Utilization of ADAMS Software in Project-Based-Learning to Stimulate Student Engagement in Basic Undergraduate Mechanical Engineering Courses.

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Abstract: The purpose of this paper is to report progress made in adapting Automatic Dynamic Analysis of Mechanical Systems (ADAMS) in project based learning (PBL) and assessment methods in basic undergraduate mechanical engineering courses. Specifically, the method has been implemented in a sophomore level, engineering course, called Dynamics for Mechanical Engineers (ME 335) at a moderate sized research university in the Midwest U.S. ME students take this course in their sophomore year. In spring 2017, students in this course have been given a couple of introductory lectures on modeling and simulation techniques using ADAMS software. This software is used in many industries for multi-body dynamics, crash and safety and other simulations and is freely available for students. ADAMS based semester long projects were designed to accommodate ME 335 course contents and that outside of the students' major(s) to involve real product operation cycles and to promote undergraduate research in engineering (URE) and self-directed learning readiness (SDLR). A dynamic rubric is also designed to empower learners to be responsible for various decisions associated with the project, to involve different activities such as self-guided reading and to promote group discussion and participation. The project's significance and importance lie in its emphasis on addressing both the motivational aspects to perform systematic research and to reduce conceptual learning barriers for students in early mechanical design courses. These courses demand a good understanding of mechanics and advanced mathematics, which make it difficult for many students to capture concepts. At the end of the semester, a survey was conducted through Qualtrics to assess students' perception towards the PBL instructional method and the assessment method in developing SDLR. Students have shown a strong interest in the PBL and ADAMS modeling and simulation approach to engage in the course and to develop curiosity towards research.

Introduction

In most institutions, research and development in undergraduate STEM programs are left aside or overlooked. However, to translate theory into practice, programs must be projected to promote research and innovation. Capstone design project offered in the final year of graduation is too late for the students to learn the state of the art of research and to solve community based and practical problems. The learning curve and the quality of work could have been improved highly, if this engagement and exposition to research started early in their first and sophomore years (Dym, Agogino et al. 2005, Savage, Chen et al. 2007). The involvement of undergraduate students in innovative projects and research as part of their curriculum, will greatly benefit the students as well as the society. As the new generation students are well familiar with social networking, internet browsing and gamming, new instruction and engagement methods are required to utilize their experience for good (O'Keeffe and Clarke-Pearson 2011). Moreover, to capture students' interest and to maximize learning, projects need to use a compelling and feeling element that involves authentic problems. Research has shown that Computer Modeling and Simulation is a powerful tool for furthering scientific knowledge as it provides a great connection between the observed phenomena and underlying causal processes (Feurzeig and Roberts 2012). Thus, for mechanical engineering students, modeling and simulation training for instance, using ADAMS will provide students the confidence and readiness to engage in internships early in their plan of study and add value to the product development cycle. As it provides them the ability to see the real world implementation of mathematics and dynamics equations with a visual modeling and simulation results.

Traditionally, to develop and verify the performance of a complex mechanical components/system, people go through multiple build-and-test hardware prototype cycles which are time-consuming and expensive process. On the other hand, ever-changing consumer demand and highly competitive marketplace, are forcing companies to be innovative, while keeping the costs down. This drives companies to rely on modeling and simulation to reduce product development cycles, and to perform the plentiful tests required to ensure the required performance of the products (Jandaurek and Johst 2017). For instance, Airbus used ADAMS simulation to save €3 Million by replacing the physical testing in the Aircraft Certification (Michael Vetter 2017), Armor Company increases machine productivity by 20% with ADAMS software simulations (Hubert 2016). ADAMS is also widely used in the automotive industry to simulate mechanical and control systems; recently, ADAMS simulation is used to design a new control strategy that reduces truck stopping distance (Kim, Kim et al. 2003, Kim, Hwang et al. 2008). Thus, equipping the next generation engineers with required modeling and simulation training will inspire them to engage in real, industrial related problems and to develop entrepreneurial mindset, while actively engaged in their study.

A recent study indicates that the traditional lecture and test-based teaching and evaluation methods result in 55% failure rate with regards to student success. On the other hand, active learning leads to increase in examination performance of students by an average grade of half a letter (Freeman, Eddy et al. 2014). Higher enrollment may impact the faculty to student ratio, and with the traditional lecturing method, students may not receive a chance to frequently interact with their faculty and build upon or challenge their ideas. This affects the active participation of learners, quality of education and interest in the program and enrollment. These problems could be resolved with new monitoring and assistive strategies that empower a large number of students to develop skills that enable them to captivate and internalize new information, apply it to a range of different situations and help to gage the quality of their work. Overall, students need to be trained to develop self-directed learning (SDL), research interest, analytical and critical thinking skills while they are in school. Several studies have shown that SDL helps individuals to have a higher quality of life, as self-learning efforts help in crossing many hurdles (Candy 1991, Towle and Cottrell 1996, Brookfield 2009). Similarly, adopting of research activities into classroom engagements by proper documentation and coordination are some of the key steps to train and equip students with the needed skills to resolve challenging problems.

In this paper, an implementation of project based learning through the utilization of modeling and simulation software, ADAMS and research based assessment methods were implemented in ME 335 course. A similar, but design oriented rubric has been utilized by the author in other Mechanical Engineering Design courses. And students have shown a greater interest towards the rubric and classroom engagement activities (Yihun, Nair et al. 2016). Successful implementation of such instructional and assessment methods may provide a possible route for students to develop curiosity towards research and SDLR, to create an opportunity for collaboration/connection among students, to engage students in real, industrial related problems with the required modeling and simulation skills.

Implementation

In order to implement the project based learning approach in the ME 335 course and to promote SDLR, three basic general tasks have been performed:

i. Course project preparation:
ii. Preparing guidance and assessment methods:
iii. Effective team formation mechanisms and student engagement methods:

Course Project Preparation: *ME 335* is designed to increase the depth of understanding of Newtonian mechanics to predict the effects of force, motion and their interaction in the design and operational cycles of machines and mechanical components. Therefore, the projects were designed based on this course objective as well as contents outside of the course to encourage SDLR. Specifically, in spring 2017, students were tasked to do the kinematic and dynamic analysis of four bar mechanism to observe the response variation due to clearance at a joint and link flexibility and compare the analytical solution with the simulation result in ADAMS software. Whereas, the specific application of the mechanism were left open for the student to research and choose.

Preparing Guidance and Assessment Methods: The semester-long projects are assigned to the students in the second week of the semester. The projects have had three deliverables. A separate rubric was designed for each deliverable to guide students and to specify the expected tasks.
Rubric I: a month was given to review the most recent and related articles and conference papers regarding the given project, and discuss their findings and come-up with a five page report. It was observed that the majority of students were not familiar with standard procedures and rules that should be considered in writing a technical draft. The applicability of these steps along with students' curiosity led to an appropriate understanding of the guidelines needed in writing a technical manuscript. While they are doing this task, an introduction to Modeling and Simulation lecture was given along with a simplified teaching manual for ADAMS software and small projects for practice. This stage has been evaluated through the rubric shown in Figure 1.

Dynamics for Mechanical Engineers (ME 335)
Spring-2017
Mechanical Engineering Department
Project Grading Rubric -Part I

Group #: ______________________ Date: __________

Format	Totally complete	Mostly complete	Partially complete	Mostly incomplete *	Points
• Cover page (Follow the given format) • Follow font size and spacing and other given format related guidelines • Show sections clearly, follow roper citation	5	4	2	1	
Introduction & Background: Answer clearly what the core of your project is, what you plan to do, why people should care about it? Tell about the specific application of your analysis	10	9	7	4	
Literature Review • Enough, RELEVANT articles reviewed in the area (at least 20) • Does the review answer the following Questions? ✓ Has this work already been done? ✓ Does your review convinces the need for this project? ✓ Is there a compelling reason to do it now? ✓ Demonstrating that there is a hole in this research that your project will fill.	30	25	20	10	
Gantt chart • Show tasks clearly and the expected due date (start and finish dates) • Show task assignments to the group members with their initials, • Use excel or ProjectLibre to prepare the Gantt chart • Indicate tentative group meeting dates • The chart should show the whole project flow From part1 to part3	5	4	3	2	
					Total=

Note: The cover page format and the guideline for the report will be available on blackboard.
* For mostly incomplete parts, a lower point may be given regardless of the above table. Your Gantt chart should fit within the given due dates of the project

Figure 1: Project Rubric- Part I

Rubric II: a month was given for students to practice brainstorming and come-up with their own solution to fill the gap, which was identified in the first part of the project. Also perform preliminary analysis using the textbook. The classroom engagement activities were used to strengthen group collaborations and sharing information. This stage has been evaluated through the rubric shown in Figure 2.

Dynamics for Mechanical Engineers (ME 335)
Spring-2017
Wichita State University
Mechanical Engineering Department

Project-Part 2- Grading Rubric

Project Title: ______________________

Group #: ______________ Date: __________

Format	Totally complete	Mostly complete	Partially complete	Mostly incomplete *	Points
• Cover page (Follow the given format) • Follow font size and spacing and other format guidelines given, show each heading and sections clearly • Proper citation, follow the IEEE citation rule	5	4	2	1	
Select Specific application for your project • Put the figure of the selected application and discuss the role of the four bar mechanism within the selected application (provide citations) • List the requirements of the four bar in the selected application (range of motion, precision, link lengths of the mechanism, external forces etc) (provide citations) • State any assumptions that will be used in the analysis and modeling etc. • Put a paragraph or two to demonstrate the effect/ advantage of clearance in the joint and link flexibility in the selected application. And discuss how the system will be benefited from your analysis.	20	8	6	3	
Methodology • Discus the procedure how your selected mechanism and analysis will be implemented, simulated, manufactured, tested etc. A diagram to describe the hierarchy of a system's functions. • Discuss the possible testing or experimental procedures that can be used to verify your solutions	25	14	8	4	
ADAMS Modeling • Model the mechanism in Adams with all boundary conditions based on the selected application • Apply the required law for contact modeling and adding flexibility in the links (provide references) • Discuss any modeling assumptions, input parameters, output/measured parameters etc. • Run the simulation with the actual scenario (based on the actual application)	50	8	6	3	
Result and Discussion • Put a very neat graphical results from the ADAMS simulation (each graph needs to be given the appropriate label and title. • Discuss each graph's result, what it means in regard to clearance or/and flexibility effect. (a graph with no discussion about it, is considered as useless and will affect your grade) • Discuss the effect of the result on the selected application, just based on your simulated result and the accuracy and precision requirement of the selected application. You can support all your result discussions through references.	40	20	14	9	
Conclusions and Recommendations • Based on your solutions and the application requirements, preliminary results, draw a conclusion • list the unique features of your solutions and advantages • list the limitations of your solutions and add a recommendation to it • If there is a change to your Gantt chart, put here the updated one.	10	8	6	3	
					Total= /150

Note: Points may be given in between of the given ranges. For mostly incomplete parts, a lower point may be given regardless of the above table.

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Figure 2: Project Rubric-Part II

Rubric III: The third stage is the modeling and simulation of the best solution to validate the performance and closed-form analytical solutions. Students were challenged during ADAMS modeling for clearance simulation. They were recommended to find and utilize recently developed published methods based on the background from the ADAMS tutorial sessions along with some practical applications and articles. At the end of the semester, students prepare a comprehensive report, prototypes and poster presentations.

Effective team formation mechanisms and student engagement methods: In general, a team project is a natural practice in engineering courses, to fully utilize the potential benefits of this project engagement method, the instructor may be benefited by understanding the factors that can affect team effectiveness and effective team formation mechanisms. Mostly, in a semester long group project assigned at the beginning of the semester, there will be challenges as some of the group members barely knew each other, this is common especially in sophomore and junior level classes, and will be difficult to expect effective collaboration with equally shared responsibilities to assure quality end-product/result. A timed, collaborative based closed book exams, In-classroom group exercises, ADAMS based group projects and peer evaluation methods were implemented to address this issue. A separate study was conducted by Yihun et al. , on how students respond to these engagement methods to promote effective collaboration (Yihun, Nair et al. 2017)

WICHITA STATE UNIVERSITY

Dynamics for Mechanical Engineers (ME 335)
Spring-2017
Wichita State University
Mechanical Engineering Department

Project-Part 3- Grading Rubric

Project Title: ____________________

Group #: ____________________ **Date:** ____________

Format	Totally complete	Mostly complete	Partially complete	Mostly incomplete *	Points
• Cover page (Follow the given format) • Follow font size and spacing and other format guidelines given, show each heading and sections clearly • Proper citation	5	4	2	1	
Analytical Analysis • Put a paragraph or two about the type of analytical analysis and its formulation you plan to use, you can use two or more approaches and compare and select the best result, which will better validate the ADAMS result. (provide citations) • Use the same **requirements and assumptions** as your ADAMS model • State any assumptions that will be used in the analysis and modeling etc. • Develop **graphical and numerical results** from your analysis to conform/ compare with the design requirements (**is advisable to use software like excel, MATLAB, VB etc. to analyze and plot results).** • Discuss each graph's result, what it means in regard to clearance or/and flexibility effect. (a graph with no discussion about it is considered as useless and will affect your grade)	70	60	45	20	
Result Validation • Compare **the simulated results from ADAMS with your analytical results. (If possible, plot both results with the same scale and super imposed in one plot area.)** • Discuss each comparison graph's result, if there is an error, discuss the possible sources of this error. (a graph with no discussion about it is considered as useless and will affect your grade)	25	14	8	4	
Prototype & Testing • Make a prototype for your project and Implement the necessary sensors, actuators, and controllers. Conduct the experiments/ testing using the prototype. • Give a **clear procedure and outcomes for each testing you made** • Validate/compare with your simulation and analytical results etc.	100	80	50	30	
Presentation • **Prepare power point and upload it to blackboard** • Based on **the given template, prepare a poster. All the group members should be there to explain and answer any questions. Guests will be invited in the poster presentation session (MAY 2, 2017)**	40	30	20	9	
Final Report • Write an abstract about the project (not more than 200 words), which can address the selected application, analysis type, ADAMS modeling and results with respect to clearance and flexibility effects etc., provide quantitative data as well. The final report should contain part1, part2, and part3 of the project • Correct and incorporate all the corrections and suggestions given for part1 and part2 • Check the contents, report flow, typos, grammars and guidelines, correct reference number and sequence • Attach a summary of each member's contribution to the whole project • Spiral Binding or similar should be used for the final hard copy of the report.	60	45	30	15	
					Total=$\frac{}{300}$

Note: Points may be given in between of the given ranges. For mostly incomplete parts, a lower point may be given regardless of the above table.

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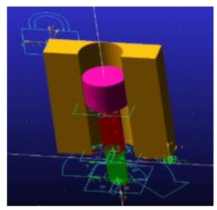
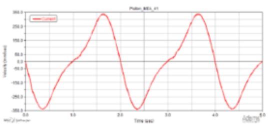
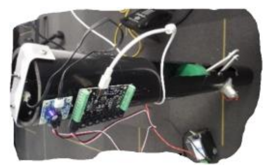
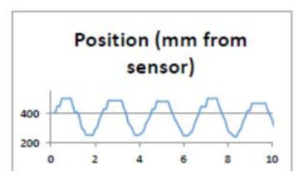
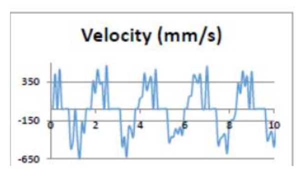
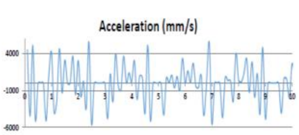
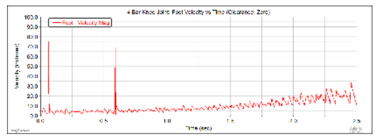
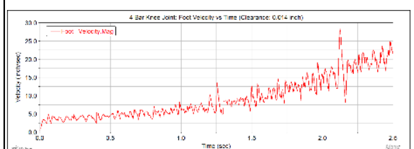
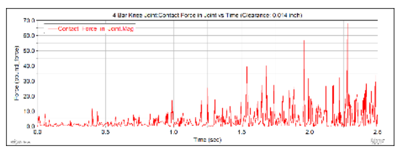
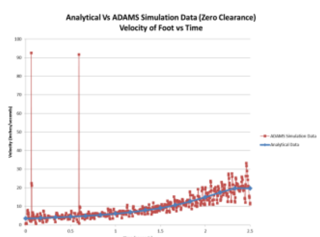
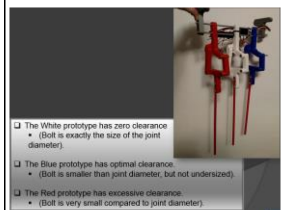
Figure 3: Project Rubric-Part III

Result and discussion

Project outcomes: the research based assessment method with the rubric helps students to generate ideas, read high-level journal publications and adopt techniques to the analysis and construction of prototypes. There were 13 groups, each group has at least five members. Two sample students' project are shown in Table 1.

Table 1: Sample students project work from spring 2017 ME 335 course (a &b)

	Abstract	***Analysis Results***	***Prototype and Test Results***
a	*The target of this venture is to investigate the effect of clearance in the joints and link flexiblelity in slider-crank mechanism of an automobile engine. To better understand the slider-crank mechanism, the mechanism is simulated and analyzed in ADAMS, CATIA and Microsoft Excel. Also, the group has constructed a prototype. In the model, the Piston mass, length, cross sectional area, mass of rigid and flexible rod and the dimensions of both rods are considered constant parameters.* *The results have shown that, while extra flexibility can help with dampening vibration and stopping failures on a system, but it also causes deterioration to the smoothness of acceleration and velocity as shown in the graphs. This will cause mechanical failures in other parts of the mechanism.*	 ***ADAMS model***  ***Velocity-Time graph: with 1 mm clearance at the piston pin***  ***Acceleration-Time graph: with 1 mm clearance at the piston pin***  ***Acceleration-Time graph: with 1 mm clearance at the piston pin and flexible connecting rod.***	   Prototype modle   

	Abstract	*Analysis Results*	*Prototype and Test Results*
b	*In this project the group has chosen to create a prosthetic knee based on the foundation of a four bar mechanism as shown in* Figure 4. *Compared to a traditional hinged prosthetic knee, a four bar knee offers a more natural movement and can potentially be more desirable for everyday use. For example, it will keep the recipients foot from dragging while walking, and keep both legs at the same height while sitting. To make this knee actually function the group has modeled it using ADAMS software. Using the model, the rear joint was analyzed to see the effects of joint clearance on the movement of the knee. Since these joints are the only point of wear, this is where the most of the group research went into. Too tight of joint clearances could cause the knee to seize and result in failure. However, too loose of clearances could cause the whole knee assembly to feel sloppy and rattle apart. The group has found that a joint clearance of 0.008 inches gave the knee the best results. This investigation will provide good insight for the design of prosthetic knee that is safe, reliable, and feel natural.*  *Figure 4: Four Bar Linkage Knee Joint with tube clamp (KITA*	     	   

Overall, through these project and instructional method students were expected to be able to accomplish the following outcomes.

- Apply the course content through the analysis of velocity, acceleration and reaction forces in the project.
- Learn and apply ADAMS, modeling and simulation software.
- Over the ADAMS learning sessions, students had an opportunity to have a comparison between the theoretical results driven from mathematical and dynamics equations with visual and animated results in ADAMS modeling.
- Read literatures and learn the different facet of the project to build the prototype and analyze, for instance, couple of groups have implemented position sensors and capture the data through microcontroller. These topics are off the lecture and content of the course, however students have done these through reading literatures and teaching themselves with collaborations, the authors believe that such exercise will strengthen students' SDLR skill.

- The poster presentation helped them to communicate their findings and learn from other group projects.

Student perception towards the project engagement and assessment methods:

A preliminary assessment of the utilization of the research-oriented rubric, the Project and ADAMS software to maximize learning and develop their SDLR is assessed through anonymous survey. The analyzed data based on 53 respondents are shown in Figure 4, where response 1 means 'completely disagree' and response 5 is 'completely agree' and the rest falls in between.

Participants

Participants consisted of 53 engineering college students at a moderately sized research university in the Midwest U.S. The mean age of participants was 22.32 (SD = 3.50). A majority (94.20%) of participants were male. Whites (37.70%) made up the largest racial group in our sample followed by Asian (30.20%).

Table 2: Participants Racial group

Race	n	%
African American	4	7.5
Asian	16	30.2
Hispanic	4	7.5
Latino/a	2	3.8
Native American	1	1.9
White, non-Hispanic	20	37.7
Other	6	11.3

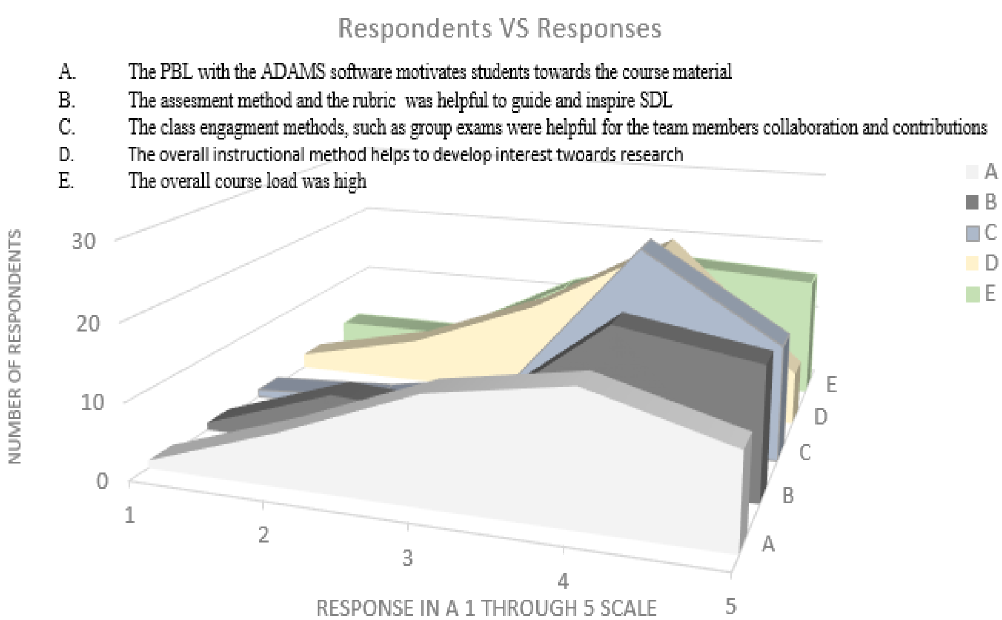


Figure 5: Student Perspective towards the Instructional method and its outcome

Conclusions

Through the ADAMS training and the PBL instructional method, Students were able to model and simulate mechanical systems, which can help them to conduct multi-run design improvement studies to assess design sensitivity and performances. And through the adopted literature review process, students were exposed to a variety of research topics which can help to develop SDLR and research skills that can empower students to work with minimal guidance. Students were able to work in a team setting to achieve a better result, as the classroom activities of knowledge sharing based discussions, group projects that bring students with different background and skills together to solve practical problems. This eventually helps students to generate innovative ideas and develop entrepreneurial mindset. Over all, the adopted ADAMS-based PBL instruction approach will benefit students, especially minorities. For example, in the agrarian state of Kansas, majority of the students are first-generation students, for instance, 40% of the students in the College of Engineering at WSU are first generation students. The PBL and RA methods will expose this group of students to research and help them to develop SDLR and be competent and successful later in their career.

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