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Connected Mechanical Engineering Curriculum through a Fundamental Learning Integration Platform

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Connected Mechanical Engineering Curriculum Through a Fundamental Learning Integration Platform

This paper proposes a hands-on learning object that can ubiquitously connect courses throughout a mechanical engineering curriculum. We call the object a fundamental learning integration platform (FLIP), as it integrates the entire curriculum via integrated learning techniques. Ultimately, it will create a physical connection between theoretical and practical engineering concepts while actively engaging each student in the learning process. Higher retention rates, increased passing rates of the Fundamentals of Engineering exam, and increased student inclusion in the classroom will all be resulted with the implementation of the FLIP.

Throughout an engineering curriculum, there should be a realistic and practical connection between courses such that each course is not represented as an individual silo of knowledge[1]. To retain such knowledge, studies have shown that students need to make connections between a new word or image to remember it[2]. Before either of these issues can be mitigated, students must also be engaged in the learning process[3]. To address each of these issues, literature was reviewed to develop a curriculum-wide solution.

Course integration has been shown to promote student engagement[2]. Project based scenarios are often used to connect course concepts that are individually important for the students to understand. Previous works demonstrating this include studies of vertical integration framework for capstone design projects by Hardin and Sullivan[4], an investigation of the importance of integration of engineering curricula by Froyd and Ohland[2], and the use of a spiral learning curriculum in the first two years of mechanical engineering by Roemer and Bamberg[5]. Research of hands on learning has been shown to increase student retention[6]. Diverse courses such as mechanical design and thermodynamics have been integrated by the implementation of a hybrid powertrain project as discussed by Constans[7]. The powertrain project integrated six courses together over a three-year span. A desktop steam engine was used at Rowan University in two junior level courses. Students associated with this project indicated that they felt an increase in their knowledge of course fundamentals[8]. Research by Dym[9] discusses how project based learning has been shown to increase student engagement and performance of all students involved. Though these curriculum changes were successful for the affected part of the curriculum, much of the curriculum was not addressed. A student's enduring knowledge after they leave the university needs to be constructed from every course in the curriculum. These previous studies have made great strides in integrated curriculum design, however this paper proposes how an entire curriculum can be connected.

To reduce the issues associated with the lack of course integration, hands on learning, and student engagement, we propose a physical object in the form of a desktop steam engine that can be used in every course in a curriculum. Identifying key concepts from previous research, the FLIP will be used to integrate each course in a unified curriculum through hands on learning.

Fundamental Learning Integration Platform

In this paper, a desktop steam engine will be used as the FLIP. Steam engines take latent heat energy and convert it into useful kinetic energy. Although power cycles can be quite complex, the general concepts behind them are quite simple and can be understood by first year engineering students. A schematic of the steam engine model proposed is shown below.

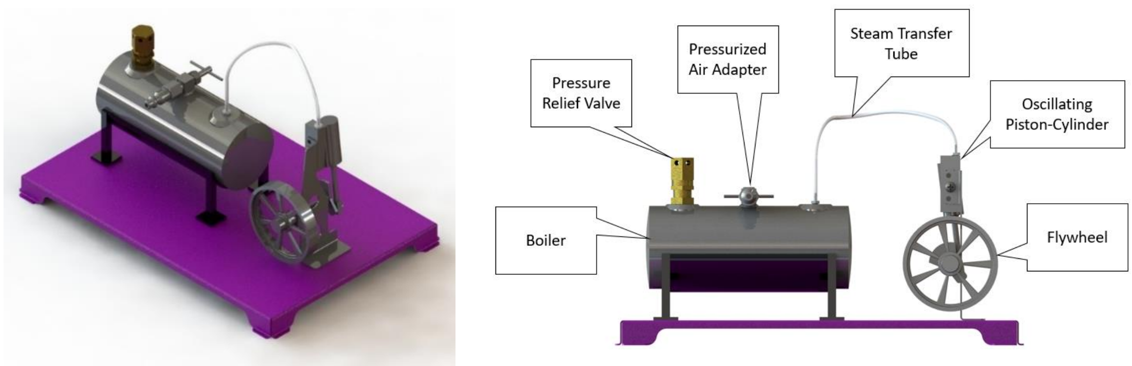

Figure 1: Proposed FLIP

Curriculum Implementation

Various curricula were evaluated to compile a list of common courses contained in a mechanical engineering curriculum. This section will show how the fundamental learning object will be implemented into all of these common courses. Each course outline will contain a brief course description and the object implementation strategy.

Table 1: Common Mechanical Engineering Courses

University:	Missouri S&T[10]	Texas A&M[11]	University of Nebraska-Lincoln[12]	University of Kansas[13]	Kansas State University[14]
First Year	Introduction to Mechanical Engineering	Introduction to Mechanical Engineering	Introduction to Mechanical Engineering	Introduction to Mechanical Engineering	Introduction to Mechanical Engineering
	Engineering Graphics	Engineering Mechanics	Engineering Graphics	Computer Applications in Mechanical Engineering	Engineering Graphics
	Thermodynamics	Engineering Graphics	Thermodynamics	Engineering Graphics	Thermodynamics
	Dynamics	Thermodynamics	Statics	Statics	Statics
	Machine Dynamics	Measurements and Instrumentation	Dynamics	Mechanics of Materials	Dynamics
	Model Analysis of Dynamic Systems	Engineering Analysis for Mech.	Kinematics and Dynamics of Machinery	Thermodynamics	Computer Applications in Mechanical Engineering
	Machine Design	Dynamics	Fluid Mechanics	Dynamics	Machine Design
	Heat Transfer	Materials and Manufacturing Selection in Design	Machine Design	Machine Design	Fluid Mechanics
	Fluid Mechanics	Fluid Mechanics	Control of Mechanical Systems	Fluid Mechanics	Control of Mechanical Systems
	Measurements and Instrumentation	Heat Transfer	Measurements and Instrumentation	Control of Mechanical Systems	Measurements and Instrumentation
	Mechanical Engineering Systems	Control of Mechanical Systems	Manufacturing Methods and Processes	Heat Transfer	Heat Transfer
	Control of Mechanical Systems	Machine Design	Heat Transfer	Measurements and Instrumentation	Interdisciplinary Industrial Design Projects
Fourth Year	Interdisciplinary Industrial Design Projects	Interdisciplinary Industrial Design Projects	Interdisciplinary Industrial Design Projects	Interdisciplinary Industrial Design Projects	

Introduction to Mechanical Engineering

Introduction to Mechanical Engineering is the curriculum cornerstone class taught mainly to first year students. In this course, students study fundamental concepts of mechanical engineering such as mechanical advantage and energy conversion. Very broadly, students learn how latent energy can be turned into useful work by using simple machines. As this will be the initial implementation of the steam engine fundamental learning object, students will study the history of steam engines and their basic function. To enforce that the design process is an iterative process, students can research how steam engines have evolved through the years. As done by Rowan University, students should be encouraged to design their own steam engine and participate in a friendly competition[8]. Students can use their creativity in a controlled hands-on learning environment.

Engineering Graphics

Engineering Graphics develops visualization skills that are critical for communication. Students study hand drafting and a computer aided design (CAD) program. After conceptually designing their own steam engines in the Introduction to Mechanical Engineering course, students will be ready to create a physical design. Working in teams, students will be given a sample steam engine to disassemble, measure, and model. Through this process, the students will have hands on experience with the physical device and a working knowledge of how it functions. Upon completion of a CAD model of the physical learning object, they can be guided through the process of 3D printing their own functional steam engine.

Thermodynamics

Thermodynamics develops an understanding of energy conversion from heat to work. Students study how the expansion of a gas can create mechanical work. The piston-cylinder assembly of the steam engine will demonstrate this concept. The students' familiarity with the specific components will give them a physical object they can analyze, thus deepening their understanding of Thermodynamics.

Statics

Statics develops an understanding of methods to analyze reaction forces on engineering systems. Students study the forces associated with static engineering systems. A truss structure supporting the boiler of the steam engine will demonstrate this concept. The students' familiarity with the boiler will give them a physical object they can analyze, thus deepening their understanding of Statics.

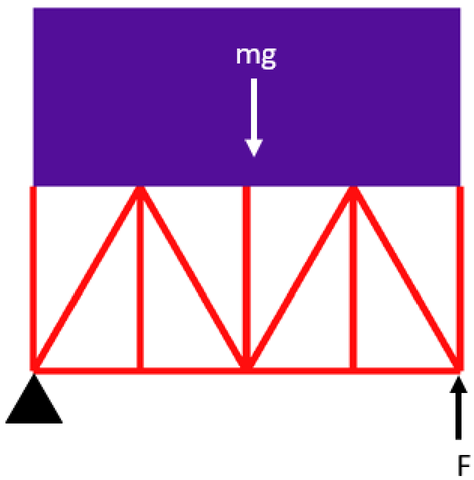

Figure 2: Force Diagram

Dynamics

Dynamics develops an understanding of kinematic concepts such as angular momentum. Students study how geometry changes effect the angular momentum of objects.
Students can demonstrate this concept by designing and experimenting with different types of flywheel geometry. The students' familiarity with the specific components will give them a physical object they can analyze, thus deepening their understanding of Dynamics.

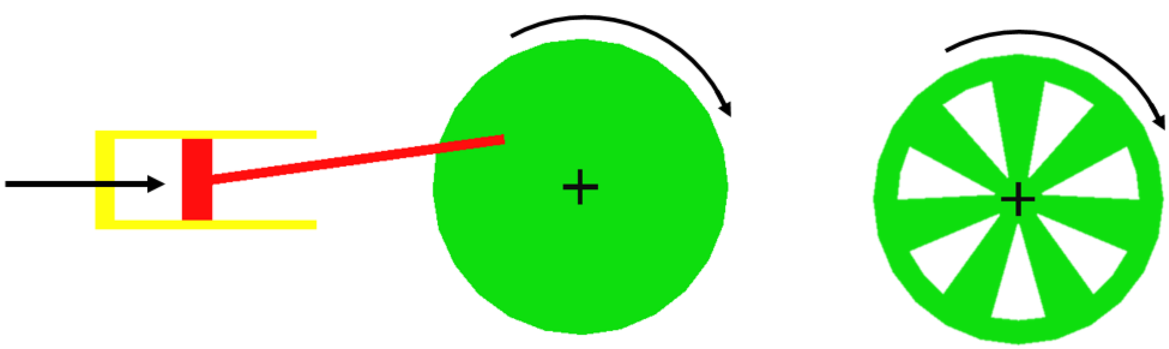

Figure 3: Dynamics Diagram

Computer Applications in Mechanical Engineering

Computer Applications in Mechanical Engineering develops an understanding of computer programming. Students study how data can be analyzed and interpreted with the use of computer automation. Students can demonstrate this concept by analyzing data recorded from an operating steam engine. The students' familiarity with the specific components will give them a physical object they can analyze, thus deepening their understanding of Computer Applications in Mechanical Engineering.

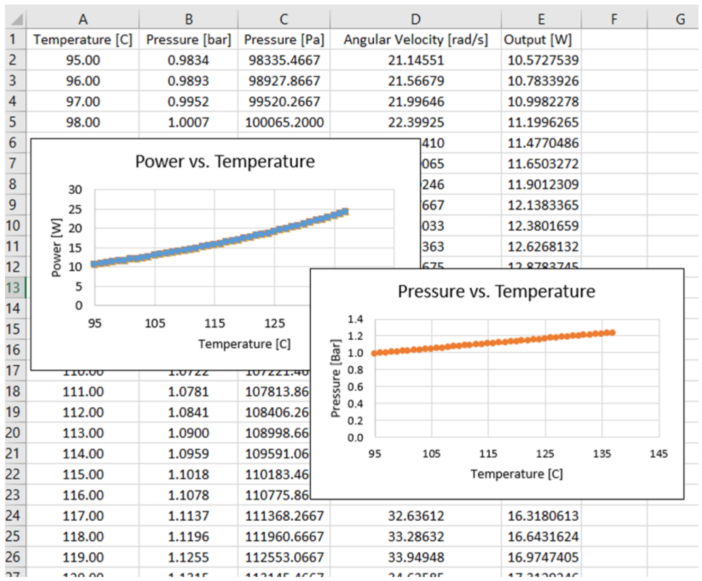

Figure 4: Example Computer Applications Data

Machine Design

Machine Design develops an understanding of different types of mechanical mechanisms. Students study how multiple linkages can be used in a particular mechanism. Students can demonstrate this concept by designing different linkages to be used between the piston and flywheel. The students' familiarity with the specific components will give them a physical object they can analyze, thus deepening their understanding of Machine Design.

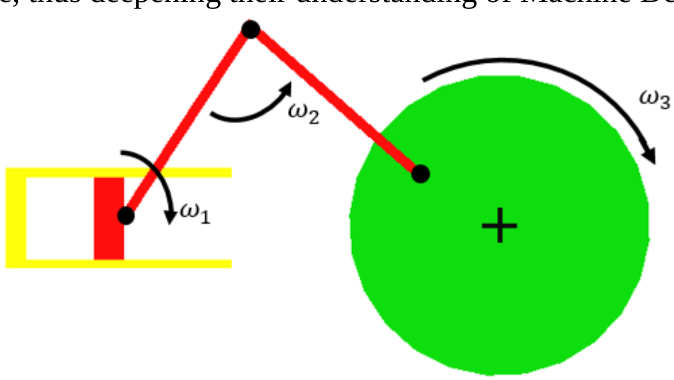

Figure 5: Two Bar Linkage Diagram

Measurement and Instrumentation Laboratory

Measurement and Instrumentation Laboratory develops an understanding of different measurement devices and techniques. Students study how there is uncertainty associated with every measurement device. Students can demonstrate this concept by experimenting with different temperature measuring devices on the boiler. The students' familiarity with the specific components will give them a physical object they can analyze, thus deepening their understanding of measurement and instrumentation.

Control of Mechanical Systems

Control of Mechanical Systems develops an understanding of controlling a dynamic system. Students study how to model a control loop diagram. Students can demonstrate this concept by creating a model to control the water level in a steam engine boiler. The students' familiarity with the specific components will give them a physical object they can analyze, thus deepening their understanding of mechanical systems control.

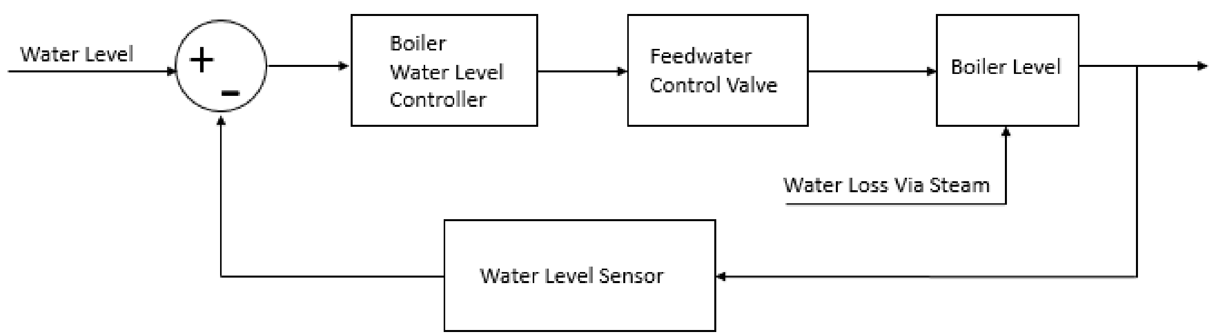

Figure 6: Water Level Control Loop

Fluid Mechanics

Fluid Mechanics develops an understanding of fluid flow, especially in pipes. Students study how pressure loss in pipes is due to fluid friction. Students can demonstrate this concept by experimentally measuring the pressure loss between the boiler and the piston-cylinder. The students' familiarity with the specific components will give them a physical object they can analyze, thus deepening their understanding of Fluid Mechanics.

Heat Transfer

Heat Transfer develops an understanding of the different modes of heat transfer. Students study how heat is lost through conduction, convection, and radiation. Students can demonstrate this concept by experimenting with the addition of insulation around the boiler. The students' familiarity with the specific components will give them a physical object they can analyze, thus deepening their understanding of Heat Transfer.

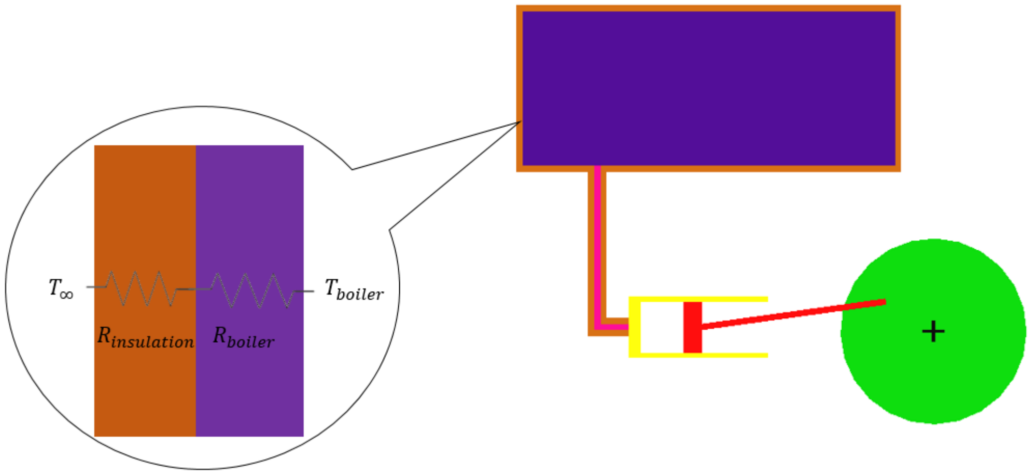

Figure 7: Thermal Resistor Diagram

Interdisciplinary Industrial Design Projects

Interdisciplinary Industrial Design Projects is the capstone course of the mechanical engineering curriculum. Students study design theory while also learning the basics of project management. Students can demonstrate this by designing a new steam engine to be manufactured. The students' familiarity with the specific components will ease the design process, thus deepening their understanding of Interdisciplinary Industrial Design Projects.

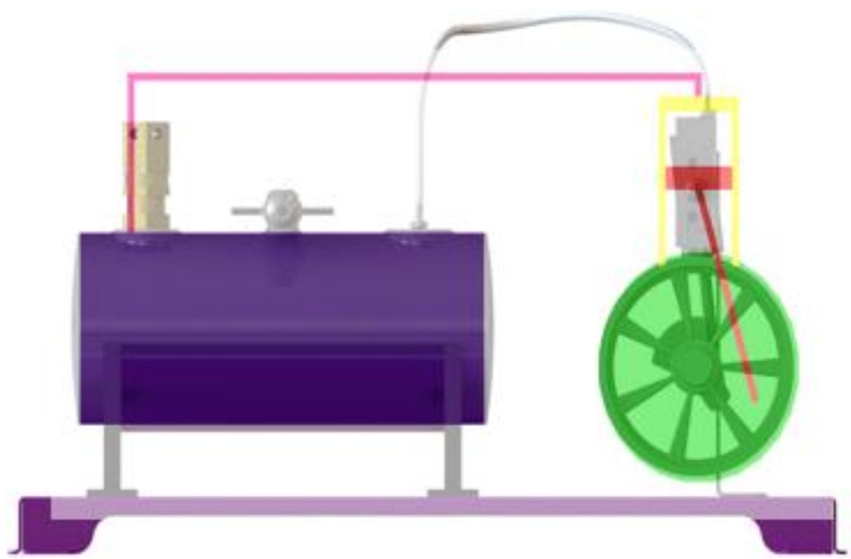

Figure 8: Steam Engine Integration

Non-Traditional Curriculum Progression

To mitigate issues of students that do not follow the curriculum sequentially, instructors must rely only on knowledge from prerequisite courses. For example, some curriculums require students to take the Engineering Graphics and Dynamics courses before they can take the Machine Design course. As a result, the Machine Design instructor can only rely on those courses when implementing the FLIP. Adhering to these restrictions will reduce the confusion of students who are not in mechanical engineering and unfamiliar with the FLIP.

Determining the Effectiveness

Research indicates that the FLIP will integrate the curriculum, create a physical connection for students to tie knowledge to, and engage students in the learning process. Related research was identified to constitute a means for measuring the effectiveness of the FLIP.

Similar to research on hands on learning conducted at the University of Colorado at Boulder, retention rates of first through fourth year students will be collected and analyzed[6]. This data will be compared to legacy retention rates from the traditional curriculum. An increase in student retention rates will signify that students are more satisfied with their curriculum. Similar to research of integrated curricula at North Carolina State University, critical thinking abilities of students will be assessed through integrated exam and homework problems[15]. Integrated exam problems such as from the Fundamentals of Engineering exam will test students' abilities to apply their enduring knowledge and common sense to solve integrated problems. Fundamentals of Engineering passing rates will be compared to rates from previous years. Increased critical thinking skills of students will signify that students are reasoning with their homework, rather than just completing it. Student and faculty surveys similar to the steam engine project implemented at Rowan University will be implemented[8]. Comparing these to course and teaching evaluations currently used, these will show an increase in student engagement due to the FLIP.

Conclusion

The use of a desktop steam engine as described in this document will connect courses throughout a mechanical engineering curriculum. Termed as the FLIP, the entire curriculum will be centered around and built upon it. Literature shows that creating a physical connection between theoretical and practical engineering will engage each student in the learning process. The results of this FLIP curriculum will advance progress towards a fully integrated curricula benefiting both students and educational institutions through applied hands on learning.

Bibliography

1. Lim AG, Honey M. Integrated undergraduate nursing curriculum for pharmacology. *Nurse Education in Practice.* 2006;6(3):163-168.
2. Froyd JE, Ohland MW. Integrated engineering curricula. *Journal of Engineering Education.* 2005;94(1):147-164.
3. Smith KA, Sheppard SD, Johnson DW, Johnson RT. Pedagogies of engagement: Classroom-based practices. *Journal of engineering education.* 2005;94(1):87-101.
4. Hardin J, Sullivan G. Vertical-Integration Framework For Capstone Design Projects. Paper presented at: Proceedings of ASEE Annual Conference2006.
5. Roemer R, Bamberg S, Kedrowicz A, Mascaro D. A SPIRAL Learning Curriculum in Mechanical Engineering. Paper presented at: American Society for Engineering Education2010.
6. Carlson LE, Sullivan JF. Hands-on engineering: learning by doing in the integrated teaching and learning program. *International Journal of Engineering Education.* 1999;15(1):20-31.
7. Constans E, Angelone B, Bhatia K, Kadlowec J, Merrill T, Zhang H. Integrating the Mechanical Engineering Curriculum Using a Long-Term Green Design Project. Paper presented at: Proceedings of the 2012 American Society for Engineering Education Annual Conference, San Antonio, TX2012.
8. Bhatia KK, Constans E. Steam Power: Novel Use of an Engine Design Project to Cross-Link Knowledge from Courses in both Mechanical Design and Thermodynamics. Paper presented at: Proceedings. Frontiers in Education. 36th Annual Conference2006.
9. Dym CL, Agogino AM, Eris O, Frey DD, Leifer LJ. Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education.* 2005;94(1):103-120.
10. S&T M. ME Curriculum Worksheet. 2017; https://mae.mst.edu/media/academic/mae/documents/advising/MEwPrereq4DigFS14.pdf.
11. University TAM. MEEN Curriculum Flowchart. 2017; https://engineering.tamu.edu/media/3717002/Prereq%20Flowchart%20for%20ME%20May%202016-139.pdf.
12. Nebraska-Lincoln UO. Mechanical Engineering. 2015; https://bulletin.unl.edu/undergraduate/2014/major/Mechanical+Engineering/plans.
13. Kansas Uo. Curriculum Flowchart (Fall 2015 and After). 2017; http://me.engr.ku.edu/sites/me.drupal.ku.edu/files/docs/ME_Curriculum_Flowchart_Fall_2015.pdf.
14. University KS. Mechanical Engineering Flow Chart. In:2016.
15. Felder RM, Beichner RJ, Bernold LE, Burniston EE, Dail PR, Fuller H. Update on IMPEC: An integrated first-year engineering curriculum at NC State University. *age.* 1997;2:1.