

## Introduction to Engineering at Walnut Hills High School

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### Abstract

Many high school students, particularly women and minorities, are not familiar with the engineering profession and do not recognize it as a viable career option. To familiarize students with engineering, help them to develop skills necessary for success in engineering courses, and build their confidence in those skills, a new course, Introduction to Engineering, is being offered at Walnut Hills High School. Walnut Hills is a 6-year traditional college preparatory school with a diverse student population. The course is nearly identical to the Introduction to Engineering sequence required of beginning engineering students at The Ohio State University, but has been modified to be taught over an entire school year instead of two 10-week quarters. Fifty-nine students are enrolled. A math teacher and a science teacher at Walnut Hills High School are team teaching the course during the 2001-02 school year with support from OSU faculty and staff. A grant from General Electric provided the funds to purchase laboratory equipment, textbooks, and software for the course. In addition, the grant supported the high school instructors' preparation to teach the course.

This paper was prepared by the Walnut Hills High School teachers and OSU faculty and staff directly involved in preparation and presentation of the course. It outlines the course objectives, content, structure, and management. Details on establishing a university/high school/ industry team to support development and implementation of the course are provided. Finally, the authors describe the assessment plan and the lessons learned during the first year.

### Introduction

Many students with the talent and skills to become engineers are not aware that engineering is a career option for them and do not consider it as a college major. As a result, those students lose an opportunity to pursue a rewarding and challenging career, and society does not benefit from the contributions they could have made. This pattern continues even though the demand for engineers is growing rapidly. The Ohio State University (OSU) College of Engineering has recently developed a 2-course sequence entitled Introduction to Engineering which gives students a chance to explore a variety of engineering disciplines, learn many skills engineers need, and experience the joys and frustrations of solving engineering problems in hands-on laboratory activities. Unfortunately, the only people who have the opportunity to learn about engineering in these courses are those who have already entered college and selected engineering as their major. If the number of engineers graduating from our colleges is to keep pace with the demand, more students need to learn that engineering is a viable career option before they choose their college majors.

In an effort to address this need, a team consisting of faculty and administrators at Walnut Hills High School in Cincinnati, Ohio, faculty and staff of the OSU College of Engineering,

and the General Electric Corporation joined together to make the OSU College of Engineering's Introduction to Engineering (IE) course available to seniors at Walnut Hills High School during the 2001-02 school year. The Walnut Hills IE course is very similar to the one offered at Ohio State, but the course material has been reorganized so it can be delivered over two 18-week semesters rather than two 10-week quarters. Fifty-nine students have enrolled in the high school class. It is team taught by two Walnut Hills faculty members, one math teacher and one science teacher, with support from a variety of OSU faculty and staff. Students receive one high school credit for the course and have the option of requesting credit for the OSU Introduction to Engineering course sequence should they choose to attend Ohio State and major in engineering. The course at Walnut Hills is a pilot and is being continuously assessed; at the end of this academic year, the course will be modified as necessary. In future years, efforts will be made to form additional teams with other high schools and other companies so that the course may be offered at several locations within Ohio.

This paper outlines the Walnut Hills course objectives, content, structure, and management. It provides information on how the high school/university/industry team was formed and the roles each team member plays. The paper concludes with a description of the assessment program and a discussion of the lessons learned.

### **Course Objectives**

The primary objectives of the Introduction to Engineering course at Walnut Hills High School are to make the students aware of engineering as a career option and to give them an opportunity to explore that option while developing skills important for success in an engineering curriculum and building confidence in their skills. However, the course is designed so that most of the skills taught will be valuable to the students regardless of which career or college major they choose. Examples include teamwork, written, oral and graphical communication, computer, and problem solving skills.

Another reason to offer IE in a high school is to reach a broader audience than can be found in college engineering classes, which are predominantly white and male. As our nation becomes more reliant on technology, the demand for engineers and other people with technical skills increases. In order to meet the increased demand, we must attract women and minority students to engineering. Partly because they have so few role models, those students are often hesitant to make a commitment to study engineering in college. They may be more willing to try an engineering course in high school, in a familiar environment, with teachers they know, and surrounded by family and long-time friends who are supportive.

### **Course Content**

Introduction to Engineering at Walnut Hills is essentially the same course as is offered at Ohio State for beginning engineering students. The class consists of two parallel and integrated tracks, basic skills and hands-on laboratory activities. In the first semester, the laboratory activities focus on two existing products, a bicycle and a single-use camera. Students learn about the design process and the types of engineers involved in the design and manufacture of each product. In the second semester, students design, build, test, and document a product of their

own design. That product is a conveyor/sorter system that will sort 3 different types of recyclable materials into bins. The system must sort 30 objects in all, 10 of each kind, into 3 bins and include an automatic counting system that keeps track of the number of items falling into one of the bins.

The basic skills taught in this class are ones expected to be valuable to engineers and also to those students who choose careers in other fields. In the “basic skills” portion of the course, students learn to

- work in teams
- analyze and present data using a variety of coordinate systems
- use spreadsheet software
- draw and analyze simple electrical circuits
- use a mathematics package (MATLAB)
- write laboratory and technical project reports
- prepare visual aids using computer software
- give effective oral presentations
- make multi-view and isometric sketches
- make section views
- make working drawings, including dimensions and tolerances, to be used in manufacturing a product
- use CAD (computer aided design) software.

The basics skills portion of the course also includes discussions of professional ethics, the design process, and project management.

In the bicycle labs, students learn how to make accurate measurements of the bicycle frame components and calculate the weight of the frame. They do a beam deflection experiment to explore some of the properties of a variety of materials that might be used in a bicycle. They gather and analyze data on static and dynamic forces on the bicycle’s components as they sit on and ride a bicycle with strain gages on the front fork. Students consider how each of the topics they study affects the bicycle’s design. Student teams also investigate various manufacturing processes for bicycles, taking into account both technical and business aspects, and give an oral presentation on their findings.

In the camera labs, students investigate the mechanical, electrical, and optical systems of the camera as well as learning how many of the metal and plastic parts of the camera are made. They estimate the camera shutter speed using the “blur angle” of a moving wheel in a photograph and then measure the speed using an oscilloscope. They disassemble the camera and learn how the shutter and flash work. Negatives of photos students take with the cameras are used to help determine the focal length and depth of field for the camera, and students discuss what impact those values of those parameters have on camera design. Using the oscilloscope, students measure voltage in various parts of the camera’s flash circuit as a function of time.

There are five bicycle laboratory exercises and five camera labs. Student teams prepare a written report for each lab. The reports are to be typed and include any tables, graphs, or illustrations necessary to convey clearly and completely the work done in the laboratory and the results. Students are also required to discuss the results of their experiments and any inconsistencies in

the data. While all students are involved in preparing the report, the final product is to be a coherent, polished document, not four or five separate pieces of work stapled together. Time is provided in class for students to assemble, review, and revise their reports.

The team design project in the second semester is quite different from the bicycle and camera labs. Instructors provide the student teams with a package of materials and a set of specifications the final conveyor/sorter system must meet. All teams are expected to build a standard conveyor, and its design is constrained by the materials provided. However, students have a great deal of freedom in the design of the sorter system. In preparation for building the counter that must be incorporated into the sorter system, students receive some additional instruction on electrical circuits and sensors. Otherwise, students plan their own laboratory activities.

As noted in the section on basic skills, students receive instruction on the design process, project management, and preparing written and oral reports. Those skills are employed in the team design project. Each team must prepare a design project schedule showing the tasks to be done, the person responsible for each task, and the due dates. Teams must also document their design process and their final design in a report that is sufficiently detailed to allow another team to recreate their design. Near the end of the semester, the quality of the reports is tested by giving each team's draft final report to a team in the other class and having that team build the sorter described in the report.

Teamwork is an important component of the course. Through trial and error, group discussion, some coaching, and formal evaluations of their own and team members' performance, students learn how to be an effective member of a team. They grow to understand the importance of teamwork in completing a complex task that one person could not do alone in the time allotted, and they learn to equitably distribute the workload.

### **Course Structure and Management**

Two sections of Introduction to Engineering are taught at Walnut Hills, one with 30 students and one with 29. Each class meets one period (50 minutes) a day, 5 days a week. The course is offered for one high school credit and may be counted as either a math or a science credit since it fully integrates the two subjects. It is team taught by one math and one science teacher from Walnut Hills with some support from OSU faculty and staff.

The classes are taught in three different classrooms, depending on the material being covered. Basic skills not requiring computers are taught in a regular classroom. When the skills being taught require a computer or when students are completing lab reports that require integration of text and graphics, the class meets in a computer lab. Hands-on laboratory activities are done in a physics lab, which has seven lab stations, each equipped with a computer and a variety of tools.

A typical class period begins with a presentation on the topic of the day and perhaps an example. Students then begin working on an assignment that illustrates the concept or employs the skill being taught. Walnut Hills teachers make almost all of the class presentations, generally using slides prepared by OSU faculty. Those slides are similar, if not identical, to the ones used in the OSU course. The high school teachers also have copies of videotaped presentations by OSU

faculty and staff on some topics. A graduate teaching associate from Ohio State is assigned to help with the Walnut Hills course and usually visits the high school once a week, primarily to help with the lab activities. Concepts are presented using a variety of techniques and formats to accommodate many learning styles.

Each Walnut Hills student maintains a portfolio of all of his or her work in the Introduction to Engineering course. If a Walnut Hills student chooses to attend Ohio State and study engineering, he or she may present the portfolio to the IE Director at Ohio State for review. If the Director determines that the student's portfolio demonstrates mastery of the material covered in IE, the student receives 6 hours of university credit for Engineering 181 and 182, the Introduction to Engineering sequence at Ohio State. As with other transferred credit, no specific grades for Engineering 181 and 182 are entered on the OSU transcript for the Introduction to Engineering course taken at Walnut Hills.

To help ensure that the material covered in the Walnut Hills IE course is equivalent to what is covered in the OSU courses, Ohio State faculty and staff prepare materials for the Walnut Hills course. Those materials include laboratory procedures, exams, and student notebooks containing copies of the presentation slides, supplemental reading materials, and homework assignments. OSU faculty and staff specify the textbooks, software, and laboratory equipment to be used in the course and arrange for their purchase. The grant from General Electric provides the funds to print the student notebooks and purchase the other materials.

### **Establishing a University/High School/Industry Team**

All three members, Walnut Hills High School, Ohio State University, and General Electric were important to the success of this project. The Ohio State University College of Engineering took the lead in forming the team. The first step was to identify a school with a strong academic program, particularly in math. Faculty teaching IE at Ohio State had observed that there was a strong correlation between a student's initial math placement and his or her success in IE. Students who started their college math sequence in pre-calculus or higher generally had higher grades in IE. Walnut Hills was the only urban school identified in Ohio where most of the juniors take pre-calculus, making the seniors excellent candidates for an Introduction to Engineering course.

The next step was to talk with the high school principal to see whether the school had any interest in offering IE. In the case of Walnut Hills, the principal was enthusiastic and asked the OSU team to present the proposal to the faculty to see whether they were interested. They were. By December 2000, OSU and Walnut Hills had decided to offer IE at Walnut Hills High School beginning in the fall of 2001.

Moving forward required immediate action on three tasks: recruiting students, preparing Walnut Hills faculty to teach IE, and assembling the materials and equipment for the course. The last two items, and particularly the last one, required significant funds. OSU team members had been talking with potential industry partners for some time, but no final agreements had been reached. We did not want to begin recruiting students, preparing teachers, and gathering course materials, unless we were certain that the course would be taught. The College of Engineering and Walnut

Hills High School, along with the Walnut Hills Alumni Association, were determined to make the IE course at Walnut Hills a reality and pledged to find the resources to offer the course, at least at a bare-bones level. Work on the course and discussions with potential industrial sponsors continued in parallel. The addition of General Electric to the team assured that the students would have the materials and equipment they needed to achieve the best possible understanding of and appreciation for engineering.

While the proper equipment and instructional materials are important to the success of the class, experienced, enthusiastic, and well-prepared teachers are absolutely essential. Walnut Hills High School had experienced, enthusiastic teachers. However, those teachers had not studied engineering and needed to learn the material in the course before they could teach it. Members of the OSU team visited Walnut Hills many times during the spring and summer of 2001 to work with the teachers in the classrooms where the course would be taught. In addition, Walnut Hills teachers visited the OSU IE labs to do the laboratory experiments and work with the software that would later be installed at Walnut Hills. In the summer of 2001, OSU faculty and staff offered a 3-credit hour course on teaching IE, and the Walnut Hills faculty planning to teach IE took that course for graduate credit. The General Electric grant covered the cost of teacher preparation.

### **Project Assessment and Lessons Learned**

Teaching Introduction to Engineering at Walnut Hills is a pilot project. The intention is to continue offering IE at Walnut Hills and eventually to offer a similar course in selected high schools in other areas of Ohio. Continuous project assessment is needed to guide course modifications as well as to determine the IE course's impact on the students enrolled. A number of assessment tools are being used, including a slightly modified version of the Pittsburgh Freshman Attitudes Survey and a survey for evaluating each team member's performance on the team (Team Developer, developed and used by members of the Gateway Engineering Education Coalition). Student performance on homework assignments, lab reports, and exams are also a measure of the effectiveness of the course. One of the most important formal assessments will be determining the number of students from the IE course who enroll in, and graduate from, college engineering programs and comparing the percentage of this year's Walnut Hills seniors selecting engineering as a college major with the percentages from previous years. Other assessment instruments include asking students to answer some questions about the course every few weeks and discussions with focus groups at the end of each semester. The focus groups consist of about 10 students from a variety of backgrounds and having varying degrees of success of the course.

Perhaps the most extensive and valuable course assessment is by the two Walnut Hills faculty members teaching the course. The faculty members each have a notebook containing all of the PowerPoint slides used to present the course, one slide to a page, with space for notes on the bottom half of the page. They also have copies of the class examples and homework assignments. The faculty members have been keeping notes on the IE course materials; these notes include questions the teachers have about the materials and suggestions for improvements. In addition, the OSU project team has been keeping notes on the questions the teachers ask.

Observations by the Walnut Hills students and teachers as well as the OSU team members will be used during the summer of 2002 to modify the course.

Listed below are some of the most useful lessons learned about this IE pilot project during its first year at Walnut Hills High School.

- The course requires 2 teachers, and the more “computer savvy” they are, the better.
- Having easy access to the OSU staff during the year and having a TA assisting with the lab activities in the high school is important.
- Teachers need time to get familiar with the technology.
- Teachers prefer learning the course material in several short sessions to one long session.
- Having the teacher preparation sessions held during the school year at OSU, away from the high school and demands of the students, was helpful.
- Teachers need a complete set of assignments with solutions and a full set of “A+” lab reports.
- The course schedule has to be flexible to accommodate high school activities.
- There is barely enough time to cover two 10-week quarters’ worth of college material in two 18-week high school semesters.
- Occasional quizzes are needed in the high school course to ensure that students read the assignments and prepare for labs.
- Students help each other learn to use computer software such as CADKEY, Excel, and MATLAB and help each other with computer-related difficulties in the classroom or lab.
- Learning equitable teamwork is an experiential process, greatly aided by reflection and team feedback.

## Conclusions

The Introduction to Engineering course required for beginning engineering students at the Ohio State University has been successfully piloted at Walnut Hills High School in Cincinnati, Ohio. The course has introduced a diverse group of students to engineering and made them aware of career options in that discipline. In addition, it has given students a chance to build skills that will be useful to them in school and on the job - regardless of what career they choose. Students, parents, teachers, and administrators believe that the course has been beneficial to the students, several of whom have selected engineering as their college major.

However, introducing a college course into a high school curriculum requires substantial commitment and effort from the high school administration, college faculty and staff, and especially the high school teachers presenting the course. Close and frequent communication between the high school teachers and college faculty and staff is essential. In addition, successful implementation can require significant funding to ensure that the high school students have the textbooks, lab materials, and computer hardware and software required for the course and that the teachers have sufficient time and instruction to prepare for their teaching assignment.

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## **BIOGRAPHICAL INFORMATION**

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ARTEMUS HERZOG is a graduate student in Electrical Engineering at The Ohio State University. During the 2000-01 academic year, he was a graduate teaching associate in the Introduction to Engineering program at Ohio State, and this year, he is supporting the Introduction to Engineering course at Walnut Hills.

JOHN MERRILL is the Administrator of the Introduction to Engineering program at The Ohio State University. He holds a Ph.D. in Education. He has developed and carried out the assessment of Introduction to Engineering both at Ohio State and at Walnut Hills.

LIV RAMSTAD teaches Introduction to Engineering and 8<sup>th</sup> grade honors science at Walnut Hills High School.

FERD M. SCHNEIDER is a certified Math and Chemistry teacher currently teaching Introduction to Engineering at Walnut Hills High School. Mr. Schneider received his degree from Miami University and is currently finishing his Masters in Math Ed. Mr. Schneider has been teaching Algebra, Geometry, Advanced Algebra, and Pre-calculus at Cincinnati Public since 1990. Mr. Schneider also coaches football and swimming while spending his weekends playing rugby for the Cincinnati Wolfhounds.