the effectiveness of this learning model and any errors that students may have with understanding the subject material.

The model’s usefulness was measured through the practice of the cognition-observation-interpretation triangle of learning assessment. “The corners of the triangle represent the three key elements underlying any assessment…: a model of student cognition and learning in the domain, a set of beliefs about the kinds of observations that will provide evidence of student competencies, and an interpretation process for making sense of the evidence” (Council 2001). The cognitive processes of the student can be difficult for instructors to understand, but the feedback from in-class worksheets provides a greater depth of insight into student’s thoughts on the subject matter, this is especially effective in the first phases of the IBLA. The first phase of the IBLA is an individual answer to a given question and a survey question on the amount of confidence the student has on the answer that was given ranging from confidence levels of “Total Guess” to “High”. The observations on the subject matter were shown through the experimental set-up. The physical world is the absolute principle that the student must accept as the truth of the matter, preconceptions are either enforced or expelled. The interpretation of the material was the student’s explanation of the physical phenomena that were just witnessed. This interpretation was done with a guided worksheet through questions about the motion that was just observed.
Three experimental set-ups of the IBLA were designed to test a student’s knowledge of: force and acceleration, inertia and kinetic energy, and rigid body general motion due to moments and forces. Worksheet examples of these are included in Appendix A. In each IBLA that was carried out in the classroom, the student was faced with a concept that had been introduced in both lecture and homework problems; the change in environment allowed students to have his/her schema tested in the physical world. In these scenarios the reaction of objects in the physical world was the reality that the student had to analyze and learn from.

2.1.1 Introduction to the IBLA Study

In order for the IBLA to be effective the student’s understanding should be both separated from misleading prior knowledge and lead to greater cognitive and observational understanding of the material (Shapiro 2004). For a student’s learning to be successful in the classroom it is necessary for them to be able to cognitively recognize a new topic and to become familiar with it. When a new idea is first explained to a student there are many different types of assumptions that can be made by the student in order for them to make sense of the new idea. This is because when someone is introduced to a new topic or an old topic in a new setting there can be a large range of metacognitive processes in action within the individual (Council 2001). Instructors at the level of higher education take on the task of helping students learn a new subject with the aspirations of passing on an understanding of the material and giving students the ability to solve novel problems. One of the difficulties that instructors face is that of prior knowledge and knowledge bias in a subject area. Misconceptions in a student’s knowledge can be
difficult for the instructors to spot because of the type of interaction that an instructor has with a group of students in a traditional lecture format classroom. This situation is particularly true in larger classroom sizes.

To change the feedback system between lecturer and student with the goals of reducing the amount of possible learning error and increasing a sense of one-on-one instruction a direct method of student observation and misconception recognition was introduced into the learning curriculum. Hands-on learning is based on information that comes from using the physical reality of the problem to dispute their preconceptions (Prince and Vigeant 2006). It is for this reason that IBLAs were used in the Fall 2014 and Spring 2015 semesters of the undergraduate dynamics course to help students learn about forces and acceleration, kinetic energy and inertia, and rigid body general motion. The purpose of the IBLA is to test student metacognition on different concepts based on the cognition-observation-interpretation of new subject material (Council 2000, Council 2001, Georgette 2013, Self, Widmann et al. 2013, Baheej Nabeel James Saoud 2015). The IBLA was designed with several “cases” that test student understanding of different types of scenarios of motion. The scenarios can be both intuitive and non-intuitive to a student. There were four cases in each of the IBLAs used in this study. Each case had the order of: prompted question to the student, individual reflection by the student to answer the question, team discussion of the question, running the experiment, and answering questions on a worksheet based on the initial prompt. There was a teacher intervention that happened after Case 2 of each of the IBLAs. Each of these IBLAs are described in detail below.
2.1.2 Case Format for the IBLA

This section is dedicated to describing each of the IBLAs that were included in the Fall 2014 and Spring 2015 ME 242 curricula. The class results on the IBLAs can be found in section 2.4. Each IBLA begins with the following instructions, shown in Figure 2. These instructions are displayed to ensure students are following the correct order of events for the IBLA. The IBLA contains two worksheets given to students at the start of the activity, one is an individual worksheet and the other is a team worksheet.

- Complete predictions individually without talking to your team or playing with the experimental set-up.
- After everyone on the team completes their prediction sheet, then talk about the Case as a team.
- Then you will run the experiment.
- Then you will explain the experiment.

Figure 2. Instructional layout of each IBLA Case.

The Weight-Pulley Inquiry-Based Learning Activity (IBLA):

An example individual answer sheet for Case 1 of the weight-pulley IBLA is shown in Figure 3. A complete description of each of the four cases can be found in Appendix A at the end of this document. Case 1 is an example of a comparison question. Students are meant to use their reasoning of each system to analyze and compare what the differences are between each system. In this IBLA each set of cases is a comparison of acceleration between “Mass A” of the system on the left and “Mass B” of the system on the right. Students were asked, “Which mass accelerates faster?”
The weight-pulley IBLA is designed to ask about system forces and accelerations. The cases go as follows: Case 1 same net force, different system masses; Case 2 same net force, different system masses; Case 3 same system masses, different net forces; and Case 4 same net force and different system masses.

**Case 1**

Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

- Mass A will accelerate faster than mass B
- Mass B will accelerate faster than mass A
- Mass A and B will accelerate at the same rate
- Neither Mass A or B will accelerate

How confident are you in your answer (circle one)?

<table>
<thead>
<tr>
<th>Total Guess</th>
<th>Low</th>
<th>Low-Moderate</th>
<th>Moderate</th>
<th>Moderate-High</th>
<th>High</th>
</tr>
</thead>
</table>

**Figure 3. Weight-pulley IBLA Case 1 individual worksheet.**

Case 1 (Figure 3) is meant to also test a student’s background knowledge of what a system of masses is and what a net force on a system is. The confidence level is a way for instructors to gauge the depth of understanding or self-confidence a student may have.
with the question. Self-confidence becomes a problem in cases where a student has a high confidence in their answer, but is wrong in their answer. The same is true when a student has low confidence, but is correct in their answer. If self-confidence is a problem, more positive feedback is needed to enhance student learning in the subject area.

After self-reflection on the prompt and the worksheet is filled out, the team prediction worksheet (Figure 4) is then completed. First there is a team discussion on individual choices and then as a team an answer is selected for which of the options they each consider to be (most) correct. Once an answer has been chosen, students are then able to test the experimental set-up. After the experiment has been conducted, students must provide an explanation for the results that were witnessed using dynamics principles.

1. Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly? Before discussing the scenario with one another, make a prediction on the individual sheet and turn it in.

2. As a team, discuss the scenario. What do you predict about the accelerations of the masses if they are released from rest? Indicate the # of votes on your team of the four give possibilities below.

   ______ Mass A will accelerate downwards faster than mass B
   ______ Mass B will accelerate downwards faster than mass A
   ______ Mass A and B will accelerate downwards at the same rate
   ______ Neither Mass A or B will accelerate downwards

3. What did you observe when performing the experiment?

4. Please explain the results of your experiments using dynamics principles.

Figure 4. Weight-pulley IBLA team worksheet.
**Case 2**, shown in Figure 5, was designed to test and analyze student thinking after the team intervention of Case 1. Similar to Case 1, the net forces are the same but the system masses are different. Since Case 2 tests the same basic concept as Case 1 and the instructor has not intervened in any way, any improvements are due to direct feedback and/or peer instruction.

**Case 2**

![Diagram of weight-pulley system](image)

Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

- Mass A will accelerate faster than mass B
- Mass B will accelerate faster than mass A
- Mass A and B will accelerate at the same rate
- Neither Mass A or B will accelerate

**How confident are you in your answer (circle one)?**

<table>
<thead>
<tr>
<th>Total</th>
<th>Guess</th>
<th>Low</th>
<th>Low-Moderate</th>
<th>Moderate</th>
<th>Moderate-High</th>
<th>High</th>
</tr>
</thead>
</table>

Figure 5. Weight-pulley IBLA Case 2 individual worksheet.

Directly Following Case 2 of each IBLA the instructor conducts an intervention. The reasoning for using inquiry as the emphasis of the activity is to push students toward
recognizing facts about the material that are known and facts that need to be known better. Important to the IBLA is the timing of the teacher intervention, students begin to question their own ideas on the subject material after the first case, then peer feedback is given, but the instructor only gives feedback on these ideas after Case 2. In this teacher intervention the class as a whole is addressed to discuss previous cases and to answer any questions students may have about the scenarios that are being presented.

**Case 3**

Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

- Mass A will accelerate faster than mass B
- Mass B will accelerate faster than mass A
- Mass A and B will accelerate at the same rate
- Neither Mass A or B will accelerate

**How confident are you in your answer (circle one)?**

<table>
<thead>
<tr>
<th>Total Guess</th>
<th>Low</th>
<th>Low-Moderate</th>
<th>Moderate</th>
<th>Moderate-High</th>
<th>High</th>
</tr>
</thead>
</table>

Figure 6. Case 3 of the weight-pulley IBLA.

Case 3, shown in Figure 6, was designed to have identical total masses in systems A and B but with different net forces (essentially the opposite of Cases 1 and 2).
Case 4, shown in Figure 7, was designed to test a student’s understanding of mass versus force. There is a common misconception of mistaking a pure force as being the same as the acting force of gravity with this case. The net forces are the same but the system masses are different.

**Case 4**

Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

- Mass A will accelerate faster than mass B
- Mass B will accelerate faster than mass A
- Mass A and B will accelerate at the same rate
- Neither Mass A or B will accelerate

**How confident are you in your answer (circle one)?**

<table>
<thead>
<tr>
<th>Total Guess</th>
<th>Low</th>
<th>Low-Moderate</th>
<th>Moderate</th>
<th>Moderate-High</th>
<th>High</th>
</tr>
</thead>
</table>

Each case was designed to ask students about a different part of the concept being learned. In the case of the weight-pulley activity, acceleration, net forces, and system mass are used as a tool to learn about Newton’s second law (\(F = ma\)).
The follow up survey, shown in Figure 8, contains questions at the end of the activity that were used to gather data on how helpful students feel the activity was toward their learning the concept.

**Follow-up Questions:**

*Answer each of the following questions by marking an “X” on the line that corresponds with your level of agreement with the statements at each end of the line.*

1. **Do you think this activity was helpful for learning Dynamics?**
   - Yes, very helpful
   - No, not helpful

2. **How would you say this activity compares to lecture to explain and help you understand this concept?**
   - The activity is most helpful
   - Lecture is most helpful

3. **How would you say this activity compares to a homework problem to explain and help you understand this concept?**
   - The activity is most helpful
   - A homework problem is most helpful

*Figure 8. Rolling-cylinder IBLA follow-up questions.*

**The Rolling-Cylinder IBLA**

The case-by-case sequence of the rolling-cylinder activity was the same as the weight-pulley activity. There are two cases that introduce the idea and build student interest on
the model, which is followed by an intervention. After the teacher intervention, two additional cases are introduced to help enforce correct thinking on the concept ideas. The individual cases of the rolling-cylinder IBLA are shown in Figure 9. The class was given similar supplies of large and small solid cylinders made of steel, aluminum, and plastic as well as large and small thin walled pipes made of steel, aluminum, and plastic. In addition to the case-by-case questions the group questions had additional guidance on how to approach the problem. The problem was the same in each case: determine which object will reach the bottom of the ramp the fastest.

The Case 1 team worksheet had the two cognition guidance questions shown in figure 9 (the individual worksheets can be found in Appendix A). Question 2 was meant to engage thought toward the relationship between the mass moment of inertia of an object and angular acceleration of that object (Euler’s second law of motion $\mathbf{M} = l\alpha$).
CASE 1: Big Solid Cylinder (A) vs Metal Pipe
Same Radius and Same Mass

1. Fill out your case 1 anonymous prediction sheet and then discuss the question as a group. Get the Big solid cylinder (marked A) and the Metal pipe (they have the same radius and mass but different shapes). Before rolling the objects, discuss with your team – which do you predict will reach the bottom first? After discussing, vote and indicate the number of votes for each possibility below.

Number of votes: Big solid cylinder _____ Metal pipe _____ Same time ____

1. Now roll the two cylinders, and state the results below. Explain the race result using principles of dynamics.

2. Which object has the larger mass moment of inertia, the Big solid cylinder or the Metal pipe (they have the same mass and radius)? Explain your answer.

Number of votes:
Big solid cylinder _____ Metal pipe _____ Same Inertia____

Figure 9. Case 1 rolling-cylinder IBLA team questions.

The Case 2 team worksheet also included two cognition guidance questions. Question 2 guided students toward thinking of the total kinetic energy of each object. This was difficult because students had to resolve two conflicting notions: 1) the object that reached the bottom first had the higher kinetic energy because it was moving faster (an incorrect assumption) and 2) the object with the greater mass had the largest potential energy. This activity forced students to examine the kinetic energy due to both rotation and translation.
CASE 2: Small Solid Cylinder (B) vs Big Metal Cylinder (A)
Different Radius and Different Mass
1. Fill out your case 2 anonymous prediction sheet and then discuss the question. Then get the Small solid cylinder (marked B) and the big solid cylinder (marked A) (they have both different radius and different mass). Discuss with your team – which do you predict will reach the bottom first? After discussing, vote and indicate the number of votes for each possibility below.

   Number of votes: Small solid cylinder ____ Big solid cylinder ____ Same time____

1. Roll the two cylinders, and state your results below. How does mass and diameter influence rolling behavior? Explain the race results.

2. Which has larger Total Kinetic Energy when it reaches the bottom, the Small solid cylinder (B) or the Big solid cylinder (A) (they have different mass and radius)? Explain your answer

   Number of votes:
   Small solid cylinder (A)____ Big solid cylinder (B) ____ Same Energy____

Figure 10. Case 2 rolling-cylinder IBLA team questions.

The Case 3 team worksheet also had two cognition guidance questions. This time students were directly required to give feedback on the work-energy equations, the meaning behind this was to directly show students why the cylinders had similar/different velocities at the bottom of the ramp. The teacher intervention between Case 2 and Case 3 went over different types of energy and how to solve for the kinetic energy of a rolling object. Case 3 asked students if they could understand the method of solving for velocity that the teacher had just shown the whole class.
CASE 3: Small Solid Cylinder (B) vs Metal Pipe
Different Shape, Mass, and Radius

1. Fill out your case 3 anonymous prediction sheet and then discuss the question. Get the Small solid cylinder (marked B) and the Metal pipe (they have different shape, mass and radius). Discuss with your team – which do you predict will reach the bottom first? After discussing, vote and indicate the number of votes for each possibility below.

   Number of votes: Small solid cylinder (B)____ Metal Pipe ____ Same time ____

1. Roll the two cylinders and state the results below. Explain the results.

2. Write the work-energy equation for any rolling object using position one at the top of the ramp and position two at the bottom. Express the mass moment of inertia as

   \[ I_G = cmr^2 \]

   where \( c \) is a constant that depends on the shape (solid, hollow, thin-walled, etc.). Use rolling without slipping kinematics \( (v = \omega r) \) to eliminate \( \omega \) and solve for the velocity of the mass center at the bottom position.

The Case 4 team worksheet had a multi-part cognition guidance question, shown in Figure 12. This question was designed to positively reinforce the concepts that were covered in Case 3.
CASE 4: Small Plastic pipe vs Big Plastic pipe vs Metal pipe
Different Mass and Radius

1. Fill out your case 4 anonymous prediction sheet and then discuss the question. Get all 3 pipes: the Small plastic pipe, the Big plastic pipe and the Metal pipe (they all have different mass and radius). Discuss with your team – which do you predict will reach the bottom first? After discussing, vote and indicate the number of votes for each possibility below.

   Number of votes: small plastic pipe ____ big plastic pipe _____ metal pipe______

1. Roll the cylinders and state the results below. Explain the results.

Put number of votes for each of the following questions
a. All solid cylinders regardless of radius and mass arrive at the bottom at the same time
   True ____  False ____

b. All thin walled pipes regardless of radius and mass arrive at the bottom at the same time
   True ____  False ____

c. Which will arrive first, a thick walled pipe or a thin walled pipe regardless of radius and mass?
   Thick walled ____  Thin-walled ____
   They will arrive at the same time ____

Figure 12 Case 4 rolling-cylinder IBLA team questions.

Similar to the weight-pulley IBLA these cases were meant to compare one object to another object. This comparison became obvious once the experiments had taken place, but unlike the weight-pulley experiment less students had background knowledge of rolling cylinders. This concept of work-energy in relation to Case 2 and Case 4 is
strongly emphasized as most students predict the speeds to be different when they are in fact the same in these two cases.

**The Spool-Friction IBLA**

The spool-friction IBLA was designed to help students learn about general two-dimensional motion of rigid bodies – essentially combining the previous two IBLAs. Students had to deal with both Newton’s (\( F = ma \)) and Euler’s (\( M = I\alpha \)) second laws of motion. This IBLA was run in the same exact case format as the previous two IBLAs. Case 1 is shown in Figure 13:

![Image](Figure 13. Spool-friction IBLA Case 1 individual worksheet.)

The questions associated with Case 1 (Figure 13) of the spool-friction IBLA helped students to understand the motion of the spool. These were mostly an aid in understanding friction and the direction of friction in a free-body diagram (FBD) and
inertial response diagram (IRD). The value of friction enforces knowledge of the concept of when an object has static friction acting on it, is slipping, or rolling without slip. The direction of friction is often non-intuitive. Teacher instruction was given after Case 1 to ensure the correct modeling and use of the FBD-IRD.

- Now pull on the string a bit harder so that it isn’t rolling without slip. Which way do you think the friction force acts? It is probably in the same direction as above, but now it will be equal to what value?
- Draw your FBD and IRD for the problem. From these diagrams, can you predict which way the disk will roll when gently pulled?

Figure 14. Spool-friction IBLA Case 2 individual worksheet.

The Case 2, Figure 14, follow-up questions were also meant to emphasize the free-body diagram and inertial-response diagram (FBD-IRD) in relation to the spool. The pull of the string and friction both create moments about the center of mass on the spool that can mathematically prove the direction in which the spool will begin to roll. The moment also changed at an angle between that of Case 1 and Case 2. The angle of the applied force
and the frictional force were designed for students to observe and explain the phenomena that were happening with the frictional force as the angle changed.

- Draw the FBD and IRD for the problem. From these diagrams can you predict the direction it will roll?
- Try varying the angle of your pull, and how hard you pull on the string. When is the friction force equal to \( m_sN \)? \( m_kN \)? Explain your answers.

Teacher intervention was also given after Case 2 to positively reinforce student use of equations and student definitions of friction

Figure 15. Spool-friction IBLA Case 3 individual worksheet.

The teacher intervention in between Case 2 and Case 3 addressed student concerns about the activity, explained and enforced how to draw the FBD-IRD, and the definitions of each of the different values of friction. Case 3 questioned the direction of motion of the spool if the string was pulled downward, helping students gain practice and experience in
drawing diagrams in which the direction of friction is not necessarily known yet. The following questions are related to Case 3 shown in Figure 15.

- Place two desks side by side and put the spool over the gap so that the string hangs down. Now pull gently on the downward. Which way does it go? Which way does the friction go?
- Draw out your FBD and IRD for the problem. You can use this to predict which way it will roll.

![Case 4](image)

*Figure 16. Spool-friction IBLA Case 4 individual worksheet.*

The final Case 4 of each IBLA was designed to present a slightly different scenario than those of the previous three cases. The spool-friction IBLA Case 4 did this by altering the distance from the center of mass of the spool on which the pulled string is acting. This IBLA, more than the weight-pulley and rolling cylinder IBLAs, emphasized work with non-intuitive directions of forces and rotations. This exercise included more additive steps that include figure drawing, FBD-IRD equations, and unknown directions of motion. The following question is related to Case 4 shown in Figure 16.
- Place the spool between two desks with the axle resting on each surface and spool extending into the gap. Now pull gently in the direction shown. Which way does it go? Which way does the friction go?

Teacher intervention was also given after Case 4 to answer student questions and to reinforce each of the concepts being learned.

2.1.3 Approach to the IBLA Study

The approach of this study was to examine the amount of change in student outcomes due to the added activities into the curricula. Exam scores and student surveys were analyzed in order to evaluate these activities objectively and subjectively in their effectiveness.

2.1.4 Model for Activities in Previous Semesters

Prior to the Fall 2014 semester, a traditional method of learning was followed in the undergraduate dynamics class at UNR - that of largely lecturer based learning using PowerPoint presentations. Typical enrollment was 80-120 students. It is a requirement that all mechanical engineering and civil engineering students take (and pass) the course. Throughout the class, as new topics were introduced homework problems were given and example problems were explained within a 50-minute lecture. In addition to the lecture and homework problems an occasional instructor driven demonstration would be used to introduce a new concept.
Until recent years, the techniques of active learning, or hands-on learning and inquiry-based learning have not been researched in depth in the field of undergraduate dynamics (Baheej Nabeel James Saoud 2015). The information in this thesis will add to the current research being conducted in the field of inquiry-based learning activities.

2.1.5 Model for Newly Added Activities

In contrast to the traditional lecture based instruction, conceptual learning done by students in higher education with the use of IBLA was investigated in ME 242 in Fall 2014 and Spring 2015. The IBLA approach is aligned with the conceptual theory that if a subject is understood through multiple facets of learning then there is a greater chance of success in that subject area (Council 2001, Reeve 2008).

The design of the IBLA is to help students find intrinsic motivation for learning in a new subject area. Intrinsic motivation is a helpful manifestation of mastery goals, which result in working harder, persisting longer, and performing better when faced with challenges. In an IBLA the role of the instructor changes from purveyor of knowledge through lectures to now center on student autonomy-support. Reeve states that “When classrooms support students’ initiatives (rather than teach them what to learn), students gain academic confidence, show greater mastery motivation, and participate more actively during learning activities” (Reeve 2008). Mastery motivation is a level of understanding that helps to ensure student academic success and life-long learning in a subject area.
To learn about force and acceleration, kinetic energy and inertia of rolling cylinders, and direction of friction and angular acceleration of spools, a student must gain more experience in using and manipulating tools that are reflections of these concepts. This experience of doing an activity is meant to expose the student to the area of study in a cognitive process that includes a greater amount of observation. For each student, the knowledge base in each of the subject areas is different, and as a basis of this study a few assumptions are made. The level of students that attend this course are of the sophomore level, so the assumption being made is that students have autonomy in learning, but that there is a possibility of a lack of experience in higher-level thinking in concepts like inertia, kinetic energy, angular acceleration, and momentum. Another assumption being made is that the knowledge base of the student is very high in understanding physics, calculus, and statics concepts. An additional assumption in this study is that students in this course had not participated in these particular IBLAs prior to taking ME 242.

2.2 Background Information about Learning Activities

2.2.1 Classroom Learning Processes

There are categories of learning as prescribed by many different educators and psychologists; this thesis uses the three categories of learning as described by Hillocks (Hillocks Jr 1981). These categories of learning styles are: presentational, in which lecture is assumed to provide students with knowledge necessary to attain course goals; environmental, in which the instructor minimizes lecture and relies primarily upon engaging students with problems selected to provide the kinds of experiences which enable them to attain course goals; and nondirectional, in which the instructor relies upon
students to raise concerns, the examination of which will enable students to attain course goals.

For each type of classroom learning process there are myriad factors involved, such as, the amount of instruction the professor can give to the student and the type of motivation a student has to inherently learn the topic at hand. In order for students in undergraduate dynamics to attain course goals, inquiry-based learning is meant to enhance the environment in which students learn. This is to enable as many different types of learning styles as possible and to promote individual nondirectional learning.

2.2.2 Metacognitive Analysis of Activities

How do you teach students a concept in an effective way when there is a high possibility of knowledge bias within the subject area? It has been shown that prior knowledge in a subject area can be helpful, but if the prior knowledge is largely assumptive (the way physics can be) there is a larger chance for that knowledge to change outcomes of learning (Shapiro 2004, Jackson, Dukerich et al. 2008). It was also shown in the studies looked at by Shapiro that the more detail in which the information was given, the more positively a student would respond to the information (Shapiro 2004). In addition, inaccurate prior knowledge is a hindrance to learning and information recall. In order to overcome the learning challenges of knowledge bias and variation in pedagogical techniques a student has to become more familiar with the subject’s schema. The Shapiro study also outlines that an important part of learning a concept comes from the domain knowledge of the subject area (Shapiro 2004). Student schema are related to the
situations given in homework problems, but when a student can interact with a physical model the metaphors and schema are then able to transform to be aligned with the equations that are being learned (Hestenes 1997, Laws, Sokoloff et al. 1999, Georgette 2013, Self, Widmann et al. 2013, Powell, Richards et al. 2014)

The modeling tactics of Hestenes are also an interesting way to construct a model of the physical world, see Figure 17 below (Jackson, Dukerich et al. 2008). This method of learning Newtonian mechanics includes recognizing an object or objects as a system and using Socratic method of questioning to interpret the actions of that system. This method also includes verbal analysis of the model and group presentations on motions and governing equations of the system (Hestenes 1992, Hestenes 1997, Jackson, Dukerich et al. 2008).
To build upon these theories, researchers in the mechanical engineering department at Cal Poly have explained that one of the greatest ways of making sure a concept is learned is with an in-class activity (Georgette 2013, Self, Widmann et al. 2013, Baheej Nabeel James Saoud 2015). To ensure effectiveness, the design of the activity has to be without bias. The examples will, depending on the student, have the range of possibilities of being very familiar to the student to not being familiar at all to the student, and range from cases that may be confusing or non-intuitive to the student to cases that are automatically understood by the student (Georgette 2013). More scenarios must be covered in order to achieve a greater base knowledge in a dynamics concept. In other words, students often try to use intuition to solve problems in dynamics. However,
because their intuition is based on a limited set of experiences, it is important to present students with cases that produce non-intuitive results in order for them to change schemas. It is the atypical case that sparks a change in the knowledge base of a student, an inquiry into why or why not an object would behave the way you believed it would.

### 2.2.3 Assessment of Learning

Learning assessments for inquiry-based learning activities are those of pre-activity test, in-activity test, and post-activity test. These tests were used to find out what students knew before the activity, student level of learning interaction during the activity, and what students retained after the activity in final exams.

### 2.2.4 Student Self-Assessment of Learning

Using student surveys: a student’s self-assessment can show instructors how much a student knows about a subject and the amount of satisfaction or dissatisfaction that the student may have for the new concept. This information is meant for both the future improvement of the instructor and for the student to gauge their own understanding; this emphasizes how crucial it is for the student and the teacher to be self aware in any situation in which an important concept is being taught/learned.

### 2.3 Assessment Methods for the Application of Learning Activities

#### 2.3.1 What is an Inquiry-Based Learning Activity?

In order to test the efficacy of an IBLA, the concept is initially tested with an individual response to the first question of each IBLA that is being presented with a Likert scale
question, the range was from “Total guess” to “High” confidence for the level of their understanding of the answer given to the question (e.g. Figure 3). This first question acts as a guide for understanding any knowledge bias that a student may have, which is later compared to a student’s willingness to accept a new concept and learn from the activity despite the background of their knowledge. The concept is then prompted to the student on paper and then experimentally observed first hand by the students in the activity. The outcomes of the final examinations were then compared to both the activity and the Dynamics Concept Inventory (DCI) in order to evaluate the influence of the IBLA on the curriculum.

2.3.2 Case Format for the Inquiry-Based Learning Activity

The importance of the inquiry-based learning activity is to discover and explore concepts; examples in engineering mechanics describe a case-by-case process of investigation and intervention (Adam, Self et al. 2015, Prince and Vigeant 2006, Georgette 2013, Self, Widmann et al. 2013, Baheej Nabeel James Saoud 2015). The concepts can be novel, in that the sole knowledge a student may have is gained from the classroom in which the concept was presented, but it may also have been introduced to the student long before this class (e.g. in Physics).

2.3.3 Survey Format for the Inquiry-Based Learning Activity

The survey format for the inquiry-based learning activity is that of a ten point Likert scale in the Fall 2014 class and a five point Likert scale in the Spring 2015 class, in which students could express on a continuum from “Strongly Disagree” to if they “Strongly
Agree” with the level of the motivation from the activity. Questions from the survey ask the student to relate the activity to a traditional lecture, relate the activity to a homework problem, and ask the student about intrinsic motivation in learning more about the topic after having completed the activity.

2.4 Results and Discussion of the Inquiry-Based Learning Activity

2.4.1 Mastery Assessments

In order to assess the efficacy of the inquiry-based learning activity in the undergraduate dynamics curriculum, a comparison to the DCI was used as a guide to compare student-learning outcomes (Self and Widmann 2009). Pre-testing or post-testing of students in the subject area with quizzes was also used as a guide in informing the extent of student knowledge on the subject material. For this study a comparison was made between IBLAs and final exams in the Fall of 2014 and the Spring of 2015 undergraduate dynamics curricula.

2.4.2 Data Analysis of the Inquiry-Based Learning Activity

The Weight-Pulley Inquiry-Based Learning Activity:

This IBLA included the following cases previously shown in Figures 3 through 8, but they are again shown in Figures 18 and 19. These cases were meant to help students understand what their notions about Newton’s second law equation $F = ma$ as well as enhance those notions with positive hands-on reinforcement.
Figure 18. Cases 1 and 2. These representations are meant to test student understanding of net force and acceleration.

Figure 19. Cases 3 and 4. These representations are meant to test student understanding of mass and acceleration.

The individual results and team results from the in-class weight-pulley inquiry-based learning activity of the Fall 2014 undergraduate dynamics course are shown in Table 1. Table 2 shows mostly moderate self-confidence for each of the cases.

Table 1. Fall 2014 Weight-Pulley IBLA. These data are from the individual and team scores of the Weight-Pulley IBLA.

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th></th>
<th>Case 2</th>
<th></th>
<th>Case 3</th>
<th></th>
<th>Case 4</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2014</td>
<td></td>
<td>n</td>
<td></td>
<td>n</td>
<td></td>
<td>n</td>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Individual</td>
<td>85</td>
<td></td>
<td>85</td>
<td></td>
<td>85</td>
<td></td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Team</td>
<td>22</td>
<td></td>
<td>22</td>
<td></td>
<td>22</td>
<td></td>
<td>22</td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Fall 2014 weight-pulley IBLA confidence levels.

<table>
<thead>
<tr>
<th>Fall 2014 Confidence</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total guess</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td>Low</td>
<td>5%</td>
<td>2%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Low-moderate</td>
<td>1%</td>
<td>4%</td>
<td>4%</td>
<td>11%</td>
</tr>
<tr>
<td>Moderate</td>
<td>53%</td>
<td>39%</td>
<td>24%</td>
<td>31%</td>
</tr>
<tr>
<td>Moderate-high</td>
<td>18%</td>
<td>25%</td>
<td>28%</td>
<td>14%</td>
</tr>
<tr>
<td>High</td>
<td>18%</td>
<td>25%</td>
<td>33%</td>
<td>26%</td>
</tr>
</tbody>
</table>

Understandably, many students arrived at the incorrect answer for Case 1. Case 2 was very promising in the amount of increased knowledge. This was most likely a result of feedback and interaction between team members (the instructor has not yet provided any guidance at this point). After Case 2, the instructor had led a discussion about the results. Case 3 provided a twist in that the total system masses were the same but the net forces varied – which resulted in mixed improvements between individual and team scores. Surprisingly, many students were apparently swayed by the minority in the group and arrived at the incorrect answer. In Case 4, the concept of force versus weight was tested. Clearly there was still misunderstanding of the concept. Anecdotally, students felt this was a “trick” question and appeared to grasp the difference as soon as it was pointed out.

Rolling Cylinder Inquiry-Based Learning Activity:

Appendix A and Figures 20 through 24 show a possible set-up of the experiment and the case examples of the rolling cylinder IBLA. In each case students were asked, “Which object will reach the bottom of the ramp first?” This exercise was meant to challenge the ways in which students think of kinetic energy, mass, and the mass moment of inertia of a cylindrical object. The key to this concept is the relationship between kinetic energy and
both velocity and mass-moment of inertia. This scenario relates different states of motion, from when the object is at rest at the top of the ramp to when the object has a velocity (linear and angular) at the bottom of the ramp. The concepts of conservation of energy and work-energy are used to solve for the velocity of the rolling cylinder. The governing energy equation is:

\[ mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 \]  

(1)

The difference in the velocity at the bottom of the ramp for each case is determined by the amount of energy that is transferred into rotational versus translational kinetic energy, which depends solely on whether the object is a solid cylinder or a thin walled cylinder/pipe. Figures 21-24 show each of the case examples of the rolling-cylinder IBLA.
The results from the Fall 2014 rolling cylinder IBLA individual and team scores are shown in Table 3.

**Table 3. Fall 2014 Rolling Cylinder Activity Results**, These data are from the two different sections that participated in the Fall 2014 Rolling Cylinder IBLA.

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2014</td>
<td>n</td>
<td>Correct</td>
<td>n</td>
<td>Correct</td>
</tr>
<tr>
<td>Individual</td>
<td>84</td>
<td>51%</td>
<td>83</td>
<td>14%</td>
</tr>
<tr>
<td>Team</td>
<td>19</td>
<td>79%</td>
<td>19</td>
<td>32%</td>
</tr>
</tbody>
</table>

The Case 1 results were promising in that it appears the majority of students/teams grasped the concept of moment of inertia and its impact on rolling cylinders. Case 2 (and 4) were the most difficult for students to understand in both individual prediction and in team discussion. This was most likely due to the misconception that the radius and mass of the object dictate the original potential energy at the top, and the idea that the potential energy at state one is the only factor in the velocity of the object at the bottom of the ramp, state two. This IBLA was meant to identify the difficult concept that the velocity at the bottom of the ramp does not always correlate to the difference between $mg\,h$ and $\frac{1}{2}mv^2$, but to help students realize that there is kinetic energy associated with the rotation of the cylinder as well.

This rotational energy is related to the shape factor of the mass-moment of inertia. It is described as the letter $c$ in the moment of inertia equation:

$$ I = cmr^2 $$

(2)
With the relationship of the no-slip condition of friction, the linear velocity of the center of mass of the object and the angular velocity can be related by:

\[ v = r \omega \] (3)

By manipulating the energy equation (1), it is found that the length, the radius, and the mass of a rolling cylinder do not make a difference in the velocity of the object at the bottom of the slope, the result is equation (4). The difference in the shape factor, or coefficient of inertia, \( c \) of those rolling cylinders is the difference in velocity between a solid cylinder (\( c = 0.5 \)) and a pipe (\( c = 1 \)).

\[ gh = \frac{1}{2} v^2 (1 + c) \] (4)

This explanation was provided to students after Case 2, so not surprisingly the Case 3 results were improved. However, while it is clear that students understood the difference that the shape factor, \( c \), would have on the final velocity, Case 4 clearly showed that students still did not grasp the combined impact (or lack thereof) of mass and radius. But surprisingly, the team results were higher than the individual results in each of the cases. Although there was a greater amount of dialogue happening toward the correct answer through peer response, this was not enough to help students find the right solution individually (Table 3).

The IBLA based question given on the final exam and the final exam results are shown in Figure 25 and Table 4. Since this question was essentially the same as Cases 1 and 3, it can be concluded that retention was an issue concerning kinetic energy.
The two objects in the figure below are released from rest at the position shown and roll without slipping down identical hills. Both objects have the same mass \( m \) and same outer radius. Object \( A \) is a thin hoop whose mass is concentrated in its edge. Object \( B \) is a uniform solid cylinder. Neglecting air resistance, how do the speeds of the two objects compare when they reach the bottom of their respective hills?

![Diagram](image)

**Figure 25. Fall 2014 Final Exam Question.** This question was given to the Fall 2014 undergraduate dynamics class.

**Table 4. Fall 2014 final exam question results.**

<table>
<thead>
<tr>
<th>Fall 2014 Final Exam Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
</tr>
<tr>
<td>91</td>
</tr>
</tbody>
</table>

During the Spring 2015 semester the same IBLAs were conducted in ME 242. There were three different sections to this undergraduate dynamics class, each of which had the same instructor, but each of which had a different number of students enrolled. The Spring 2015 outcomes of the same weight-pulley IBLA are shown in the following tables 4-10 and figures 26-29.
The pre-activity assessment that was part of the Dynamics Concept Inventory, shown in Figure 26, was identical to Case 4 and the results are shown in Table 5. This question tested student knowledge of mass, force, and acceleration by asking students whether Mass A or Mass B will accelerate faster. A majority of students arrived at the incorrect answer.

Figure 26. Spring 2015 weight-pulley pre-activity question.

<table>
<thead>
<tr>
<th>Spring 2015 pre-activity DCI</th>
<th>Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td></td>
</tr>
<tr>
<td>139</td>
<td>16%</td>
</tr>
</tbody>
</table>

Spring 2015 undergraduate dynamics weight-pulley IBLA results are shown in Table 6. Comparing the results from Table 1 to those in Table 6, there was a general trend in
scores from case to case of a slightly worse overall performance for the Spring 2015 semester. As mentioned earlier, the Spring 2015 semester used a flipped classroom approach – which appears to have had a detrimental effect on students’ overall performance. Table 7 shows students had moderate levels of confidence with a slight increase in confidence as the IBLA progressed.

Table 6. Spring 2015 Weight-Pulley IBLA Results. These data are from the combined sections of the Spring 2015 undergraduate dynamics class.

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual</td>
<td>139</td>
<td>135</td>
<td>134</td>
<td>129</td>
</tr>
<tr>
<td>Correct</td>
<td>42%</td>
<td>80%</td>
<td>86%</td>
<td>34%</td>
</tr>
<tr>
<td>Team</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>39</td>
</tr>
<tr>
<td>Correct</td>
<td>53%</td>
<td>85%</td>
<td>78%</td>
<td>41%</td>
</tr>
</tbody>
</table>

Table 7. Spring 2015 Weight-Pulley IBLA confidence levels.

<table>
<thead>
<tr>
<th>Spring 2015 Confidence Levels</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total guess</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Low</td>
<td>2%</td>
<td>1%</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td>Low-moderate</td>
<td>10%</td>
<td>4%</td>
<td>1%</td>
<td>6%</td>
</tr>
<tr>
<td>Moderate</td>
<td>41%</td>
<td>29%</td>
<td>18%</td>
<td>22%</td>
</tr>
<tr>
<td>Moderate-high</td>
<td>29%</td>
<td>25%</td>
<td>26%</td>
<td>25%</td>
</tr>
<tr>
<td>High</td>
<td>11%</td>
<td>37%</td>
<td>49%</td>
<td>37%</td>
</tr>
</tbody>
</table>

Post-activity results from final examinations of each of the three sections are shown in the following tables 8-10 and figures 27-29. Each section was given a slightly different question because the final exams occurred on different days.
Figure 27 and Table 8 show the final exam question and percent score correct for class section 1.

![Image of pulley question and options]

Both systems shown have massless and frictionless pulleys. On the left, an 8-oz weight and a 10-oz weight are connected by an inextensible rope. On the right, a 4-oz weight and a 6-oz weight are connected by an inextensible rope. Which of the following statements is true immediately after unlocking the pulleys?

A) In both cases, the acceleration of the blocks A and B will be equal to zero.
B) The block B will have the larger upward acceleration than block A.
C) The block A will have the larger upward acceleration than block B.
D) The tension in the rope on the left system is 8-oz.
E) Blocks A and B will have the same upward acceleration.

*Figure 27. Spring 2015 Final Exam Weight-Pulley Question. This question was given to Spring 2015 class section 1.*

*Table 8. Spring 2015 Final Exam Weight-Pulley Results. These data are from the Spring 2015 class section 1.*

| Weight-Pulley Final Exam Results section 1 |
|-----------------|----------------|
| n | Correct |
| 64 | 75% |

Case 1 of the IBLA was similar to the final exam question given to course section 1 of the Spring 2015 semester. The comparison of the section 1 final exam scores and the Case 1 results showed that there was an increased improvement in student understanding of the Case 1 scenario for the weight-pulley system from an overall score of 42% correct (Table 6) to 75% correct (Table 8).
Figure 28 and Table 9 show the final exam question and percent score correct for class section 2.

Both pulleys shown are massless and frictionless. The horizontal surface is also frictionless. The pulley on the LEFT has a 10lb weight on the left and a 20 lb weight hanging from the right. The pulley shown on the RIGHT has a 10 lb weight on the left and a constant 20 lb force (oriented vertically down) on the right. Both pulleys are released from rest from the positions shown. Which of the following statements is true immediately after the pulleys are released?

F) The 10 lb blocks both have the same acceleration to the right.
G) The 10 lb blocks both have the same acceleration to the left.
H) The 10 lb block on the LEFT has a larger acceleration.
I) The 10 lb block on the RIGHT has a larger acceleration.
J) Neither 10 lb block has any acceleration.

Figure 28. Spring 2015 Final Exam Weight-Pulley Question. This question was given to Spring 2015 class Section 2.

Table 9. Spring 2015 Final Exam Weight-Pulley Results. These data are from the Spring 2015 class section 2.

<table>
<thead>
<tr>
<th>Weight-Pulley Final Exam Results section 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
</tr>
<tr>
<td>47</td>
</tr>
</tbody>
</table>

This final exam question matches Case 4 of the weight-pulley IBLA, the data in Table 9 show that the IBLA was helpful in teaching students about net force and mass.

Figure 29 and Table 10 show the final exam question and percent score correct for class section 3.
Both systems shown have massless and frictionless pulleys. On the left, a 10N weight and a 50N weight are connected by an inextensible rope. On the right, a constant 50N force pulls on the rope. Which of the following statements is true immediately after unlocking the pulleys?

A) In both cases, the acceleration of the 10N blocks will be equal to zero.
B) The 10N block on the left will have the larger upward acceleration.
C) The 10N block on the right will have the larger upward acceleration.
D) The tension in the rope on the left system is 40 N.
E) In both cases, the 10N block will have the same upward acceleration.

Figure 29. Spring 2015 Final Exam Weight-Pulley Question. This question was given to the Spring 2015 class section 3.

Table 10. Spring 2015 Final Exam Weight-Pulley Results. These data are from the Spring 2015 class section 3.

<table>
<thead>
<tr>
<th>Weight-Pulley Final Exam Results section 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
</tr>
<tr>
<td>39</td>
</tr>
</tbody>
</table>

The final exams in comparison to the in-class IBLA show that there was a large difference in the percent correct and the final exam scores for each of the class sections. These final exam scores had a direct correlation to the case questions in the weight-pulley IBLA. The section 1 final exam question was very similar to Case 1 of the IBLA whereas the section 2 and section 3 final exam questions are similar to Case 4 of the IBLA. These data, from a pedagogical point of view, show that there was an error in information recall for the moving mass systems. This problem was also discussed in Chapter 4. Student confusion on this type of question stems from a student knowing the difference between a weight and a pure force and the amount of mass the weight and pulley system has. A
positive outcome is that there was a large amount of improvement in comparison to the pre-activity DCI question that are similar to Case 4 going from 16% in the pre-activity to 34% in activity and 47% correct in the Section 3 final exam question.

The weight-pulley IBLA was also taught at two local high schools the week following Advanced Placement exams. The results from these two high schools are shown in Table 11.

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reed HS</td>
<td>n</td>
<td>Correct</td>
<td>n</td>
<td>Correct</td>
</tr>
<tr>
<td>Individual</td>
<td>55</td>
<td>42%</td>
<td>55</td>
<td>80%</td>
</tr>
<tr>
<td>Team</td>
<td>14</td>
<td>21%</td>
<td>14</td>
<td>71%</td>
</tr>
<tr>
<td>McQ HS</td>
<td>n</td>
<td>Correct</td>
<td>n</td>
<td>Correct</td>
</tr>
<tr>
<td>Individual</td>
<td>77</td>
<td>71%</td>
<td>77</td>
<td>83%</td>
</tr>
<tr>
<td>Team</td>
<td>21</td>
<td>57%</td>
<td>21</td>
<td>81%</td>
</tr>
</tbody>
</table>

It is interesting to note that both sections of the high school classes understood Case 2 and Case 3 better than Case 1 or Case 4. This trend is similar to the results of the higher education undergraduate dynamics courses. It must be noted that the high school students participated at the end of their school term as opposed to the beginning of the semester for the undergraduates.
For the Spring 2015 semester, the rolling cylinder IBLA was modified slightly as shown in Figure 30 with the use of cylinder material type. The outcomes are shown in the following tables (12-14) and figures (30-31).

![Figure 30](image)

**Figure 30. Spring 2015 Rolling Cylinder IBLA.** (A) case 1: cylinder vs. pipe. (B) case 2: small vs. big cylinder. (C) small cylinder vs. big pipe. (D) small plastic pipe vs. big plastic pipe vs. small metal pipe.

**Table 12. Spring 2015 Rolling Cylinder IBLA Results.** These data are from the combined sections of the Spring 2015 undergraduate dynamics class.

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th></th>
<th>Case 2</th>
<th></th>
<th>Case 3</th>
<th></th>
<th>Case 4</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 2015</td>
<td>n</td>
<td>Correct</td>
<td>n</td>
<td>Correct</td>
<td>n</td>
<td>Correct</td>
<td>n</td>
<td>Correct</td>
</tr>
<tr>
<td>Individual</td>
<td>118</td>
<td>74%</td>
<td>118</td>
<td>16%</td>
<td>118</td>
<td>84%</td>
<td>118</td>
<td>19%</td>
</tr>
<tr>
<td>Team</td>
<td>33</td>
<td>67%</td>
<td>33</td>
<td>18%</td>
<td>33</td>
<td>88%</td>
<td>33</td>
<td>21%</td>
</tr>
</tbody>
</table>

The rolling cylinder IBLA questions ask the student about the cross sectional geometry of each type of cylinder in relation to the total kinetic energy of the cylinder at the bottom of the ramp. The examples of the Case scenarios are found in Appendix A, the results of the ranking questions can be found in Figures 9-12.
• “Which object has the larger mass moment of inertia?"

• “Which has larger Total Kinetic Energy when it reaches the bottom?”

The result of these two questions is shown in Table 13. These data show clearly that the vast majority of students understood how to calculate mass moment of inertia (which was covered in class and in the homework). But this was not the case in terms of their ability to determine the kinetic energy correctly.

Table 13. Spring 2015 Rolling Cylinder IBLA Case 1 and Case 2 Questions. These data are from all three of the sections of the Spring 2015 class.

<table>
<thead>
<tr>
<th>Moment of Inertia</th>
<th>Total Kinetic Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Individual</td>
<td>118</td>
</tr>
<tr>
<td>Team</td>
<td>33</td>
</tr>
</tbody>
</table>

Final exam results of each of the three sections for the Spring 2015 undergraduate dynamics class are shown in Table 14 and Figure 31. Section 1 was given a ranking task question, shown in Figure 31, while sections 2 and 3 each had the question shown previously in Figure 25.
(15 points) There are four objects shown below: (A) a thin-walled aluminum cylinder, (B) a thick-walled aluminum cylinder, (C) a solid aluminum cylinder, and (D) a solid steel cylinder. Each object is to be released from rest at the top of the ramp shown. If all the objects are released at the top of the ramp simultaneously, list the order, from fastest to slowest, the objects will reach the bottom of the ramp given that $h = 0.13\ m$ and $\theta = 15$ degrees (if two or more objects reach the bottom at the same time, indicate “tie”). Some common mass moments of inertia are shown on the last page.

![Diagram of rolling cylinders with mass values: $m_A = 2\ kg$, $m_B = 2\ kg$, $m_C = 6\ kg$, $m_D = 10\ kg$, $r_A = 0.1\ m$, $r_B = 0.05\ m$, $r_C = 0.13\ m$, $r_D = 0.13\ m$.](image)

Figure 31. Spring 2015 Final Exam Rolling Cylinder Comparison Question. This Question was given to Spring 2015 class section 1.

Table 14. Spring 2015 Final Exam Rolling Cylinder Comparison Question Results.

<table>
<thead>
<tr>
<th>Section</th>
<th>n</th>
<th>Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>64</td>
<td>39%</td>
</tr>
<tr>
<td>2</td>
<td>47</td>
<td>70%</td>
</tr>
<tr>
<td>3</td>
<td>39</td>
<td>95%</td>
</tr>
</tbody>
</table>

The exam results from Table 14 show that there is a high success rate in section 3, and that section 2 is on par with the initial individual guesses of Case 1 from the in-class activity. Both these two sections show better results from the previous semester (Table 3), which had the same final exam question. Section 1 was given a different type of question, but the success in retention with respect to Case 2 (16% correct) and Case 4 (19% correct) of the rolling cylinder IBLA shows an overall improvement with a score of
39% correct in relating different geometries with total energy and velocity as seen in Table 12.

Spool-Friction Inquiry-Based Learning Activity:
The spool IBLA was newly added for the Spring 2015 curriculum. This activity was designed to challenge students’ preconceptions on the following models: the direction of motion of the center of gravity for a spool, the direction of friction acting on the spool, and the value of the frictional force acting on the spool. The direction of friction is not intuitive to the rotating spool. Therefore, if a student had not thought in depth about the values of a frictional force, then this activity helped to improve and promote a greater understanding of what $F_{friction} \leq \mu_s N$, $F_{friction} = \mu_s N$, or $F_{friction} = \mu_k N$ mean.

Newton’s second law, $\mathbf{F} = m\mathbf{a}$, as well as Euler’s second law, $M = I\alpha$, were observed in this activity. These concepts explored the non-intuitive nature of the direction of friction in relation to an applied torque. The four cases of this IBLA are shown in Figures 32-35.
Table 15. Spring 2015 spool IBLA results. These data are from the spool direction of motion, direction of friction, and value of friction activity questions from the combined sections of the Spring 2015 undergraduate dynamics class.

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motion</strong></td>
<td>n</td>
<td>Correct</td>
<td>n</td>
<td>Correct</td>
</tr>
<tr>
<td>Individual</td>
<td>117</td>
<td>24%</td>
<td>117</td>
<td>69%</td>
</tr>
<tr>
<td>Team</td>
<td>33</td>
<td>30%</td>
<td>33</td>
<td>70%</td>
</tr>
<tr>
<td><strong>Friction</strong></td>
<td>n</td>
<td>Correct</td>
<td>n</td>
<td>Correct</td>
</tr>
<tr>
<td>Individual</td>
<td>117</td>
<td>55%</td>
<td>117</td>
<td>37%</td>
</tr>
<tr>
<td>Team</td>
<td>33</td>
<td>70%</td>
<td>33</td>
<td>42%</td>
</tr>
<tr>
<td><strong>µ*N</strong></td>
<td>n</td>
<td>Correct</td>
<td>n</td>
<td>Correct</td>
</tr>
<tr>
<td>Individual</td>
<td>117</td>
<td>31%</td>
<td>117</td>
<td>54%</td>
</tr>
<tr>
<td>Team</td>
<td>33</td>
<td>33%</td>
<td>33</td>
<td>61%</td>
</tr>
</tbody>
</table>
In terms of the direction of motion for the spool, the percent correct for each of the cases increased from Case 1 to Case 3. Case 4 was again a case in which the schema of the student about the spool was challenged on another level. There was a similar trend on the frictional force value for the individual and team results. Final exam questions and their results are shown in Table 16 and Figure 36. The final exam question correlating to the spool-friction IBLA related a forced rotation to the reaction of the frictional force on the tires of a vehicle. While not identical to the IBLA, understanding of the same concepts was required to correctly answer the question.

For the rear wheel drive car, consider a situation in which the car starts from rest and accelerates to the left. The tires do not slip on the road. Assume the normal force on the rear tires is \( N_{\text{rear}} \) and the coefficients of static and kinetic friction at \( \mu_s \) and \( \mu_k \), respectively. The friction force, \( F_{\text{rear}} \), on the rear tires is given by what expression and what is the direction?

A) \( F_{\text{rear}} \leq \mu_s N_{\text{rear}} \) to the right  
B) \( F_{\text{rear}} \leq \mu_k N_{\text{rear}} \) to the left  
C) \( F_{\text{rear}} = \mu_k N_{\text{rear}} \) to the right  
D) \( F_{\text{rear}} = \mu_k N_{\text{rear}} \) to the left  
E) Not enough information is given.

Figure 36. Spring 2015 final exam direction of friction question. This question was given to section one and section two of the Spring 2015 class.

Table 16. Spring 2015 final exam results. Section 2 did not have a quested related to this IBLA on their final exam.

<table>
<thead>
<tr>
<th>Section</th>
<th>n</th>
<th>Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>64</td>
<td>31%</td>
</tr>
<tr>
<td>2</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>39</td>
<td>54%</td>
</tr>
</tbody>
</table>
The final exam question in Figure 36 was a similar concept to Case 4 of the spool-friction IBLA. The data in Table 15 show that in Case 4 68% of individual students were able to correctly recognize the direction of friction, but only 31% of students in section 1 and 54% of students in section 3 were able to recognize the direction of friction in the final exam. The lack of student recognition between the IBLA and the exam question could be due to an inability of students to see the connection between a spool and a tire rotation. The final exam question results show that there was greater success in section 3 than there was in section 1 for retaining the information about the direction of friction. This could be due to lower attendance for this activity, but it could also be due to class size, as section 1 had an additional twenty students in class. Another factor could have been the feedback received by students, the same instructor and teaching assistants were present for sections 1 and 3.

2.4.3 Survey Results of the Inquiry-Based Learning Activity

Shown in Table 17 are the results of the in-class surveys of the IBLAs; students expressed positive feelings toward each category including: the activity compared to a lecture, the activity compared to a homework problem, and the motivation level of the activity. The difference in scales is due to the method for answering, for the Fall 2014 semester the questions were rated symbolically along an arrow as seen in Appendix A, the Spring 2015 survey used a five point Likert scale.
Table 17. In-class IBLA survey results.

<table>
<thead>
<tr>
<th>IBLA Survey outcomes</th>
<th>Fall 2014 Weight-Pulley</th>
<th>Spring 2015 Weight-Pulley</th>
<th>Spring 2015 Rolling Cylinder</th>
<th>Spring 2015 Spool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity was helpful</td>
<td>7/10</td>
<td>6.7/10</td>
<td>4.2/5</td>
<td>4.1/5</td>
</tr>
<tr>
<td>Compared to a lecture</td>
<td>6.2/10</td>
<td>6/10</td>
<td>3.7/5</td>
<td>3.6/5</td>
</tr>
<tr>
<td>Compared to a homework problem</td>
<td>6.5/10</td>
<td>6.4/10</td>
<td>3.7/5</td>
<td>3.6/5</td>
</tr>
</tbody>
</table>

2.4.4 Limits of the Results

One of the limits of the results is the number of students in attendance for the IBLAs. Classes did not have full attendance during each of the IBLAs, and because of this it was difficult to completely infer how the IBLAs directly correlated to the final exam results, seen in Table 18. Section 2 was shown to have the lowest attendance of the three sections. The number of students in attendance for the activities for each of the Spring 2015 sections is shown in Table 19.

Table 18. Combined final exam scores related to IBLAs

<table>
<thead>
<tr>
<th>Weight-Pulley Final Exam Results</th>
<th>Rolling-Cylinder Final Exam Results</th>
<th>Spool-Friction Final Exam Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section</td>
<td>n</td>
<td>Correct</td>
</tr>
<tr>
<td>Fall 2014</td>
<td>91</td>
<td>54%</td>
</tr>
<tr>
<td>1</td>
<td>64</td>
<td>75%</td>
</tr>
<tr>
<td>2</td>
<td>47</td>
<td>49%</td>
</tr>
<tr>
<td>3</td>
<td>39</td>
<td>28%</td>
</tr>
</tbody>
</table>
Table 19. Spring 2015 percentage of student attendance to IBLAs. These data are from attendance taken during each IBLA.

<table>
<thead>
<tr>
<th>Spring 2015</th>
<th>n</th>
<th>Weight-Pulley</th>
<th>Cylinder</th>
<th>Spool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 1</td>
<td>68</td>
<td>97%</td>
<td>79%</td>
<td>72%</td>
</tr>
<tr>
<td>Section 2</td>
<td>49</td>
<td>86%</td>
<td>67%</td>
<td>67%</td>
</tr>
<tr>
<td>Section 3</td>
<td>40</td>
<td>100%</td>
<td>85%</td>
<td>90%</td>
</tr>
</tbody>
</table>

With respect to the attendance percentages it is interesting that the relationship of the weight-pulley IBLA does not show a large difference in the percent of correct answers. Section 2 and section 3 answered questions that were both similar to the Case 4 question of the weight-pulley IBLA, so in fact there was a negative correlation with the results for section 3. The attendance numbers in relation to the exam results with respect to the rolling-cylinder IBLA show that a greater number of students scored higher than the number of students in attendance to the IBLA itself for sections 1 and 3, but for section 2 the same number of people in attendance got this questions correct. The final exam question, which related to the spool-friction IBLA, shows that there is a correlation in the amount of people who attended class and answered correctly on the final exam question. The data from Tables 18 and 19 show that there is a positive correlation to the number of students who attended the activities and the scores received on final exam questions. The results of this analysis were difficult to compare, though, due to the anonymity of the students.

2.5 Summary and Conclusion of Student Learning Outcomes

This research looked into the learning outcomes for students in relation to the IBLAs for students enrolled in undergraduate dynamics at the UNR over the Fall 2014 and Spring
2015 semesters. The post-activity surveys showed that students viewed the activities as motivational for their learning in the subject area in comparison to receiving traditional lectures or homework. The weight-pulley IBLA in-activity results showed 42% of students answering Case 1 correctly and 34% of students answering Case 4 correctly (Table 6). Course section 1 received a question similar to Case 1 of the weight-pulley IBLA on the end of semester final exam and resulting in scores of 75% correct answers, seen above in Table 8. Course sections 2 and 3 received questions similar to Case 4 from the weigh-pulley IBLA receiving final exam results of 49% and 28% correct (Tables 9 and 10), showing that there was a gain in understanding for section 2 and a drop in understanding for section 3.

The rolling-cylinder IBLA results show that there was improvement in thinking for the concepts of moment of inertia and kinetic energy for each of the course sections. In the Fall 2014 semester a question similar to Case 1 of the rolling-cylinder IBLA was given, initial answers of this in-class case showed 51% of students answered correctly (Table 3) compared to the final exam results of 54% correct (Table 4). Additionally, in the Spring 2015 semester Case 2 resulted in 16% correct for individual students answering correctly and 19% of students answering Case 3 correctly, seen above in Table 12. Course section 1 received a final exam question that ranked the order in which the cylinders would reach the bottom of a hill, this question was similar to Cases 2 and 4 of the IBLA, and the final exam score was 39% (Table 13). Course sections 2 and 3 answered a question that was similar to Case 1 of the rolling-cylinder IBLA; section 2 results showed a lower score of
70% correct, and course section 3 showed the greatest improvement with an increase to 95% correct, as seen in Table 14.

The final exam question given to course sections 1 and 3 relating to the spool-friction IBLA regarded the direction of friction acting on the tire of a vehicle, this question related closely to Case 4 of the IBLA, the score of which was 68% correct in answering the direction of friction and 51% correct in answering the value of the frictional force (Table 15). Course section 1 scored 31% correct on the final and section 3 scored 54% correct on the final (Table 16) demonstrating a decrease in understanding of the concept of rigid body rotation.

These results showed that the IBLA, in which the students had the greatest amount of interest in, the rolling-cylinder IBLA, achieved the highest final exam scores of the three IBLAs. This correlation of liking the activity and doing well on the exam shows that through behavioral analysis the intrinsic motivation found by students through this activity helped with their final exam retention and cognition.

2.5.1 Effects of Environmental Learning

The main difference in student learning was not from the amount of questions that were given to them, but in the way that the questions were presented. With the IBLA there was a greater amount of environmental stimulation for the student. When a pupil was faced with a challenge that was given in this type of environmental setting, as opposed to a more traditional setting in which a lecturer would go over an example problem and the
solution that goes with that problem, there was a newly added complexity of autonomy that the learner had to use in order to gain insight in the newly presented scenario. In the case of an IBLA there was a large amount of confirmation bias associated with the activity, the design of each IBLA was to challenge and affirm correct notions of the concept that was given to the student. The nature in which the new set of questions was presented and the sequences in which the cases were presented were meant to help achieve overall student success in the new concept area. In the data that has been acquired from the IBLAs it had been shown that students had a greater amount of information retention with the IBLA incorporated into the curriculum. Also, from student surveys it was shown that students had shown a greater amount of interest in the subject area with the use of the IBLAs incorporated into the undergraduate dynamics curriculum.

2.5.2 Student Learning Outcomes

Activity based learning has been shown in the past to improve student concept knowledge (Adam, Self et al. 2015, Laws, Sokoloff et al. 1999, Prince and Vigeant 2006, Georgette 2013, Self, Widmann et al. 2013, Baheej Nabeel James Saoud 2015). The IBLAs included in the UNR undergraduate dynamics curricula showed a high amount of motivation in subject learning more than in the amount of conceptual retention. Student subjectivity towards the activities displayed that a change from the lecture to the activity was helpful toward learning the subject material and the activities were interesting and motivating for students.

2.5.3 Future Research
The hands-on experience of learning can be brought to a higher level if the students find an intrinsic understanding of a concept within their everyday lives. It is recommended to include additional activities that help the student find more examples of dynamics concepts with small modeling “games,” much like the research done by Hestenes (Hestenes 1992). These models of games could be introduced to the IBLA with the use of a greater amount of Cases or scenarios gone over in class and homework problems. From these models, it is also useful for students to nurture their own motivations in the subject area. In order to test these motivations future research could be based on finding out more about the intrinsic and extrinsic motivations that students have toward each facet of the course and alter the amount of classroom design needed to make the course more efficient. This is because, as with most learning, the role of the instructor is to help the student so that they may discover and hone their interests in the subject matter. It is not the purpose of the instructor to be the sole source of material, but to add guidance in the subject matter.
Chapter 3 Solution Manual Analysis

3.1 Introduction and Background

3.1.1 Motivation
Past experience with the University of Nevada, Reno undergraduate dynamics course (ME 242) as a grader and as a teaching assistant has shown me, anecdotally, that a large number of the students enrolled in the course rely heavily on the use of solution manuals to complete their homework. I have noticed that many students believe that there is a “right” way to use a solutions manual and that there is a “wrong” way to use a solutions manual. This study analyzes student reliance on solution manuals to complete their homework and the ways in which the solutions manuals are being used. This study was done in the undergraduate dynamics ME 242 course over the 2013-2014 and 2014-2015 academic years.

3.1.2 Introduction
The purpose of this study is to examine the use of solution manuals by students in ME 242. The study looked at student perceptions of solution manual use, their uses of solution manuals in general, and the implications of those uses. The data for the students’ insights on solution manual use were collected through survey questions.

Graded homework problems are a traditional part of the feedback system between teachers and students. If a student is using a solutions manual as an aid to complete their homework this feedback can work either more efficiently or less efficiently for a student,
depending on the way it is used. A positive side to this is the immediate feedback a student is able to receive while working on a homework problem. With the use of a solutions manual a student can compare their answer with the correct one, and if the results do not match then the manual can be used as a guide to help the student understand the process of finding the solution (unless otherwise noted, the solution manual is assumed to show the entire solution, not just the correct numerical answer). On the negative side, as a grader for the undergraduate dynamics class, I have witnessed the direct copying of work from solution manuals. This is unfavorable toward student learning if the work is copied without the student taking the time to understand the material. This is also harmful to the feedback information that the instructor is receiving because the work does not correctly reflect the level of understanding of the student.

Hestenes stated that students are most likely unaware that their own ideas about Newtonian force differ drastically from those of the teacher (Hestenes 1992); most students systematically misunderstand what they hear and read in traditional introductory physics. Consequently, they cannot understand why they fail at problem solving, and they are forced to resort to rote methods for learning meaningless formulas and procedures (Hestenes 1992). Anecdotally the instructor for ME 242 has noted, on occasion, that on the “formula sheet” which students compile in preparation for midterm and final exams there is a large amount of rote copying of the homework problems on the formula sheet. Jackson and Hestenes also direct this behavior toward a students “inability to construct (in their heads) appropriate system schemas” (Hestenes 1997, Jackson, Dukerich et al. 2008).
A student’s lack of practice in identifying forces or a general lack of practice with the material demonstrates that there is a problem with the amount of solution manual usage. A usual student concern in relation to the instructor and the class around the end of the semester is: “I found the hardest part of this class was always getting the problem started. You did a great job of lecturing and things seemed to make sense, but I always struggled with where to start.” Another common request by students toward the instructor is to “go over more example problems.” These comments are strong indicators of the fault in students’ schema on the subject matter.

One reason for the student request to go over more example problems could be for a gain in structural schema. Traditional lectures and note taking are the most effective ways for students to improve in skill acquisition. Fluency and retention are needed for a student to have high outcomes in any subject area. Retention of information is obtained through structured practice of concepts. This structure of practice can be described in many ways, but the most influential part of this practice is the size of the increments in which the subject is studied. The use of incremental study is traditionally emphasized in the curriculum starting from free-body diagrams and moving to three-dimensional rigid body motion. The complex concepts of Newtonian mechanics are split into small sections for learning, but if any of the steps in learning and practice of the material is missing it can become many times more difficult for a student to gain fluency in the subject area in general. This is due to a change in the process of traditional student learning which is

A fault in schema can be difficult for both an instructor and a student to find, and it is difficult to remedy within the time period of one semester. This is because of the type of feedback a student receives with the use of a solution manual. The feedback from an exam is usually a very serious one, worth 25-30% each (depending on the semester, check Appendix C) of a student’s final grade. The feedback from a homework set is worth 30% of a student’s final grade. If the work for solving homework problems is not done with ample time and understanding the exams can have a negative affect on student learning and goal seeking.

Negative affects of goal seeking were also witnessed when students began to make the comment about exam outcomes “as long as I do better than the average.” This type of language suggests that the goal of the class and the motivation behind learning the class material is changed from a mastery goal to a performance goal. Reeve states that, “Achieving a mastery goal means making progress according to a self-set standard… Achieving a performance goal means doing better than others” (Reeve 2008). Teachers want their students to gain mastery goals rather than superficial performance ones.

A study done by Jordan, from a series of surveys given to a liberal arts college, found a correlation between cheating on homework and the type of emotional behavior of the student. “… Cheaters were found lower in mastery motivation and higher in extrinsic
motivation in courses in which they cheated than in courses in which they did not cheat. Cheaters, in courses in which they cheated, were also lower in mastery motivation and higher in extrinsic motivation than were noncheaters” (Jordan 2001). This study also shows that there is a linear relationship in how a student scores on exams and the type of motivation they have toward learning that skill, “Mastery motivation scores for cheaters in courses in which they did not cheat were significantly higher than their mastery motivation scores in courses in which they did cheat. In contrast, extrinsic motivation scores were significantly higher in courses in which cheaters cheated than in courses in which cheaters did not cheat” (Jordan 2001). If a student’s class goal is changed from being intrinsically motivated to extrinsically motivated that student’s learning outcomes can be directly affected for the worse.

The motives for academic dishonesty can lead to larger consequences and it is believed to be easily deterred in a classroom environment in which this type of behavior is kept in check with an honor code and a classroom in which academic integrity is held in high regard (Nuss 1984, Harding 2000, Harding, Carpente et al. 2001, Jordan 2001). But it is also true that students do not necessarily believe the use of solution manuals to be cheating (Lipson and McGavern 1993, Widmann and Shollenberger 2006, Widmann, Shollenberger et al. 2007). Instead most students believe it to be a tool for checking work and learning the material (Lipson and McGavern 1993).
It is the goal of this study to find out if adding questions without an available solutions manual is helpful in discouraging students from using a solutions manual and raising levels of intrinsic motivation for learning the material without a solutions manual.

3.1.3 Approach to the Study

In order to find out the profundity of use of the solution manual surveys were issued to the students in ME 242 for the 2013-2014 and 2014-2015 academic years at the end of each semester. The Fall 2013 survey was a questionnaire based on the amount of the perceived knowledge base that students enrolled in ME 242 had as a causal factor in solution manual use. This survey was used as a basis to gain knowledge about student prior knowledge in prerequisite courses for the purpose of making possible changes to the ME 242 curricula in order to enhance student schema. The Spring 2014 survey was a questionnaire based on student awareness of the solution manual and student use of the solution manual. The Fall 2015 student survey was a questionnaire based on student perception of their knowledge base and solution manual awareness and use during their enrollment in ME 242.

3.2 Background: Student Solution Manual Applications

In order to ensure student success with the mastery elements of self-practice it was imperative to obtain information about student use of homework solution manuals and to design material in which students were able to complete homework without the possible use of solution manuals.
The way in which students find out about or obtain a solution manual has been shown to environmentally affect the way in which students use a solutions manual (McCabe 1997, Passow, Mayhew et al. 2006). This influences the frequency in which students are willing to use a solution manual and the ethical feelings a student has toward using a solution manual. McCabe has shown that students who have seen or been given homework solutions by other students will environmentally use solution manuals (McCabe 1997). Passow has shown that the behavior of a student in this environmental situation has been shown to cheat with little thought on the consequence of the behavior (Passow, Mayhew et al. 2006). It is stated that “…Performance feedback in its various forms – task-generated, self-generated, social comparisons, and other-generated – supplies the information individuals need to formulate a cognitive evaluation of their perceived level of competence” (Reeve 2008). The social environment of ME 242 fosters behavior in which students believe solution manuals are okay to use to complete homework problems, but for students the solution manual can become a crutch that when lost in an exam can be painful.

3.2.1 Student Learning with Solution Manuals

Student learning potential is changed in the choice of how a solution manual is used. The possible ways in which students could use the manuals were shortened into the following five ways: using the solution manual to check work done, to view the steps involved to solve the problem, to save time, to copy down the steps of the problem, or to use the solution manual when the student is unable to complete the homework due to lack of knowledge on the material. Each use of the solution manual is a valid reason to help in
student learning, but it is the way in which the information from the solution manual is used that can be helpful or detrimental toward student success in mastery of the subject materials.

The mastery level of the subject can be shown to be much higher in students that use the solution manual for feedback in work rather than for copying the work. Using the solution manual as a basis for feedback in work that has already been made toward learning the material is a helpful source of guidance, but if the solution manual is used before a student has the chance to challenge themselves with the material, then the task of completing a homework problem is no longer as useful and the goal of gaining more knowledge in the subject domain is lessened.

Reeve has described the benefits of mastery goals with the following flow chart:
This description of mastery skills shows the ability of motivation to enhance student learning in a subject. The quality of a mastery goal rather than a performance goal is what pedagogues strive for to give their pupils a higher level in student success (Johnson and Layng 1996).
3.2.2 Student Assessment with Solution Manuals

It is a difficult task to assess the mastery level of a student based on the outcomes of homework and exam grades alone. This is due to the complexities of learning inherent in each student. So, in order to better understand the thinking processes of students taking ME 242, a set of novel questions without a solution manual were introduced to the ME 242 curricula for the Fall 2014 and Spring 2015 semesters. These questions were designed to be similar to homework questions from the assigned book in both difficulty and presentation, they were added to the regularly assigned weekly homework questions available via the course’s online LMS (learning management system), WebCampus.

3.3 Methods for Surveying Usage of Solution Manuals

3.3.1 Survey Background

Homework problems are assigned to students in order to help them gain fluency in a subject area. Fluency can be related to frequency of practice as described by Johnson and Layng (Johnson and Layng 1996):

The frequency aims allow few, if any, errors, and are selected to predict that learners will (a) remember and perform the skill, at the frequency aim, after a significant period of no practice (a month or more); (b) show performance endurance, that is, perform the skill at the frequency aim for periods of time that are longer than the timing period used during practice; (c) perform the skill with stability, that is, performance will not be easily distracted; (d) easily apply the skill as a prerequisite or component of a more complex performance to be learned; and (e) demonstrate increasing capacity to learn skills instantly, and on their own, as they move through a subject matter. In fact, increasing problem-solving orientation and creativity become readily apparent. These behavioral aspects are a function of contingency adduction.

Contingency adduction is the behavioral psychology term that indicates the use of multiple skills needed to solve a specific problem. This term describes problem solving as
an addition of different types of foundational knowledge to solve new types of problems. The contingency adduction of the dynamics course is exemplified by the amount of creativity that can be used to solve problems with the use of Newtonian mechanics. Johnson and Layng describe the most efficient way to help students learn problems solving is by starting from the “…bottom up, beginning with essential tool skill frequencies, and then moving on to other component behaviors, then to component sequences, then to composites” (Johnson and Layng 1996). This is the application of simple problem solving patterns into a well-rounded collection of composite problem solving skills. Confidence in problem solving stems from the repertoire of fundamental cases and scenarios that a student has; students with a larger repertoire of information are more successful in future engineering endeavors. This is one of the reasons why satisfaction of prerequisite courses is asked directly on the student surveys. It is necessary to analyze the amount of foundational knowledge a student may have in order to solve composite based problems in the undergraduate dynamics class.

3.4 Results and Discussion of Student Surveys and Grades

3.4.1 Student Output Implications for Using Solution Manuals

In order to assess the foundational knowledge of students, the end of semester survey asked questions with regards to the prerequisite courses. Table 20 presents the survey results in terms of the satisfaction held for prerequisite courses on a five point Likert scale (1 = strongly disagree to 5 = strongly agree). The results show that overall student satisfaction was agreeable to the prerequisite courses. The level of students’ perceived preparedness was of that obtained in the Physics, Statics, and Calculus courses.
Table 20. Survey results of the level of satisfaction of course preparedness from the required prerequisite courses.

<table>
<thead>
<tr>
<th>Course preparedness</th>
<th>Spring 2014</th>
<th>Spring 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics (PHYS 180)</td>
<td>3.98/5</td>
<td>3.5/5</td>
</tr>
<tr>
<td>Statics (ME 241)</td>
<td>3.4/5</td>
<td>3.6/5</td>
</tr>
<tr>
<td>Calculus (MATH 182)</td>
<td>3.4/5</td>
<td>3.4/5</td>
</tr>
</tbody>
</table>

The Fall 2013 survey format was that of Likert scale based questions that assessed student agreement or disagreement with prerequisite courses and with the use of WebCampus as a tool for learning subject material by watching videos online. The Spring 2014 survey format was a yes/no multiple choice survey that was given through WebCampus to assess student use of solution manuals. The Fall 2014 and Spring 2015 survey formats were similar to the Spring 2014 survey examples. An example of each of the surveys can be found in Appendix C.

3.4.2 Survey Results

The outcomes of the Spring 2014 dynamics course were not readily compared to the Fall 2014 and Spring 2015 classes mostly due to the classes having different professors. The Fall 2014 class had a different instructor from the Fall 2014 and Spring 2015 classes.

When students were asked of his/her awareness of the solution manual the results were that a majority of the students were aware of its existence as shown in Table 21, and the majority of students obtained those solution manuals through a friend, these survey results are shown in Table 22.
Table 21. Survey results for class awareness of solution manuals.

<table>
<thead>
<tr>
<th>Awareness of solution manuals.</th>
<th>Spring 2014</th>
<th>Fall 2014</th>
<th>Spring 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>83%</td>
<td>97%</td>
<td>88%</td>
</tr>
<tr>
<td>No</td>
<td>13%</td>
<td>3%</td>
<td>12%</td>
</tr>
</tbody>
</table>

Table 22. Survey results of how a student obtained a solutions manual.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bought one</td>
<td>17%</td>
<td>6%</td>
<td>9%</td>
</tr>
<tr>
<td>From a former student</td>
<td>40%</td>
<td>62%</td>
<td>47%</td>
</tr>
<tr>
<td>I have an illegal copy</td>
<td>2%</td>
<td>11%</td>
<td>10%</td>
</tr>
<tr>
<td>I don't own one</td>
<td>36%</td>
<td>22%</td>
<td>30%</td>
</tr>
</tbody>
</table>

Student use of solution manuals was split into a results category by the number of homework sets in which a student may have used a manual and the average number of problems in a homework set in which a student may have used the solution manual (Tables 23 and 24). Not applicable applies to students that did not use the solution manual over the course of a semester.

Some of the respondents that replied “Did not use a solution manual” for the duration of the semester did not respond to the following survey questions about the number of homework sets on which a student used a manual. The questions pertaining to the number of problems in a set in which a student used a solution manual is shown in Tables 23 and 24.
Table 23. Survey results relating the number of weekly homework sets a solutions manual was used by a student.

<table>
<thead>
<tr>
<th>Number of Homework sets completed with the use of a solution manual.</th>
<th>Spring 2014</th>
<th>Fall 2014</th>
<th>Spring 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 3</td>
<td>23%</td>
<td>9%</td>
<td>18%</td>
</tr>
<tr>
<td>4 to 9</td>
<td>20%</td>
<td>20%</td>
<td>25%</td>
</tr>
<tr>
<td>Majority</td>
<td>19%</td>
<td>26%</td>
<td>10%</td>
</tr>
<tr>
<td>Every</td>
<td>9%</td>
<td>35%</td>
<td>24%</td>
</tr>
<tr>
<td>N/A</td>
<td>23%</td>
<td>8%</td>
<td>22%</td>
</tr>
</tbody>
</table>

The survey results on the number of homework sets that were completed with the use of a solution manual show that in the Spring 2014 semester the solution manual was used by students over a large range. From Table 23, the highest occurrence of use at 23% of students not using a solution manual and 23% using a solution manual for one to three homework sets. The data from Table 23 show a general trend in a majority of students from each of the semester courses reporting use of a solution manual for 4 to 9 homework sets or for every homework set. The trend for solution manual use by students while completing a homework set is shown in Table 24. A majority of students in Fall 2014 and Spring 2015 reported using a solution manual for each set, whereas students in the Spring 2014 semester reported using a solution manual for only one problem in a homework set.
Table 24. Survey results pertaining to the number of problems in a homework set a solution manual was used by a student.

<table>
<thead>
<tr>
<th>Number of problems in a set completed with the use of a solution manual</th>
<th>Spring 2014</th>
<th>Fall 2014</th>
<th>Spring 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>25%</td>
<td>9%</td>
<td>2.4%</td>
</tr>
<tr>
<td>1</td>
<td>36%</td>
<td>9%</td>
<td>22%</td>
</tr>
<tr>
<td>2</td>
<td>14%</td>
<td>26%</td>
<td>8%</td>
</tr>
<tr>
<td>3</td>
<td>4%</td>
<td>22%</td>
<td>34%</td>
</tr>
<tr>
<td>all</td>
<td>15%</td>
<td>32%</td>
<td>34%</td>
</tr>
</tbody>
</table>

The number of problems within a homework set in which a solution manual was used for the Spring 2014 class had a majority of 36% of students only using the solution manual for one problem in the set. The Fall 2014 class shows a majority of 32% of students using a solution manual for each problem in the set with the second largest group of 26% using the solution manual for only two problems in a homework set. The Spring 2015 class had a tie majority group of 34% of students using a solution manual for three problems with 34% of students using a solution manual to complete each problem in the homework set.

Students were asked, “How were you using the solution manual? Please select all that apply.” The question was designed as a check response because of the commonality of past responses that students have given as reasons for why they had used a solution manual. These results are shown in Table 25. Students could select more than one type of use, so the column totals do not add up to 100%.
Table 25. Survey results pertaining to the main uses of a solution manual by a student.

<table>
<thead>
<tr>
<th>How did students use the solution manual?</th>
<th>Spring 2014</th>
<th>Fall 2014</th>
<th>Spring 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check the steps</td>
<td>49%</td>
<td>58%</td>
<td>49%</td>
</tr>
<tr>
<td>Check work</td>
<td>65%</td>
<td>52%</td>
<td>45%</td>
</tr>
<tr>
<td>Save time</td>
<td>14%</td>
<td>17%</td>
<td>21%</td>
</tr>
<tr>
<td>Insufficient knowledge</td>
<td>26%</td>
<td>12%</td>
<td>11%</td>
</tr>
</tbody>
</table>

The results in Table 25 show that a majority of students used the solution manuals to check their work (65%, 52%, 45%) and/or to look at the steps involved to solve the problem (49%, 58%, 49%). Very few students reported using the solution manual to save time on a problem or because of a lack of knowledge in the subject area; the exception being in the Spring of 2014 where 26% reported insufficient knowledge. This is most likely due to the instructor’s experience as it was the first time they taught the course at UNR.

In order to find out a student’s concept of the usefulness of a solution manual as an aid for the course material, the following questions were asked. A ranking question was asked in order to find out the amount of use a student feels they had obtained from using the solution manual: “Please rank how useful you found the solution manual to be from 1 to 10. With 10 being the most useful and 1 being the least useful.” The results of this ranking question are shown in Table 26. The reasoning for asking this question is to find the quality of motivation a student had at the end of the semester for using a solution manual.
Table 26. Survey results on a student's opinion on the usefulness of a solution manual.

<table>
<thead>
<tr>
<th>Usefulness Scale</th>
<th>Fall 2014</th>
<th>Spring 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 10</td>
<td>6.75/10</td>
<td>7.1/10</td>
</tr>
</tbody>
</table>

Students were also asked, “Would you recommend using the solution manual to a friend? Please elaborate on your answer to this question.” in order to confirm the amount of motivation they were willing to pass on to their peers. This question revealed many personal feelings that students had toward the class. Results were both positive and negative in the quality of words that were used by students to describe the general use of a solution manual. The responses were sorted into comments that are considered “positive” on how to use a solution manual and “negative” on how to use a solution manual. The positive responses were chosen to be those with words like: “helpful,” “if they use it the right way,” “to check work,” “if stuck,” “if they are lost,” and “useful.” The negative responses were chosen to be those with words like: “cheating,” “crutch,” “hinder,” “copy,” and “never actually learned.” Results for the positivity and negativity of solution manual use are shown in Table 27. The data clearly show that far more students found the solution manual to be useful rather than not useful.

Table 27. Survey results of an open-ended question about the recommendation of solution manual use to a friend.

<table>
<thead>
<tr>
<th>Word choice of open answers about solution manual use.</th>
<th>Spring 2014</th>
<th>Fall 2014</th>
<th>Spring 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>A useful tool</td>
<td>65%</td>
<td>48%</td>
<td>85%</td>
</tr>
<tr>
<td>Not a useful tool</td>
<td>18%</td>
<td>6%</td>
<td>26%</td>
</tr>
</tbody>
</table>
The following survey questions, in Table 28, pertain to the novel questions (i.e. no solution manual for them) for the Fall 2014 and Spring 2015 semesters. The student opinion of these questions in comparison to the book problems is an indication of the perceived difficulty held by students.

Table 28. Survey results of difficulty of homework problems out of the book compared to the novel homework problems.

<table>
<thead>
<tr>
<th>Comparison of novel homework problems to traditional homework problems.</th>
<th>Fall 2014</th>
<th>Spring 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harder than the problems from the book.</td>
<td>74%</td>
<td>61%</td>
</tr>
<tr>
<td>Easier than the problems from the book.</td>
<td>16%</td>
<td>2%</td>
</tr>
<tr>
<td>Same difficulty</td>
<td>10%</td>
<td>36%</td>
</tr>
</tbody>
</table>

The made-up problems compared to the textbook problems resulted in a majority of students believing the made-up problems to be more difficult. It must be noted that the “novel” questions were simply problems from other textbooks paraphrased to prevent students from finding the answer via an Internet search engine. Thus, the actual difference in difficulty between the textbook and “novel” question was very minimal despite the strong majority of students feeling otherwise. In the Spring 2015 semester a flipped classroom approach was used and many of the novel problems were worked out by the students in class, this may explain the students’ perceived differences between the novel questions between the two semesters, Fall 2014 and Spring 2015.

3.4.3 Discussion of Survey Results
The results of the end of semester survey express that a majority of students were both aware of a solution manual and used the solution manual (Table 22). Of those that used the solution manual, about 30% relied on a solution manual to complete every homework problem (Tables 23 and 24). Additionally, the data show that there may be a growing trend in solution manual use; in each consecutive semester of this study the fraction of students using the solution manual for all the problems in a homework set grew while the percentage that did not use the solution manual fell. This could be due to increased Internet availability for looking up answers to questions. There are readily available sources like Chegg or sharing of downloaded answers, which were made available by students that had previously taken the course.

From the survey data in Table 25, the mainly reported reason for student use of a solution manual was to check their work and to look at the steps involved in solving a problem. The solution manual use can be attributed to students feeling that there is a “right” or acceptable way to use a solution manual. Since all the results are self-reported, it is possible that students responded with this in mind rather than admitting to a lack of knowledge.

It was also shown that a majority of students considered the solution manual to be a useful tool in helping them learn the material, but contrary to this outcome the data for the “novel” homework problem in Table 28 suggest the solution manual may not be so useful. Despite the level of difficulty of the novel questions being similar to the textbook problems, a surprising 74% and 61% of students believed these problems to be more
difficult than those out of the book (Table 28). These results indicate that the students were neither confident nor capable of solving problems without a solution manual. In the Spring 2015 semester, where the flipped classroom approach was used, the data illustrate that twice as many students, percentage-wise, felt that the novel problems were of similar difficulty to the textbook problems.

The student opinion of the novel questions having a higher difficulty shows that although students were aware that there is a “right” or “wrong” way to use a solution manual, their cognizance did not impede their behavior of solution manual use. This behavior could stem from environmental factors (Nuss 1984, McCabe 1997, Harding 2000, Harding, Carpenter et al. 2001, Jordan 2001, Harding, Carpenter et al. 2003, Passow, Mayhew et al. 2006). These student survey answers could also be the result of student dissatisfaction with their personal efficacy within the class at the end of the semester, as these surveys were given during the week prior to final exams.

3.4.4 Comparison Between Textbook Problems and Novel Homework Problems
The Fall 2014 and Spring 2015 semesters were the terms in which the novel (without solution manual) homework questions were added into the ME 242 curricula. Homework and quiz results from these semesters are analyzed in this section. The variability between the Fall 2014 and Spring 2015 semesters is most likely due to the structure in which each of the classes was implemented. The Fall 2014 semester was in a transitional phase of experimental teaching with lessons based on the “flipped” classroom technique. The
Spring 2015 semester was the first attempt at using a more complete “flipped” classroom-teaching technique.

The Fall 2014 novel questions were given as weekly WebCampus (online) problems only. The novel homework sets for the Spring 2015 semester were made up of online questions, which were given as both problems on the WebCampus platform and in the form of paper homework. For online questions, students were allowed up to five attempts, with automatic, instantaneous feedback in the form of the correct numerical solution after an attempt had been made. The paper homework was only given one attempt with no late work accepted.

One approach to solving the online problems was to guess an answer on the first attempt so that the computer would provide the correct solution (the problems were parameterized so several variables changed with each attempt). Knowing the correct answer, a student could then work backwards to arrive at a solution method. Unlike the written assignments, it was believed that giving students multiple attempts, with immediate feedback after each attempt, would encourage students to approach the homework with a mastery goal mindset rather than a performance goal mindset.

To incentivize a legitimate first attempt on the online homework problems, an extra point was awarded if the first attempt on the problem yielded the correct answer. Each problem was out of ten points so the incentive was effectively 10% extra credit.
In the Fall 2014 semester novel (online) questions were added under the title of “Weekly Quiz” to encourage student homework completion. Data on the results of the traditional homework problems compared to those of the novel homework problems are shown in Tables 29 and 30. In Table 29 the average score on each of the twelve “quizzes” along with the average paper homework score and online homework statistics are shown. Note, even though the novel questions were presented online, they are not included in the online homework data presented.

The last two rows of Table 29 provide information on the percentage of students who received the bonus point for getting the problem correct on their first attempt as well as the percentage who eventually got the problem correct within the five attempts allowed. The difference between these rows is the percentage that used multiple (two or more) attempts to arrive at the correct answer.

Table 29. Fall 2014 paper and online homework data.

<table>
<thead>
<tr>
<th>Fall 2014</th>
<th>Paper HW</th>
<th>Online HW</th>
<th>Novel question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average score</td>
<td>73%</td>
<td>89%</td>
<td>57%</td>
</tr>
<tr>
<td>Right on 1st try</td>
<td>N/A</td>
<td>30%</td>
<td>17%</td>
</tr>
<tr>
<td>Score ≥ 100%</td>
<td>N/A</td>
<td>75%</td>
<td>53%</td>
</tr>
</tbody>
</table>

The Fall 2014 data indicate that there was a significant (~30%) difference in the average scores of novel questions and the traditional homework scores. Clearly students did not perform as well on the novel problem as compared to the textbook problems, paper or online. The difference could be due to the lack of solution manual, the lack of available help at the Engineering Tutoring Center (which relies on the
solution manual), the lack of help from Supplemental Instructors who also typically use a solution manual to help students, or simply a lack of confidence. The most commonly given answers to the Fall 2014 end of semester in-class survey question number thirteen, “13) You were allowed 5 attempts to answer the Weekly Quiz questions. Under what circumstances did you not use all 5 attempts? (Why did you choose to use fewer of the attempts)”, (found in Appendix B.3) were 1) “I got the question correct on the first try” followed by the answer of 2) “I gave up on the question”. The question thirteen results also correlate to the earlier survey results regarding the question on rating the difficulty of the novel homework questions to the book homework questions. With 74% (Table 28) of students responding that the novel homework questions were harder.

In the Spring 2015 semester the novel problems were both online and submitted as the paper homework. This was done because the instructor felt too many students were submitting paper homework that was identical to the solution manual. In Table 30 the online homework was separated, similarly to the Fall 2014 data, into online homework and novel questions in separate columns.

<table>
<thead>
<tr>
<th>Table 30. Spring 2015 paper and online homework scores.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spring 2015</strong></td>
</tr>
<tr>
<td>Average score</td>
</tr>
<tr>
<td>Right on 1st try</td>
</tr>
<tr>
<td>Score ≥ 100%</td>
</tr>
</tbody>
</table>
It is clear that in the Spring 2015 semester (Table 30) all the homework scores were higher than in the Fall 2014 semester (Table 29). This is most likely attributed to the flipped classroom approach where the homework problems were solved by students working in groups or individually in class. This is especially evident when comparing the percentage of students who arrived at the correct answer for the novel questions on their first attempt online (17% versus 38%). It is obvious that working out the problem in the flipped class better prepared students for completing the online assignment.

3.4.5 Comparison Between Textbook Problems and Novel Homework Problems

Discussion

The Spring 2015 semester’s novel questions included seven more questions than in the Fall 2014 semester. Even with the larger number of novel problems, student performance on the novel questions was better than the previous semester. This could be due to the addition of questions and the types of questions that were added. Some of the questions used had multiple steps allowing for partial credit, rather than a single question without partial credit, which is how most of the Fall 2014 novel questions were given to the students. The change in comprehension could also be due to the implementation of a flipped classroom teaching style in the Spring 2015 semester. The teaching assistants and instructor openly answered any questions that students may have had pertaining to the novel questions.

The Spring 2015 data for homework scores also showed that there was a difference in the traditional online homework problems from the textbook and the novel homework
problems. The difference being the average score of the novel question was 83% and the average online homework was 92% (Table 30). This near ten percent difference is most likely due to the change in the feedback system for the solution manual and Engineering Tutoring Center. The supplemental instructors did have access to answers to the novel questions.

During the Spring 2015 class, the novel questions were used as both the paper homework to be submitted by students and were included as the online homework. Some of the turned in paper homework problems included traditional homework problems from the textbook that required students to use the computer software Matlab for the purpose of solving state variable problems. This showed that there was value in turning in paper homework along with reviewing online homework. Causes for the difference in homework scores to the same online novel scores could be discrepancies in orthography, for example incorrectly labeling units or vectors. Missed points could also have been caused by errors in the Matlab based problem.

Motivated by the hypothesis, which states that students rely heavily on the solution manual to solve homework problems, student performance on three specific online homework problems was examined in more detail. While the vast majority of the online homework problems were from the textbook, there were three problems that were not out of the textbook but were included in the traditional online homework set. The three questions included in the following tables are the questions labeled “Vectors Quiz”, “Coordinate Transformations”, and “Angular Acceleration”. The “Vectors Quiz” and the
“Coordinate Transformations” problems were not found in solution manuals and were made available to students during the first two weeks of the semester. These online homework scores are shown in Tables 31 and 32 for the Fall 2014 and Spring 2015 semesters respectively. The problem “Angular Acceleration” was based on a homework problem from the textbook, but the question was significantly modified, rendering the solution manual useless. Anecdotally, the “Angular Acceleration” problem is also the most asked question I received during office hours.

<table>
<thead>
<tr>
<th>Fall 2014</th>
<th>Online HW</th>
<th>Novel Questions</th>
<th>Vectors Quiz</th>
<th>Coordinate Transform</th>
<th>Angular Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average score</td>
<td>90%</td>
<td>57%</td>
<td>91%</td>
<td>88%</td>
<td>40%</td>
</tr>
<tr>
<td>Right on 1st try</td>
<td>32%</td>
<td>17%</td>
<td>11%</td>
<td>27%</td>
<td>14%</td>
</tr>
<tr>
<td>Score ≥ 100%</td>
<td>74%</td>
<td>53%</td>
<td>48%</td>
<td>70%</td>
<td>39%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spring 2015</th>
<th>Online HW</th>
<th>Novel Questions</th>
<th>Vectors Quiz</th>
<th>Coordinate Transform</th>
<th>Angular Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average score</td>
<td>91%</td>
<td>83%</td>
<td>90%</td>
<td>93%</td>
<td>50%</td>
</tr>
<tr>
<td>Right on 1st try</td>
<td>36%</td>
<td>38%</td>
<td>4%</td>
<td>26%</td>
<td>16%</td>
</tr>
<tr>
<td>Score ≥ 100%</td>
<td>80%</td>
<td>57%</td>
<td>57%</td>
<td>75%</td>
<td>48%</td>
</tr>
</tbody>
</table>

The Fall 2014 semester comparison between the novel questions and the vectors quiz is surprisingly similar in percent correct (53% and 48% respectively), but significantly different in average score (57% and 91%). This is most likely due to fact that the vectors quiz contained multiple questions and, thus, had ample opportunity for partial credit.
whereas most of the novel questions were mostly one-question answers with either right or wrong (no partial credit) submissions.

The Spring 2015 semester results for the novel question and the vectors quiz percent correct are again surprisingly similar (both 57%), although the average score for the novel question in comparison to the average score of the vectors quiz is 7% lower, most likely due to reasons stated above.

It is interesting that the angular acceleration problem, although it is out of the textbook, had a much lower percent correct and average score compared to the average of the novel questions for both the Fall 2014 and Spring 2015 semesters. One possible reason for this discrepancy could be that students thought the solution manual would suffice (on the surface the online problem looked nearly identical to the textbook version) and, therefore, did not prepare adequately for the angular acceleration problem (i.e. did not seek help from the instructor and/or teaching assistant). The angular acceleration problem was not covered in the flipped classroom, so this problem may be reflective of student performance on an unfamiliar problem. The angular acceleration problem scores from both semesters are comparable to the novel problem scores from the Fall 2014 semester.

3.5 Summary and Conclusion to Solution Manual Use

3.5.1 Student Learning Outcomes

The results from the surveys given over the Fall 2014 to Spring 2015 semesters to students show a consistent increasing trend in students’ awareness and use of solution
manuals. Student justification for using a solution manual was to check the steps involved in order to solve a problem rather than using it solely to check the numerical answer of the solution. The change in reasoning for using a solution manual (from checking steps to checking numerical answer) occurring over the span of these semesters was possibly due to student involvement in the class and the nature of the flipped classroom learning style compared to the lecture based learning style. The analysis of online questions given to students showed that there were similar amounts of students who answered the “Angular Acceleration” problem correctly in comparison to the novel questions of both the Fall 2014 and Spring 2015 semesters (Tables 31 and 32). This emphasizes that the tactics students used to solve an unfamiliar problem were similar with or without the context of a solution manual, demonstrating that in the Fall 2014 semester student use of a solution manual was detrimental toward learning the subject material through homework problems.

3.5.2 Future Research

The words used by students in the expression of how solution manuals were used revealed the amount of extrinsic motivation that students desire from most aspects of the class. The difference between comments from the Fall 2014 semester to the Spring 2015 semester were altered from concerns that involved the dissatisfaction in instruction as being the reason for using solution manuals to class participants analyzing their own use of a solution manual itself. In order to improve this study the word choice of the prompt questions should be changed to have the possibility of more objectivity in student answers. It is notable that the student subjectivity toward course satisfaction does show a
trend in the causal effects of a professor’s pedagogical skills and how those skills inform student behavior and contentment in personal goal outcomes for the class.
Chapter 4 Summary and Conclusions

4.1 Summary of Information on Inquiry-Based Learning Activities

The effectiveness of the IBLAs was analyzed in the Fall 2014 and Spring 2015 semesters in the undergraduate dynamics curricula through pre-activity, in-class activity, and post-activity surveys and questions. The knowledge revealed by this study showed the following about the IBLAs.

- Student response to IBLAs showed high intrinsic motivation for learning concepts.
- The IBLA with the highest reported motivation correlated with the highest exam scores.

The Spring 2015 weight-pulley IBLA showed an increase in student retention and cognition in all of the sections. There was improvement from the pre-test score of 16% correct on the DCI to the end of IBLA test of 34% (Tables 5 and 6), which is an indication of improved student schema of mass, force, and acceleration. The final exam score for sections 1, 2, and 3 with 75%, 49%, and 28% correct (Tables 8-10) showed that two of the three sections retained and improved their knowledge, and although section 3 did worse on the final exam question than on the in-class IBLA, there was an improvement from the students’ initial answer to the DCI question from 16% correct to final exam score of 28% correct.
The rolling-cylinder IBLA anecdotally showed a large increase in student motivation, schema understanding, and the highest rating in student opinion of how helpful the activity was toward learning the subject material. Spring 2015 course section 3 showed a large improvement in understanding with 95% of students answering the final exam question that corresponded to the rolling cylinder IBLA correctly (Table 14). Section 1 also showed improvement in a correlation between the rolling cylinder IBLA and the final exam question. The final exam question that corresponded to the rolling cylinder IBLA was most similar to Case 4; the individual scores were 19% correct in the IBLA and 39% correct on the final exam (Tables 12 and 14).

The spool-friction IBLA showed interest and motivation for students’ conceptual learning, but did not show definitive results in post-activity final exam scores (Table 16). One factor in this conclusion could have stemmed from the amount of study time needed in between the activity and the final. Another reason for this could have been the amount of peer discussion and feedback given to individual students during the in-class IBLA. The spool-friction IBLA is the only IBLA in which teacher intervention was given after each of the cases, this may imply that one of the most important steps in each activity is the amount of individual reflection and peer feedback involved in the learning process, with a greater amount of instructor feedback less time is given for students to work through the concept on their own.

Overall, the student-based learning environment and the low failure tolerance in the cognition-observation-interpretation design of the IBLAs has been shown to be effective
in teaching equation interpretation, effective in broadening student concept schema, and (indecisively) less effective in equation application for these undergraduate dynamics courses. Most of the student outcome surveys expressed a liking to the class, despite the difficulty in learning the material.

4.2 Summary of Information on Solution Manual Use

Solution manual use can both help and hinder student learning of subject materials. Using a manual for the immediate feedback of material can help a student if there is no other source of feedback to be found, but if there is not a proper amount of time given to the material for the student to reflect upon the questions assigned, then immediate feedback can be harmful to learning the subject material. The research done in this study showed:

- A high percent of students use a solution manual to complete homework.
- Students are unaware of the detriment to using a solution manual.
- The social/communal behavior of peers appears to be a factor in student solution manual use.
- Students seem to lose the practice of problem solving and contingency adduction through solution manual use.

In both the Fall 2014 and Spring 2015 semesters the amount of students using solution manuals as an aid in completing homework was in the majority with 35% and 24% (Table 23) of students using a solution manual on each weekly set of homework problems and the majority of students 32% and 34% (Table 24) using a solution manual to
complete each problem in the weekly homework set. The act of relying on solution manual feedback can be harmful depending on the type of learner the student is and the intrinsic or extrinsic motivations for their behavior. The high percentage of students using solution manuals to complete their homework characterizes extrinsic means of wanting a good grade in the class, which outweighs the intrinsic means of learning the material. Student use of a solution manual to complete homework also disrupts the feedback in the amount of competence implied to the instructor. There are two outcomes that result from this behavior 1) an instructor sees high homework scores and believes that students understand the material and 2) a student sees high homework scores and believes that they understand the material. But if the grades are superficial and led by the extrinsic desire for a good grade rather than learning, the feedback is incomplete in understanding the level competence of a student through the represented homework scores.

A comparison of the novel homework questions to the online homework questions scores showed that although the level of difficulty was similar, students’ average scores were 89% and 57% for the online homework and novel homework questions in the Fall 2014 semester (Table 29). Scores for the online homework and novel homework were 92% and 83% respectively in the Spring 2015 semester (Table 30). The difference in scores highlights the inability of students to answer the novel homework questions. This contrast in percentages from the Fall 2014 semester to the Spring 2015 semester could also be attributed to the flipped classroom learning approach in which some of the novel homework problems were discussed in class.
The student opinion of homework and the idea that the problem to be solved is trivial is one of the main reasons for student solution manual use (Lipson and McGavern 1993). It is in this fact that a student may be unaware of the artificial understanding that lies in copying solutions and the process of understanding and reasoning through the steps involved to solve a problem. In order to find out students’ reasoning behind this difference, survey questions were asked about the ways in which solution manuals were generally used and the amount of perceived difficulty of novel questions. Survey results have shown that the majority of students use solution manuals to check the numerical answer to the homework question and to check the steps involved in answering the question. Only 26% (Spring 2014), 12% (Fall 2014), and 11% (Spring 2015) reported using the solution manual due to insufficient knowledge of the material (Table 25).

In contrast to these practices of solution manual use percentages up to 74% (Fall 2014) and 61% (Spring 2015) believed the novel questions to be more difficult than the textbook questions (Table 28). The student belief that the novel questions were more difficult than the textbook problems reveals a reliance on solution manuals as an aid in completing homework. Student dependence on solution manuals was also exemplified in the Fall 2014 and Spring 2015 semester class’s inability to answer an original problem, like the “Angular Acceleration” homework problem.

4.3 Student Learning Outcomes

The classroom environment is directly correlated to the metacognitive processes of a student. The traditional lecture model of teaching includes note-taking and direct
instruction from a lecturer as the source of information, but a hands-on lecture includes student driven instruction with possibilities of peer instruction and experimental set-ups of class concepts. The IBLAs introduced a different learning environment in which students could explore the subject at hand with the direct feedback and direction of peers as well as from the instructor. One clear outcome of the IBLAs during the Fall 2014 and Spring 2015 semesters was the gain in students’ intrinsic motivation to learn the material that was included in each of the IBLAs. The cognition-observation-interpretation style of feedback for the IBLAs that were conducted from in-class surveys showed that students enjoyed the environmental style of learning in comparison to traditional lecture style learning (Table 17). The IBLAs themselves may not have been effective in altering a student’s performance on final exams, but the IBLAs have shown a broadened schema for students. Student improvement was exemplified in Tables 18 and 19 through the comparison of end of semester final exam DCI scores and the percent attendance of students to the in-class IBLAs. This gain in student cognition and intrinsic motivation is a major step towards students’ ability to work harder, persist longer, and perform better on tasks within the learning domain.

The immediate feedback of solution manuals can be a problem if the solution manual becomes a “crutch” for continued practice of working on homework. The novel questions implemented in the Fall 2014 and Spring 2015 semesters were designed to be a tool to help the instructor and the students gauge their solution manual use. It was the task of the student to find ways to solve these problems and to seek out help if they were unable to answer these assigned questions. Survey results from the said semesters showed a
majority of students believed the novel questions to be more difficult despite the fact that the novel questions were of the same level taken out of different books (Table 28).

This shows that students were not using the solution manual in the “correct” way. Most students reported that they received a copy of the solution manual from a friend or student that had already taken the class (Table 22). Which confirms a societal belief of justified solution manual use. In order to change the ways in which students perceive the use of a solution manual, the environment must be changed in which students view the severity of academic dishonesty in using a solution manual to complete homework problems through both instructors and student culture. The flipped classroom, which was introduced in the Spring 2015 semester, was one way in which the current instructor of ME 242 changed the classroom environment and the social behavior of students, but with little effect on student views toward solution manual use (Table 22).

4.4 Future work

The most influential part of the metacognitive analysis is the amount of gained and retained knowledge that a student has through the end of the semester and beyond. In order to enhance long term performance in a particular subject area more review is needed on behalf of the individual student. To develop learning and long-term retention in students, more motivation is needed for them to think about and work on similar problems or scenarios. Mastery motivation and feedback are the greatest tools needed to learn new topics.
One aspect of homework problems that could be studied more in depth is the affect of grading feedback. There are studies that have shown increased fluency in a subject area with the in-class implementation of self-feedback in which students grade their own work (Miller, Hall et al. 1995, Johnson and Layng 1996). A factor in which students may believe that there is a right way and a wrong way to use a solution manual could be from the output practice that the students are receiving. Without the proper feedback in learning the material, a student could intrinsically not know about the effects of using a solution manual until an exam is taken, which is a large amount of lag time on necessary feedback.

Honesty of the behavior of solution manual use also needs increased teacher to student input. Studies by Harding and Nuss have shown that there is a necessary feedback loop between the instructor and students to create a more well clearly defined system in which students are aware of academic dishonesty and the consequences thereof (Nuss 1984, Harding 2000, Harding, Carpente et al. 2001, Harding, Carpenter et al. 2003). These studies have also shown that the number one reason for student academic dishonesty was to prevent failure in the class. This rationale is a result of low student self-efficacy and high extrinsic expectations from the community (Nuss 1984, Harding 2000, Harding, Carpente et al. 2001, Harding, Carpenter et al. 2003). Student self-confidence and communal expectations are all lessened when there is a greater amount of intrinsic motivation to learn the subject material (Reeve 2008).
A future experiment could be conducted on the effects of changing the percent weight that homework and exams are worth. In ME 242 the homework score was the same as the midterms in weight, so if the homework scores were to have a lower or higher weight percentage of the final grade, a difference might show how intrinsically motivated students behave toward the subject in how they prioritize and work on their homework.

To test the effectiveness of the addition of an IBLA to the class curriculum, control studies could be implemented within separate class sections. Each section could be taught lessons containing one or more of the IBLAs and compared to another, which was taught the IBLA not included in the other section. The comparison would look at final exam scores between the sections. Any differences in exam scores to those of the Fall 2014 and Spring 2015 semesters or the course sections of the semester could help to show the effectiveness of these models toward student learning of the different concepts that are taught in the IBLAs.

Future IBLA cases could be more influential towards student learning if student practice of equations could be enhanced. The IBLAs can be made to be more effective by showing students a larger variety of scenarios and by giving students more practice problems based on the concepts of the IBLAs. The use of more examples helps students to gain a broader foundational knowledge of the new concepts and in supporting students’ future creative problem solving.
References


Case 1:

1. Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly? Before discussing the scenario with one another, make a prediction on the individual sheet and turn it in.

2. As a team, discuss the scenario. What do you predict about the accelerations of the masses if they are released from rest? Indicate the # of votes on your team of the four give possibilities below.

   _____ Mass A will accelerate downwards faster than mass B
   _____ Mass B will accelerate downwards faster than mass A
   _____ Mass A and B will accelerate downwards at the same rate
   _____ Neither Mass A or B will accelerate downwards

3. What did you observe when performing the experiment?

4. Please explain the results of your experiments using dynamics principles.
Case 2:

1. Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly? Before discussing the scenario with one another, make a prediction on the individual sheet and turn it in.

![Diagram of weights A and B with masses and pulleys]

2. As a team, discuss the scenario. What do you predict about the accelerations of the masses if they are released from rest? Indicate the # of votes on your team of the four given possibilities below.

- _____ Mass A will accelerate downwards faster than mass B
- _____ Mass B will accelerate downwards faster than mass A
- _____ Mass A and B will accelerate downwards at the same rate
- _____ Neither Mass A or B will accelerate downwards

3. What did you observe when performing the experiment?

4. Please explain the results of your experiments using dynamics principles.
Case 3

1. Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly? Before discussing the scenario with one another, make a prediction on the individual sheet and turn it in.

2. As a team, discuss the scenario. What do you predict about the accelerations of the masses if they are released from rest? Indicate the # of votes on your team of the four give possibilities below.

   _____ Mass A will accelerate downwards faster than mass B
   _____ Mass B will accelerate downwards faster than mass A
   _____ Mass A and B will accelerate downwards at the same rate
   _____ Neither Mass A or B will accelerate downwards

3. What did you observe when performing the experiment?

4. Please explain the results of your experiments using dynamics principles.
Case 4

1. Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly? Before discussing the scenario with one another, make a prediction on the individual sheet and turn it in.

2. As a team, discuss the scenario. What do you predict about the accelerations of the masses if they are released from rest? Indicate the # of votes on your team of the four give possibilities below.

   ______ Mass A will accelerate downwards faster than mass B
   ______ Mass B will accelerate downwards faster than mass A
   ______ Mass A and B will accelerate downwards at the same rate
   ______ Neither Mass A or B will accelerate downwards
Case 1

Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

_____ Mass A will accelerate faster than mass B
_____ Mass B will accelerate faster than mass A
_____ Mass A and B will accelerate at the same rate
_____ Neither Mass A or B will accelerate

How confident are you in your answer (circle one)?
Total Guess Low Low-Moderate Moderate Moderate-High High

Case 2

Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

_____ Mass A will accelerate faster than mass B
_____ Mass B will accelerate faster than mass A
_____ Mass A and B will accelerate at the same rate
_____ Neither Mass A or B will accelerate

How confident are you in your answer (circle one)?
Total Guess Low Low-Moderate Moderate Moderate-High High

Note: 1 oz = 1/16
Case 3

Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

- _____ Mass A will accelerate faster than mass B
- _____ Mass B will accelerate faster than mass A
- _____ Mass A and B will accelerate at the same rate
- _____ Neither Mass A or B will accelerate

How confident are you in your answer (circle one)?

Total Guess  Low  Low-Moderate  Moderate  Moderate-High  High

Case 4

Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

- _____ Mass A will accelerate faster than mass B
- _____ Mass B will accelerate faster than mass A
- _____ Mass A and B will accelerate at the same rate
- _____ Neither Mass A or B will accelerate
How confident are you in your answer (circle one)?

Total Guess  Low  Low-Moderate  Moderate  Moderate-High  High

Follow-up Questions:

Answer each of the following questions by marking an “X” on the line that corresponds with your level of agreement with the statements at each end of the line.

4. Do you think this activity was helpful for learning Dynamics?

Yes, very helpful  No, not helpful

5. How would you say this activity compares to lecture to explain and help you understand this concept?

The activity is most helpful  Lecture is most helpful

6. How would you say this activity compares to a homework problem to explain and help you understand this concept?

The activity is most helpful  A homework problem is most helpful

Weight and Pulley Activity

NAMES: ____________________________________________________________  Time:_______
Names: _____________________________  _____________________________
________________________  _____________________________

Rolling Objects Activity Team Worksheet

Setup
Create an incline with the ramp with a height of several inches using a book or steps. At the bottom of the ramp place a backpack or clothing to cushion the objects.

Experiment

For each exercise below, you will first make an individual prediction **before** you roll the cylinders/pipes. It is okay for your answers to be wrong, this is not graded! Then discuss with your team and write the number of votes for your predictions. Please do not change this sheet after you roll the objects. After recording your predictions, place the rolling objects close to the top of the ramp, side by side. Try to release the objects to create a ‘fair’ start. When the objects roll to the bottom of the ramp catch them or use a cushion to stop them so they are not damaged by bouncing on the ground. Run the following scenarios and respond to the prompts. Perform each exercise multiple times, with different objects on each side of the ramp. How much of a difference do think it takes for there to be a clear-cut winner as opposed to a tie (e.g., 1 inch? 5 inches?).

Big Metal Solid Cylinder
Big Plastic Pipe
Small Metal Solid Cylinder
Small Plastic Pipe
CASE 1: Big Solid Cylinder (A) vs Metal Pipe
Same Radius and Same Mass

2. Fill out your case 1 anonymous prediction sheet and then discuss the question as a group. Get the Big solid cylinder (marked A) and the Metal pipe (they have the same radius and mass but different shapes). Before rolling the objects, discuss with your team – which do you predict will reach the bottom first? After discussing, vote and indicate the number of votes for each possibility below.

Number of votes: Big solid cylinder ____  Metal pipe ____  Same time ____

3. Now roll the two, and state the results below. Explain the race result using principles of dynamics.

4. Which object has the larger mass moment of inertia, the Big solid cylinder or the Metal pipe (they have the same mass and radius)? Explain your answer.

Number of votes: Big solid cylinder ____  Metal pipe ____  Same Inertia__

And wait for the instructor before you begin the next case!
CASE 2: Small Solid Cylinder (B) vs Big Metal Cylinder (A)  
Different Radius and Different Mass

2. Fill out your case 2 anonymous prediction sheet and then discuss the question. Then get the Small solid cylinder (marked B) and the big solid cylinder (marked A) (they have both different radius and different mass). Discuss with your team – which do you predict will reach the bottom first? After discussing, vote and indicate the number of votes for each possibility below.

Number of votes: Small solid cylinder ____  Big solid cylinder ____  Same time ____

3. Roll the two, and state your results below. How does mass and diameter influence rolling behavior? Explain the race results.

4. Which has larger Total Kinetic Energy when it reaches the bottom, the Small solid cylinder (B) or the Big solid cylinder (A) (they have different mass and radius)? Explain your answer

Number of votes: Small solid cylinder (A)____  Big solid cylinder (B) ____  Same Energy____
CASE 3: Small Solid Cylinder (B) vs Metal Pipe
Different Shape, Mass, and Radius

2. Fill out your case 3 anonymous prediction sheet and then discuss the question. Get the **Small solid cylinder (marked B)** and the **Metal pipe** (they have different shape, mass and radius). Discuss with your team – which do you predict will reach the bottom first? After discussing, vote and **indicate the number of votes** for each possibility below.

Number of votes: Small solid cylinder (B) ____ Metal Pipe ____ Same time ____

3. Roll the two and state the results below. Explain the results.

4. Write the work-energy equation for any rolling object using position one at the top of the ramp and position two at the bottom. Express the mass moment of inertia as \( I_g = cmr^2 \) where \( c \) is a constant that depends on the shape (solid, hollow, thin-walled, etc.). Use rolling without slipping kinematics \( (v = \omega r) \) to eliminate \( \omega \) and solve for the velocity of the mass center at the bottom position.
CASE 4: Small Plastic pipe vs Big Plastic pipe vs Metal pipe
Different Mass and Radius

2. Fill out your case 4 anonymous prediction sheet and then discuss the question. Get all 3 pipes: the Small plastic pipe, the Big plastic pipe and the Metal pipe (they all have different mass and radius). Discuss with your team – which do you predict will reach the bottom first? After discussing, vote and indicate the number of votes for each possibility below.

Number of votes: small plastic pipe ___ big plastic pipe _____
metal pipe____

3. Roll the them and state the results below. Explain the results.

Put number of votes for each of the following questions
a. All solid cylinders regardless of radius and mass arrive at the bottom at the same time

True ___ False ___

b. All thin walled pipes regardless of radius and mass arrive at the bottom at the same time

True ___ False ___

c. Which will arrive first, a thick walled pipe or a thin walled pipe regardless of radius and mass?

Thick walled ____ Thin-walled ___
They will arrive at the same time ___

After finishing Case 4, fill out the anonymous post-activity survey.
CASE A. Take the big metal solid cylinder and the black metal pipe. (Same radius and mass). Which will get to the bottom first? Write a brief explanation of your answer on the back.

___ big metal solid cylinder     ___ black metal pipe
___ They will arrive at the same time

CASE B. Next, take the small metal solid cylinder and the big metal solid cylinder. (Different radius and mass, same shape). Which will get to the bottom first? Write a brief explanation of your answer on the back.

___ small metal solid cylinder     ___ big metal solid cylinder
___ They will arrive at the same time.

CASE C. Take the small metal solid cylinder and black metal pipe. (Different shape, mass, and radius). Which will get to the bottom first? Write a brief explanation of your answer on the back.

___ small metal solid cylinder     ___ black metal pipe
___ They will arrive at the same time

CASE D. Take the small PVC pipe and big PVC pipe and grey metal pipe. (Same shape, different radius and mass). Which do you predict will get to the bottom first, second, third place? Indicate with a “1”, “2” and “3”. If you think some will tie, give them the same number. Write a brief explanation of your answer on the back.

___ small PVC pipe     ___ big PVC pipe
___ grey metal pipe
Spool Activity Team Worksheet

CASE 1

1. Fill out your case 1 anonymous prediction sheet, turn it in, and then discuss the question as a group. Looking at the figure, if you pull on the string gently in the horizontal direction as shown, which way do you predict the spool will move? After discussing, vote and indicate the number of votes for each possibility below.

   Number of votes: Right _____  Left _____  Won’t Move _____

2. When pulling, which direction is the friction force? Indicate # of votes

   Number of votes: Right _____  Left _____  There is no friction force _____

3. What is the value of the friction force? Indicate # of votes

   Number of votes: \( f = \mu_k N \) _____  \( f = \mu_s N \) _____  \( f \leq \mu_s N \) _____

4. Now pull gently (baby soft!) on the string in the configuration shown. Which way does it move? Can you determine the direction of the friction force?

5. Now pull on the string a bit harder so that it isn’t rolling without slip. Which way do you think the friction force acts? It is probably in the same direction as above, but now it will be equal to what value?

6. Draw your FBD and IRD for the problem. From these diagrams, can you predict which way the disk will roll when gently pulled?

STOP

And wait for the instructor before you begin the next case!
CASE 2

1. Fill out your case 2 anonymous prediction sheet, turn it in, and then discuss the question. Looking at the figure, if you pull on the string gently in the vertical direction, which way do you predict the spool will move? After discussing, vote and indicate the number of votes for each possibility below.

   Number of votes: Right _____  Left _____  Won’t Move______

2. Which direction is the friction force? Indicate # of votes

   Number of votes: Right _____  Left _____  There is no friction force____

3. What is the value of the friction force? Indicate # of votes.

   Number of votes:  \( f = \mu_k N \)  \( f = \mu_s N \)  \( f \leq \mu_s N \)

4. Now Pull gently (baby soft!) on the string in the configuration shown. Which way does it move? Can you determine the direction of the friction force?

5. Draw the FBD and IRD for the problem. From these diagrams can you predict the direction it will roll?

6. Try varying the angle of your pull, and how hard you pull on the string. When is the friction force equal to \( \mu_k N \)? \( \mu_s N \)? Explain your answers.

   And wait for the instructor before you continue onto the next case!
CASE 3

1. Fill out your case 3 anonymous prediction sheet then discuss the question. Looking at the figure, if you pull on the string gently in the downward vertical direction, which way do you predict the spool will move? After discussing, vote and *indicate the number of votes* for each possibility below.

   Number of votes: Right _____ Left _____ Won’t Move_____

2. Which direction is the friction force? *Indicate # of votes*

   Number of votes: Right_____ Left _____There is no friction force_____

3. What is the value of the friction force? *Indicate # of votes*

   Number of votes: \( f = \mu_k N \) _____ \( f = \mu_s N \) _____ \( f \leq \mu_k N \) _____

4. Place two desks side by side and put the spool over the gap so that the string hangs down. Now pull gently on the downward. Which way does it go? Which way does the friction go?

5. Draw out your FBD and IRD for the problem. You can use this to predict which way it will roll.

   After finishing Case 3, fill out the anonymous prediction sheet for case 4 and then proceed to the other side.
CASE 4

1. Fill out your case 4 anonymous prediction sheet then discuss the question. Looking at the figure, the spool is now supported by an axle. If you pull on the string gently in the horizontal direction shown, which way do you predict the spool will move? After discussing, vote and *indicate the number of votes* for each possibility below.

Number of votes: Right _____ Left _____ Won’t Move_____

2. Which direction is the friction force? *Indicate # of votes*

Number of votes: Right _____ Left _____ There is no friction force_____

3. What is the value of the friction force? *Indicate # of votes*

Number of votes: $f = \mu_k N$ _____ $f = \mu_k N$ _____ $f \leq \mu_k N$ _____

4. Place the spool between two desks with the axle resting on each surface and spool extending into the gap. Now pull gently in the direction shown. Which way does it go? Which way does the friction go?

After finishing Case 4, fill out the anonymous post-activity survey.
Appendix A.3
ME242 Spool and Friction Inquiry-Based Learning Activity Worksheet

Case 1
1. Looking at the figure, if you pull on the string gently in the direction shown, which way do you predict the spool will move?
   Right _____ Left _____ Won't Move _____
2. When pulling, which direction is the friction force?
   Right _____ Left _____ There is no friction force _____
3. What is the value of the friction force?
   \[ f = \mu_s N \] \[ f = \mu_k N \] \[ f \leq \mu_s N \]
4. How confident are you in your answers (circle one)?
   Total Guess Low Low-Moderate Moderate Moderate-High High

Discuss your answers with your team before continuing onto the next case!

Case 2
1. Looking at the figure, if you pull on the string gently in the vertical direction, which way do you predict the spool will move?
   Right _____ Left _____ Won't Move _____
2. When pulling, which direction is the friction force?
   Right _____ Left _____ There is no friction force _____
3. What is the value of the friction force?
   \[ f = \mu_s N \] \[ f = \mu_k N \] \[ f \leq \mu_s N \]
4. How confident are you in your answers (circle one)?
   Total Guess Low Low-Moderate Moderate Moderate-High High

Discuss your answers with your team before continuing onto the next case!
Appendix A.3
ME242 Spool and Friction Inquiry-Based Learning Activity Worksheet

Case 3
1. Looking at the figure, if you pull on the string gently downward, which way do you predict
   the spool will move?
   
   Right _____ Left _____ Won’t Move _____

2. When pulling, which direction is the friction force?

   Right _____ Left _____ There is no friction force _____

3. What is the value of the friction force?

   \[ f = \mu_k N \quad f = \mu_s N \quad f \leq \mu_s N \]

4. How confident are you in your answers (circle one)?

   Total Guess       Low       Low-Moderate       Moderate       Moderate-High       High

Discuss your answers with your team before continuing onto the next case!

Case 4
1. Looking at the figure, the spool is now supported by an axle. If you pull on the string gently
   in the direction shown, which way do you predict the spool will move?

   Right _____ Left _____ Won’t Move _____

2. When pulling, which direction is the friction force?

   Right _____ Left _____ There is no friction force _____

3. What is the value of the friction force?

   \[ f = \mu_k N \quad f = \mu_s N \quad f \leq \mu_s N \]

4. How confident are you in your answers (circle one).

   Total Guess       Low       Low-Moderate       Moderate       Moderate-High       High
Spool Post Activity Survey

Circle your response to each of the following questions.

1. This activity helped me learn about dynamics.

   | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree |

2. This activity was interesting and motivating.

   | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree |

3. This activity was _____ compared to a lecture in terms of helping my learning.

   | Much less helpful | Less helpful | About the same | More helpful | Much more helpful |

4. This activity was _____ compared to doing similar homework problems in terms of helping my learning.

   | Much less helpful | Less helpful | About the same | More helpful | Much more helpful |

5. When did the concepts presented in this activity finally make sense to you? (e.g., you already understood them before coming to class, during or after a specific case, or it still doesn't make sense to you...?)

   | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree |

6. If you have any comments as to how to improve this activity, please write them below.
Appendix A.4
Final Exam Questions Related to in-class IBLAs

Problem #1 (5 points):
Both systems shown have massless and frictionless pulleys. On the left, an 8-oz weight and a 10-oz weight are connected by an inextensible rope. On the right, a 4-oz weight and a 6-oz weight are connected by an inextensible rope. Which of the following statements is true immediately after unlocking the pulleys?

A) In both cases, the acceleration of the blocks A and B will be equal to zero.
B) The block B will have the larger upward acceleration than block A.
C) The block A will have the larger upward acceleration than block B.
D) The tension in the rope on the left system is 8-oz.
E) Blocks A and B will have the same upward acceleration.

Figure 1. Spring 2015 final exam section 1 question 1.

Problem #2 (5 points):
For the rear wheel drive car, consider a situation in which the car starts from rest and accelerates to the left. The tires do not slip on the road. Assume the normal force on the rear tires is $N_{rear}$ and the coefficients of static and kinetic friction at $\mu_s$ and $\mu_k$, respectively. The friction force, $F_{rear}$, on the rear tires is given by what expression and what is the direction?

A) $F_{rear} \leq \mu_s N_{rear}$ to the right
B) $F_{rear} \leq \mu_k N_{rear}$ to the left
C) $F_{rear} = \mu_k N_{rear}$ to the right
D) $F_{rear} = \mu_k N_{rear}$ to the left
E) Not enough information is given.

Figure 2. Spring 2015 final exam section 1 question 2.
Appendix A.4
Final Exam Questions Related to in-class IBLAs

Problem #6
(15 points) There are four objects shown below: (A) a thin-walled aluminum cylinder, (B) a thick-walled aluminum cylinder, (C) a solid aluminum cylinder, and (D) a solid steel cylinder. Each object is to be released from rest at the top of the ramp shown. If all the objects are released at the top of the ramp simultaneously, list the order, from fastest to slowest, the objects will reach the bottom of the ramp given that \( h = 0.13 \text{ m} \) and \( \theta = 15 \) degrees (if two or more objects reach the bottom at the same time, indicate “tie”). Some common mass moments of inertia are shown on the last page.

\[
\begin{align*}
    m_A &= 2 \text{ kg} & m_B &= 2 \text{ kg} & m_C &= 6 \text{ kg} & m_D &= 10 \text{ kg} \\
    r_A &= 0.1 \text{ m} & r_B &= 0.05 \text{ m} & r_C &= 0.13 \text{ m} & r_D &= 0.13 \text{ m} \\
    r_i &= 0.15 \text{ m} \\
\end{align*}
\]

(A) (B) (C) (D)

Figure 3. Spring 2015 final exam section 1 question 6.

Problem #9
(15 points) A 50-lb spool with outer radius of 15 inches, inner radius of 9 inches, and moment of inertia of 0.8 slug-ft\(^2\) is initially at rest. If a 10-lb force, \( P \), is applied at the inner radius of the spool as shown, determine the acceleration of the center of mass, \( G \). The coefficients of static and kinetic friction between the cylinder and the ground at point \( A \) are \( \mu_s = 0.3 \) and \( \mu_k = 0.25 \) respectively. Be sure to draw the FBD and IRD (hint: you need to know if it is rolling without slipping or if it rolling with slipping).

Figure 4. Spring 2015 final exam section 1 question 9.
Problem #2 (5 points):
The two objects in the figure below are released from rest at the position shown and roll without slipping down identical hills. Both objects have the same mass $m$ and same outer radius. Object A is thin hoop whose mass is concentrated in its edge. Object B is a uniform solid cylinder. Neglecting air resistance, how do the speeds of the two objects compare when they reach the bottom of their respective hills?

A) $A$ and $B$ will have the same speed.
B) The speed of $A$ will be greater than that of $B$.
C) The speed of $B$ will be greater than that of $A$.
D) Knowledge of the friction forces is required to answer the question.
E) Knowledge of the shape of the cross-section of the thin hoop is required to answer the question.

Figure 5. Spring 2015 final exam section 2 question 2.

Problem #3 (5 points):
Both pulleys shown are massless and frictionless. The horizontal surface is also frictionless. The pulley on the LEFT has a 10 lb weight on the left and a 20 lb weight hanging from the right. The pulley shown on the RIGHT has a 10 lb weight on the left and a constant 20 lb force (oriented vertically down) on the right. Both pulleys are released from rest from the positions shown. Which of the following statements is true immediately after the pulleys are released?

F) The 10 lb blocks both have the same acceleration to the right.
G) The 10 lb blocks both have the same acceleration to the left.
H) The 10 lb block on the LEFT has a larger acceleration.
I) The 10 lb block on the RIGHT has a larger acceleration.
J) Neither 10 lb block has any acceleration.

Figure 6. Spring 2015 final exam section 2 question 3.
Problem #1 (5 points):
Both systems shown have massless and frictionless pulleys. On the left, a 10N weight and a 50N weight are connected by an inextensible rope. On the right, a constant 50N force pulls on the rope. Which of the following statements is true immediately after unlocking the pulleys?

A) In both cases, the acceleration of the 10N blocks will be equal to zero.
B) The 10N block on the left will have the larger upward acceleration.
C) The 10N block on the right will have the larger upward acceleration.
D) The tension in the rope on the left system is 40 N.
E) In both cases, the 10N block will have the same upward acceleration.

Figure 7. Spring 2015 final exam section 3 question 1

Problem #2 (5 points):
For the rear wheel drive car, consider a situation in which the car starts from rest and accelerates to the left. The tires do not slip on the road. Assume the normal force on the rear tires is $N_{rear}$ and the coefficients of static and kinetic friction at $\mu_s$ and $\mu_k$, respectively. The friction force, $F_{rear}$, on the rear tires is given by what expression and what is the direction?

A) $F_{rear} = \mu_s N_{rear}$ to the right
B) $F_{rear} = \mu_k N_{rear}$ to the left
C) $F_{rear} \leq \mu_s N_{rear}$ to the right
D) $F_{rear} \leq \mu_k N_{rear}$ to the left
E) Not enough information is given.

Figure 8. Spring 2015 final exam section 3 question 2.
**Problem #3 (5 points):**
The two objects in the figure below are released from rest at the position shown and roll without slipping down identical hills. Both objects have the same mass $m$ and same outer radius. Object $A$ is thin hoop whose mass is concentrated in its edge. Object $B$ is a uniform solid cylinder. Neglecting air resistance, how do the speeds of the two objects compare when they reach the bottom of their respective hills?

![Figure 9. Spring 2015 final exam section 3 question 3.]

A) $A$ and $B$ will have the same speed.

B) The speed of $A$ will be greater than that of $B$.

C) The speed of $B$ will be greater than that of $A$.

D) Knowledge of the friction forces is required to answer the question.

E) Knowledge of the shape of the cross-section of the thin hoop is required to answer the question.

**Problem #9**
*(15 points)* A 65-lb uniform solid cylinder with radius of 1.5 inches is shown below. If a 35 ft-lb pure torque, $T$, is applied to the cylinder, determine the acceleration of the center of mass, $G$. The coefficients of static and kinetic friction between the cylinder and the ground at point $A$ are $\mu_s = 0.35$ and $\mu_k = 0.20$ respectively. Be sure to draw the FBD and IRD (hint: you need to know if it is rolling without slipping or if it rolling with slipping).

![Figure 10. Spring 2015 section 3 question 9]
Appendix A.4
Final Exam Questions Related to in-class IBLAs

Problem #4 (5 points):
The two objects in the figure below are released from rest at the position shown and roll without slipping down identical hills. Both objects have the same mass $m$ and same outer radius. Object $A$ is thin hoop whose mass is concentrated in its edge. Object $B$ is a uniform solid cylinder. Neglecting air resistance, how do the speeds of the two objects compare when they reach the bottom of their respective hills?

![Diagram of two objects, one as a thin hoop and the other as a solid cylinder.]

A) $A$ and $B$ will have the same speed.
B) The speed of $A$ will be greater than that of $B$.
C) The speed of $B$ will be greater than that of $A$.
D) Knowledge of the friction forces is required to answer the question.
E) Knowledge of the shape of the cross-section of the thin hoop is required to answer the question.

Figure 11. Fall 2014 final exam question 4.
Thank you for agreeing to participate in the ME242 survey. We are attempting to improve ME242 for the Fall 2014 and would like your feedback regarding online content posted on WebCampus. All participants that complete the survey will be entered into a random drawing for a $25 iTunes gift-card. All answers are anonymous and do not impact your ME242 grade in any way.

Please indicate your level of agreement with the following statements regarding the prerequisites for ME242:

Physics I (PHYS 180) prepared me for this class.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

Statics (ME/CE 241) prepared me for this class.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

Calculus III (Math 283) prepared me for this class.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

Please provide any comments about how well the prerequisites prepared you for ME242:

_________________________________________________________________________

Please indicate your level of agreement with the following statements regarding online videos on WebCampus:

How many ME242 online videos that were posted on WebCampus did you watch?

<table>
<thead>
<tr>
<th>None</th>
<th>1-2</th>
<th>3-4</th>
<th>4-5</th>
<th>5-6</th>
<th>6+</th>
</tr>
</thead>
</table>

In general, what did you think of the pacing of the online videos you watched?

<table>
<thead>
<tr>
<th>Too fast</th>
<th>Fast</th>
<th>Neutral</th>
<th>Slow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too slow</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix B.1
ME242 Spring 2014 Survey End of Semester Survey

Did you ever watch a video more than once?

Yes   No   N/A

I would like more practice problems worked out in online videos

Strongly agree  Agree  Neutral  Disagree  Strongly disagree

I would like online video lectures that cover basic ME242 concepts

Strongly agree  Agree  Neutral  Disagree  Strongly disagree

I would like to see online video experiments that demonstrate basic ME242 concepts

Strongly agree  Agree  Neutral  Disagree  Strongly disagree

I would like to see online videos that discuss vocabulary terms

Strongly agree  Agree  Neutral  Disagree  Strongly disagree

I would rather have a ME242 YouTube channel instead of accessing the videos via WebCampus.

Strongly agree  Agree  Neutral  Disagree  Strongly disagree

Please indicate your level of agreement with the following statements regarding online videos replacing or supplementing in-class lectures:

It would be nice to have all the in-class lectures recorded and posted for viewing online.

Strongly agree  Agree  Neutral  Disagree  Strongly disagree

I prefer to watch an online video lecture rather than attending an in-class lecture.

Strongly agree  Agree  Neutral  Disagree  Strongly disagree
I prefer an online video that supplements rather than replaces an in-class lecture?

Strongly agree    Agree    Neutral    Disagree    Strongly disagree

I prefer to watch an online video of an example problem rather than attending a lecture where the example problem is completed.

Strongly agree    Agree    Neutral    Disagree    Strongly disagree

I prefer to an online video that supplements rather than replaces an example problem that is completed in-class.

Strongly agree    Agree    Neutral    Disagree    Strongly disagree

Please indicate your level of agreement with the following statements regarding online videos replacing or supplementing the textbook:

I prefer to watch an online video of an example problem rather than reading the example problem in the textbook.

Strongly agree    Agree    Neutral    Disagree    Strongly disagree

I prefer to an online video that supplements rather than replaces the example problem in the textbook.

Strongly agree    Agree    Neutral    Disagree    Strongly disagree

I prefer to watch an online video that explains a new concept rather than reading the textbook.

Strongly agree    Agree    Neutral    Disagree    Strongly disagree

I prefer to an online video that supplements rather than replaces the textbook’s description of a new concept

Strongly agree    Agree    Neutral    Disagree    Strongly disagree
Thank you for agreeing to participate in the ME242 survey. We are attempting to improve ME242 for the Spring 2015 and would like your feedback regarding in-class activities and homework problem solving techniques. All answers are anonymous and do not impact your ME242 grade in any way.

Are you aware of the solution manual for the book *Dynamics Analysis and Design of Systems in Motion*, by Benson H. Tongue

- yes
- no

Do you have a solutions manual for *Dynamics Analysis and Design of Systems in Motion*, by Benson H. Tongue?

- Yes, I bought it
- Yes, I got them from a former student
- Yes, I have an illegal copy
- No

With regards to question 2, is there another way that you were notified or found the solutions to class materials?

How are you using the solutions? Please check all that apply.

- I use the solutions to check my work.
- I use the solutions to save time.
- I use the solutions to look at the steps involved to solve the problem.
- I use the solutions to copy the steps of the problem.
- I use the solutions because I do not the material well enough to complete the homework on my own.

How often did you use the solutions to complete homework?

- 1-3 homework sets
- 4-6 homework sets
- 7-9 homework sets
- every homework set

On a particular homework set, how often did you use the solutions?

- At least 1 problem in the homework set.
- 2 problems in the homework set.
- 3 problems in the homework set.
- Each problem in the homework set.

Please rank how useful you found the solutions manual to be from 1 to 10. With 10 being the most useful.

1(very useful) 2 3 4 5 6 7 8 9 10(not useful)

Would you recommend using the solutions manual to a friend?

- Yes
- No

Please elaborate your answer to question 8.
Thank you for agreeing to participate in the ME242 survey. We are attempting to improve ME242 for the Spring 2015 and would like your feedback regarding in-class activities and homework problem solving techniques. All answers are anonymous and do not impact your ME242 grade in any way.

1) Are you aware that a solutions manual exists for the book *Dynamics Analysis and Design of Systems in Motion*, by Benson H. Tongue?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

2) Do you have a solutions manual for *Dynamics Analysis and Design of Systems in Motion*, by Benson H. Tongue?

<table>
<thead>
<tr>
<th>Yes, I bought it</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, I got it from a former student</td>
</tr>
<tr>
<td>Yes, I have an illegal copy</td>
</tr>
<tr>
<td>No</td>
</tr>
</tbody>
</table>

3) With regards to question 2, is there another way that you were notified or found the solutions to class materials?

4) How are you using the solutions? Please select all that apply.

| I use the solutions to check my work. |
| I use the solutions to save time. |
| I use the solutions to look at the steps involved to solve the problem. |
| I use the solutions because I do not know the material well enough to complete the homework on my own. |

5) On a typical homework set, how often did you use the solutions?

| I don’t use a solutions manual |
| 1-3 homework sets |
| 4-6 homework sets |
| 7-9 homework sets |
| Each homework set |

6) On a particular homework set, how often did you use the solutions?

| I don’t use a solutions manual |
| 1 problem in the homework set. |
| 2 problems in the homework set. |
| 3 problems in the homework set. |
| Each problem in the homework set. |
7) Please rank how useful you found the solutions manual to be from 1 to 10. With 10 being the most useful.

| 1 (not useful) | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 (very useful) |

8) Would you recommend using the solutions manual to a friend?

Yes  
No

9) Please elaborate your answer to question 8. (Please write on the back if the space provided is not enough.)

10) While completing the Weekly Quiz problems did you use a solution manual as an aid?

Yes  
No

11) How would you compare the difficulty of the Weekly Quiz problems to the homework problems?

Quizzes are much easier  
Quizzes are much harder

12) For the Weekly Quiz problems, how often did you attempt a problem before you used an outside source (e.g., tutoring center, Wikipedia, or Chegg)?

1 attempt  
2 attempts  
3 attempts  
4 attempts  
5 attempts

13) You were allowed 5 attempts to answer the Weekly Quiz questions. Under what circumstances did you not use all 5 attempts? (Why did you choose to use fewer of the attempts?)

14) What were your problem solving techniques in answering the Weekly Quiz problems? (i.e., looking for clues in your notes, going to office hours, or looking on the internet, etc.)

15) How many hours do you spend on the homework problems weekly?

1 hour  
2 hours  
3 hours  
4 hours

16) How often did you go to office hours (professor’s or TA’s)?

Once a month  
Bimonthly  
Once a week  
Never
17) How often did you attend SI sessions?

- Once a month
- Bimonthly
- Once a week
- Every session
- Never

18) How often did you go to the tutoring center?

- Once a month
- Bimonthly
- Once a week
- Every few days
- Never

19) On a scale from 1 to 10 (10 being the most helpful, 1 being not helpful), please rank each type of video:

- Concept video
- Example problem video
- Lecture video
- MATLAB video

20) Please comment on the Webcampus videos based on their usefulness: (Please write on the back if the space provided is not enough.)

21) Which subjects do you think should have been emphasized more in this course? (ie. Which topics do you think were covered too quickly or too slowly?)

22) On a scale from 1 to 10 (1 being “I don’t remember it”, 10 being very helpful), please rank each type of activity:

- Webcampus Leader Board
- FBD-IRD
- Coordinate Transformations
- Week 3 slow motion video (hockey puck velocity)
- Pulley Experiment
- Ping Pong Experiment
- Determining Dr. Wang’s mass
- Week 8 slow motion video (cart - falling mass)
- Moment and Products of Inertia
- Rolling Cylinder Experiment
Appendix B.4  
ME242 Spring 2015 End of Semester In-Class Survey

Thank you for agreeing to participate in the ME 242 survey. We are attempting to improve ME 242 for Fall 2015 and would like your feedback regarding course content. All answers are anonymous and do not impact your ME 242 grade in any way.

Please indicate your level of agreement with the following statements regarding the prerequisites for ME 242:
1. Physics I (PHYS 180) prepared me for this class.
   - Strongly agree
   - Agree
   - Neutral
   - Disagree
   - Strongly Disagree

2. Statistics (ME/CEE 241) prepared me for this class.
   - Strongly agree
   - Agree
   - Neutral
   - Disagree
   - Strongly Disagree

3. Calculus III (MATH 283) prepared me for this class.
   - Strongly agree
   - Agree
   - Neutral
   - Disagree
   - Strongly Disagree

Please answer the following questions about the ME 242 Weekly Problems:
4. How would you compare the difficulty of the Weekly Problems to book problems in this course?
   - Easier
   - Harder
   - About the same

5. In problem solving, what techniques did you use for answering Weekly Problems? (ie. Watched a video or asked a friend or read the book.)

6. Are you aware that a solutions manual exists for the book *Dynamics Analysis and Design of Systems in Motion*, by Benson H. Tongue?
   - Yes
   - No

7. Do you have a solutions manual for *Dynamics Analysis and Design of Systems in Motion*, by Benson H. Tongue?
   - Yes, I bought it.
   - Yes, I got it from a former student.
   - Yes, I have an illegal copy.
   - No
8. With regards to the previous question, is there another way that you were notified or found the solutions to class materials?

9. How were you using the solutions manual? Please select all that apply.
   - [ ] To check my work
   - [ ] To look at the steps involved to solve the problem
   - [ ] To save time
   - [ ] I did not know the material well enough to complete the homework
   - [ ] Other

____________________________________________________________________

10. Throughout the semester, on how many homework sets did you use a solutions manual?
   - [ ] I did not use a solution manual
   - [ ] 1-3 homework sets
   - [ ] 4-6 homework sets
   - [ ] 7-9 homework sets
   - [ ] Each homework set

11. On a particular homework set, on how many questions did you use a solutions manual?
   - [ ] I did not use a solution manual
   - [ ] 1 problem in the hw set
   - [ ] 2 problems in the hw set
   - [ ] 3 problems in the hw set
   - [ ] Each problem in the hw set

12. Please rank how useful you found the solutions manual to be from 1 to 10. With 10 being the most useful and 1 being the least useful.

```
1 (not useful)  2  3  4  5  6
   7  8  9 10 (very useful)
```

13. Would you recommend using the solutions manual to a friend? Please elaborate on your answer to this question. [ ] Yes  [ ] No

Please rank the following questions about the ME 242 in-class activities from 1 to 10 in terms of how useful they were for learning dynamics:
14. Mass Pulley Activity:

1 (I don’t remember)  2  3  4  5
   6  7  8  9  10 (very helpful)

15. Golf Ball and Ping-Pong Ball activity:

1 (I don’t remember)  2  3  4  5
   6  7  8  9  10 (very helpful)

16. Finding Dr. Wang’s Mass:

1 (I don’t remember)  2  3  4  5
   6  7  8  9  10 (very helpful)

17. Spool and Moment activity:

1 (I don’t remember)  2  3  4  5
   6  7  8  9  10 (very helpful)

18. Rolling Cylinder activity:

1 (I don’t remember)  2  3  4  5
   6  7  8  9  10 (very helpful)

Please answer the following questions about the ME 242 course:

19. How often did you attend ME 242 classes this semester?

20. Would you recommend this class to a friend? □ Yes □ No

21. Do you have any suggestions on improving this course?
Fall 2014 Syllabus outline of grades
Assignments 30%
Clickers 5%
Quizzes 10%
Midterm Exams 25%
Final Exam 30%

Spring 2015 Syllabus outline of grades
Online HW 30%
Clickers 5%
Paper HW 10%
Midterm Exams 30%
Final Exam 25%