# The Wobbler Steam Engine: A Connection Between the Past, Present, and Future of Mechanical Engineering

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## Abstract
The Mechanical Engineering Freshman Experience at Western Kentucky University is a blend of contemporary student success topics with a return to some of the traditional roots of mechanical engineering. Students in this course are provided basic instruction in hand sketching and the safe use of fundamental machine shop tools. Each student designs, documents, and machines their own small steam engine. This experience is a response to the broadening gap between the background of new engineering students and the diminishing opportunties to learn practical skills in modern companies actively moving production overseas.

This paper documents three years of this course and will share lessons learned by faculty, responses from industrial constituents, and student course assessments. Examples of engine designs are presented, along with a description and budget for the necessary infrastructure.

## Introduction
Every student who begins the Mechanical Engineering (ME) program at Western Kentucky University (WKU) enrolls in ME 101: The Mechanical Engineering Freshman Experience. As with most freshman seminar courses in engineering, components of this course deal with college life, academic success, introductory professional skills, and ethics. However, this course adds a unique element in an attempt to counteract several evolving trends in the ME profession.

As globalization moves through American industry, fewer companies have domestic manufacturing facilities where young engineers are exposed to a range of traditional production processes during a period of onsite practice. Too often, these young engineers will not have mentoring from experienced engineers, designers, and machinists who possess vast knowledge of these processes and their impact on design. In addition, the students who come to college to study engineering now typically possess few of the traditional fabrication skills learned in high school “shop.” Thus, many young engineers never have the opportunity to participate in any of these manufacturing processes.

ME 101 is the first in a series of four integrated ME design courses at WKU attempting to deal with emerging issues such as these. The course is not a shop course, nor is it a theoretical course in manufacturing engineering. It is an integrated experience where students spend part of the semester focusing on improving their innate design abilities with practice in basic mechanical sketching and the production of a “proof-of-concept” prototype.

The prototype expected from each student is a small steam engine, blending well with concurrent seminar discussions about the historical use of steam and the rise of the ASME. Each student is expected to design, machine, and demonstrate a unique “Wobbler” steam engine powered by compressed air. Teamwork is encouraged, but each student is responsible for his or her design, prototype, and report. Basic instruction is provided to each of the 50-60 students in the safe use of bandsaws, milling machines, lathes, and drill presses. Student have 24-7 access to a small machine shop where they work to machine these simple engines.

**Course Overview**

The Professional Component of the ABET assessment plan for the ME program at WKU has a strong emphasis on design, as documented in the program's Design Plan.[1] The Design Plan developed by the Mechanical Engineering faculty recognizes that the Engineering design process must be integrated into the Mechanical Engineering Curriculum as a continuous process from the first year to the final semester. This is necessary to provide students with the opportunity to acquire design tools and skills, as well as competency in mathematical and technical analysis, and communication.[2]

The Mechanical Engineering faculty accepts the following as a representative statement of the attributes of Engineering Design taught in this department:

- Engineering design is the systematic application of the basic sciences, mathematics and engineering sciences to generate and evaluate specifications for systems, components, or processes.
- The form and function of the design must achieve defined objectives and satisfy consumer constraints.
- Design should include aspects of creativity, complexity, and iterative decision-making to optimize a solution, and compromise between multiple, and sometimes conflicting, requirements .[3,4,5]

ME 101 is the starting point for the Design Plan. It is the first of four designated design courses[6] across the four years of the ME curriculum before the capstone design course. The Wobbler assignment attempts to meet the three attributes listed above while recognizing the limitations of a freshman class. The time spent on the design project is balanced with an academic success portion of the course, with 1/3 of the course focused on the Wobbler design. The class is team taught, with the author covering the Wobbler portion of the course. Students in this required design course are in their first semester, and are typically taking a material science course, calculus, and chemistry at the same time. Only ME students take this course, with each of the other WKU engineering programs offering discipline-specific design courses in the first semester as well. The freshman design courses in the other disciplines have projects that can be characterized by the three attributes above, but they use design experiences more appropriate to their discipline.

Deliverables for the Wobbler assignment include a set of part and assembly hand sketches of the steam engine. Students also build up a cost budget, with materials priced by the inch; their cost must be below $18.75. However, no lab fee is charged to the students, the program bears the full cost. In addition, a spreadsheet has been developed to help students size some of their engine components. Students enter some of their dimensions, and the spreadsheet computes the remaining dimensions. A copy of their spreadsheet must be included. Students are allowed to keep their engine; a digital photograph is taken of each engine for our assessment records. They are required to attend the final freshman event of the semester to demonstrate their engine.

At the end of the fall semester, the Department of Engineering sponsors Freshman Engineering Day. The projects from all three Freshman Seminars (ME, EE, and CE) are demonstrated for family and friends. Lunch is provided by the Department, and the number of external visitors to this event has grown every year. The Wobbler demonstration is particularly impressive, as approximately fifty of these highly inefficient air engines are simultaneously powered from a compressor bank outside the building. Students enjoy measuring the speed of their engine with optical tachometers, while watching some of the engines fly apart relatively quickly. Figure 1 below shows a group of the freshmen as they run their engines in unison.

Figure 1: Wobblers at Freshman Engineering Day

**Roots of the Profession**
A key reason for selecting a steam engine as the project for the ME Freshman Experience is the historical context of the ME profession. The American Society of Mechanical Engineers (ASME) student web site[7] has a wealth of searchable resources on early steam history, boiler explosions, and the rise of codes and standards. Students are shown a presentation on the development of the ME profession, and steam power plays a pivotal role in that story. In addition, students watch a video[8] on the rise of machine tools and their linkage to economic development.

**Safety Issues**
In today's litigious environment, some might be surprised to find freshman engineering students using a machine shop. The author has heard from many faculty and administrators at other institutions who have eliminated all student access to machine tools.

The Department of Engineering is fortunate that WKU has a long tradition in the arts and crafts. Industrial education was a vital element of early Kentucky teacher education, and WKU has its roots in the "Normal School" model of teacher education. Woodworking and agricultural mechanics are still very popular courses within the Ogden College of Science and Engineering.

ME students have 24-7 access to the building and machine shop with their student ID. The Department has a strict safety policy regarding safety glasses and always having a shop partner when working. The WKU occupational safety inspector regularly works with the departmental staff engineer and the author to review policies and procedures. The WKU General Counsel has reviewed our policies and plans and given her approval to our efforts.

**Wobbler Engines**

A Wobbler steam engine is a valveless oscillating engine with the connecting rod and piston formed as one rigid piece (no wrist pin). The cylinder serves as the valve porting system by oscillating ("wobbling") on a pivot, moving an air inlet hole back and forth between steam (air) inlet and exhaust ports; see Figure 2 below.

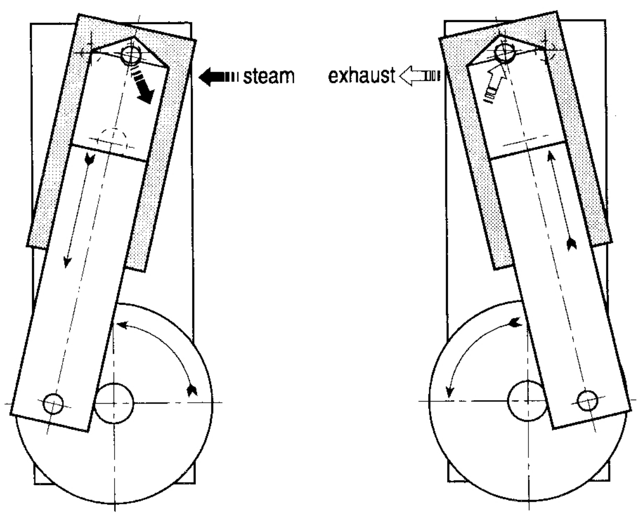


Figure 2: Operation of Wobbler Engine[9]

Wobbler engines are common beginners projects among hobby machinists.[9] A wide range of web resources are available for students to research their design[10], with some even providing animated models illustrating how the devices work.[11]

Over 150 Wobbler steam engines have been built by freshman over the last three years. Very few appear to copied from public plans, but rather are unique designs developed by the students. Figure 2 below shows a sample of some of the engines built over the last three years. All were machined by students with <u>no</u> prior machining or shop experience, except for the rare student who grew up in a family shop or attended vocational school before college. A "catalog" of photos of all the wobblers built at WKU is available for the freshmen to review during the course, and each shows unique characteristics consistent with the student's skill level and creativity.

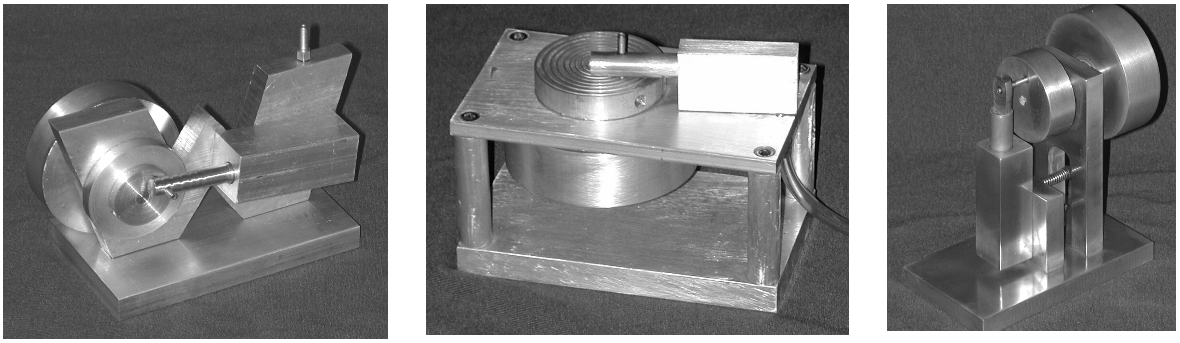

Figure 3: Student Wobbler Engines

**Facilities and Consumables**
A new building for the department of engineering will open in summer 2004. Included in the new facility is a large Prototype Fabrication Facility equipped with over $300,000 of the latest CNC and manual machine tools. However, the modest Freshman Prototype Shop necessary to run ME 101 will be moved to a space near this larger shop. This course is currently offered in a 320 $ft^2$ room with limited power resources. Formerly a circuit board etching facility, the room was converted nine years ago to a small student shop; see Figure 4 below.

Figure 4: Freshman Prototype Shop Lathe

The major equipment list and budget for the Freshman Prototype Shop are shown in Table 1 below. The equipment is modest in size and cost, but the projects designated for this shop are modest in size and accuracy. Their reduced size and power present are less intimidating to the novice machinist, allowing the students to more quickly produce usable parts. In addition, the lower cost allows for easier replacement of parts and even total machine replacement in the event of a major student (or faculty) error.

| **Item** | **Quantity** | **Cost** | **Total Costs** |
|---|---|---|---|
| 9” x 20” Lathe | 4 | $900 | $3600 |
| 24” x 10” Mill | 2 | $2000 | $4000 |
| 17” Drill Press | 3 | $450 | $1350 |
| Horizontal Bandsaw | 1 | $950 | $950 |
| General Shop Tools | - | - | $1000 |
| | | **TOTAL COST =** | **$10,900** |

Table 1: Costs of Freshman Prototype Shop

The initial startup costs for this facility were covered by support from members of the Industrial Advisory Board, with improvements and expansions covered through normal programmatic resources. The faculty of the ME program consistently support the costs of supporting this shop. Students do use it in other courses, such as for preparing tensile test specimens, and faculty see it as an important resource of the program. In addition, regional industries consistently support this shop through monetary and gift-in-kind donations to the program. Industrial visitors to the department often express surprise at the level of work produced by the ME freshman at such a modest level of capital investment.

Consumables for the course are covered completely by the program, no course fees are charged for any course in the Department of Engineering. This course is normally offered in the fall semester, with approximately fifty students completing a steam engine. Aluminum stock, fasteners, springs, taps, cutters, and replacement tools are typically $2500 per year, although these costs are amortized over the entire school year since students working on other courses and projects take supplies for their use. This recurring cost is added to the normal programmatic budget each fall.

**Summary of Course Assessment**

Course outcomes were developed for this course that reflect the established course objectives. These outcomes state the skill and knowledge students are expected to possess at the end of the course, and are shown below.

1. Sketch basic mechanical components, including projections and cross sections.
2. Select appropriate drill sizes for tapping, countersinking, and reaming.
3. Dimension a part showing an understanding for the fabrication processes involved.
4. Create a conceptual design for a simple project.
5. Verify a design using a design validation spreadsheet.
6. Create a budget and bill of materials for a simple project.
7. Perform the basic shop functions safely: drilling, turning, milling, sawing, tapping, reaming, countersinking.
8. Construct a physical prototype of a simple design.

Students used self-assessment to determine the success of the course in enabling them to achieve the course outcomes, with a 0 indicating no mastery and 10 very proficient. A typical course assessment for the course is shown in Figure 5 below. The responses of the students are compared to faculty evaluations of their performance, with a target score also shown.

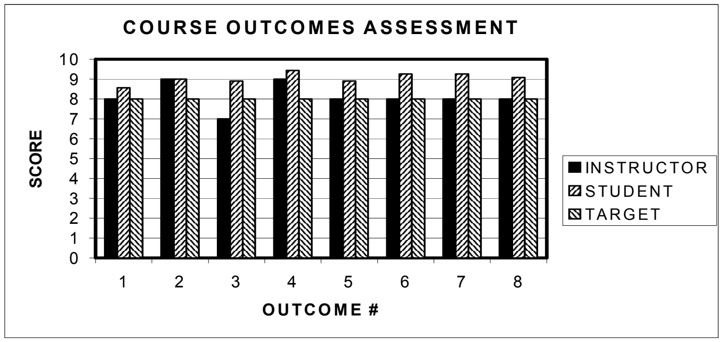


Figure 5: Course Outcomes Assessment

This type of course outcome assessment is used for every engineering course at WKU, and serves as a valuable tool for continuous course improvement. In this example assessment, the greatest difference between faculty and student perceptions occurred on the outcome related to use of the design spreadsheet. Students felt they needed greater assistance on this analytical tool. The instructor responded in the following semester by spending more time on the spreadsheet on an individual basis with students. In addition, a "Wobbler Design Guide" was developed for the students as an aid to understanding the operation of the wobbler and the interaction between dimensions and the design spreadsheet.

Student comments are also collected during this course assessment, with students consistently praising the course for opening the doors to an area of activity many of them see as a primary reason for becoming an engineer. The growth of popular cable shows documenting motorcycle construction and other vehicle fabrication activities is having an impact on young engineering students in our region. Comments suggest that they see an engineering degree blended with fabrication skills as a path to a successful career. They recognize value in the experiences of ME 101, and see the wobbler project as a rite of passage to getting their ME degree.

**Lessons Learned**

This course was offered with the Wobbler assignment for the third time in fall 2003. Based on the course outcomes assessment, specific student comments, and observations by the course instructor, several major improvements have been made to the course. The most substantial change to the course occurred between the first and second offerings. In the first offering, students spent too much time learning the machines instead of using them. In fact, all 42 Wobblers were built between Halloween and finals. Students are now moved to the shop in the sixth week, giving them ten weeks plus Thanksgiving to complete their work. Students report they are much less stressed in doing the project, although some always wait until time is nearly over before starting. Thus, the next time the course is offered the students will be required to have their Wobblers done the week before the demonstration day.

Another change to the course is that a student worker has been hired to assist with managing the shop. Students reported they needed some additional guidance with the shop tools, usually at times the instructor was unavailable. Fall 2003 saw the shop running much more efficiently, since machine repairs and maintenance was performed immediately as needed. The student worker felt a sense of pride as he mentored the younger student, and he was able to reassure the freshmen with first-hand knowledge of how to complete the project.

The last change to the course will be implemented the next time it is offered. A set of five different sample Wobblers are under construction and their drawings will be placed on the programmatic web page. Students will be able to compare these physical models to the drawings to gain a better understanding of how the devices work.

The greatest lesson learned did not come from student assessment of the course. Over the last three years, all the ME faculty have realized this course brings great value to the educational experience. However, regardless of the level of faculty endorsement, the instructor must become a champion for the course. The instructor not only needs to have machining skills, but also must be able to relate to the students and earn their trust as they attempt tasks completely unfamiliar to them. The instructor must help the students see this project as a design experience enhanced by prototype construction, not a machine shop project encumbered by design. The instructor must champion for the necessary release time to help over forty students complete the project, while still being willing to fight for the resources required to support the infrastructure of the course.

**Conclusion**

The course ME 101: The Mechanical Engineering Freshman Experience, has become an important element of the ME program at Western Kentucky University. This course builds a strong foundation for the Design Plan in the ME Professional Component. ME 101 is certainly more than a shop course, students gain a sense of identity as ME students and have a better understanding of the roots of the profession. They have a physical artifact that will be a lasting momento of their freshman year at WKU, regardless of the major they select. Course outcome assessment is an essential element of the course, already contributing valuable suggestions for substantial improvements to the course.

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## Author Biography

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