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Introduction to Engineering: An Assessment of a High School Course

Introducción a la Ingeniería: Evaluación de un Curso de Escuela Secundaria

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Abstract

The University of Mississippi in conjunction with Oxford High School (Oxford, MS) developed a course titled *Introduction to Engineering*. This one semester course was offered during the 2000-2001 academic year. The desired outcomes of this course were to familiarize students with the field of engineering, enhance academic skills, and foster critical thinking in problem solving. The purpose of this article is to present the results from an assessment study performed that suggests all three objectives were realized. Based upon the student responses to self-report instrumentation, suggestions are offered for persons interested in creating similar courses for implementation in other high schools.

Key Words: High School, Engineering, Science, Assessment

Resumen: La Universidad de Mississippi en conjunto con la Escuela Secundaria de Oxford (Oxford, Mississippi) desarrolló un curso llamado *Introducción a la Ingeniería*. Se ofreció este curso, de un semestre de duración, durante el año académico 2000-2001. Los resultados esperados eran familiarizar a los estudiantes con el campo de la ingeniería, incrementar sus habilidades académicas, y fomentar un pensamiento crítico en la resolución de problemas. El propósito de este artículo es presentar los resultados de un estudio de evaluación hecho en este curso y demostró que se alcanzaron estos tres objetivos. Basándose en las respuestas del estudiante a la instrumentación de autoevaluación, se ofrecen sugerencias a las personas interesadas en crear cursos similares para ser implementados en otras escuelas secundarias.

Palabras Clave : Escuela Secundaria, Ingeniería, Ciencia, Evaluación

Introduction

Simply stated, college students are former high school students. Thus, to increase enrollment in science and engineering programs, secondary school students must develop an interest in these fields. Unfortunately, in geographic locations where few technical role models exist, college-bound students may not consider a major in science or engineering because of their unfamiliarity with these professions. In an attempt to foster awareness specifically for the field of engineering, the first author directed an effort to create an introductory course in engineering that can be used to present the breadth of the profession to high school students in Mississippi.

During the 2000-01 academic year, a course titled *Introduction to Engineering* was offered by Oxford High School (OHS) located in Oxford, Mississippi. This course was the result of a cooperative effort between the first and third authors and five University of Mississippi engineering faculty from the disciplines of aeroacoustics, civil engineering, and chemical engineering. This course attracted nine students in the fall semester and six in the spring, and the course has been recently approved by the Mississippi Department of Education as an approved science or mathematics elective. The course was designed for minimal prerequisites (i.e., Algebra I and Geometry) in order to allow students to experience the course early enough in their high school curriculum so that they could enroll in additional mathematics and science courses if an interest to pursue a degree in mathematics, science, or engineering was developed. The major outcomes for this course include (a) developing an understanding of the field of engineering to permit an informed academic/vocational choice by the students; (b) enhancing academic skills due to the rigor of cross disciplinary problem solving; and (c) fostering critical thinking in problem solving skills that are important regardless of ultimate vocations pursued.

The course consisted of five learning modules. To a large extent, each faculty member designed the content of his respective module with the OHS teacher working as an instructional consultant. The teacher was tasked to learn the relevant content material of each module and design a learning activity based upon the module’s focus. The general topics included (a) *Designing a Coffee Maker*; (b) *Plant Chromatography*; (c) *Controlling Room Acoustics*; (d) *Designing a Bridge*; and (e) *General Problem Solving* (see Table 1). The goal of each module was to develop critical thinking skills in problem solving by allowing students to work together on solving engineering problems of personal meaning by using a foundation of relevant content knowledge. A cross-disciplinary approach was used to give added meaning to science and mathematics in solving “real world” problems. Mathematics, chemistry, chromatography, heat transfer, mass transfer, statics, fluid mechanics, acoustics, and electricity represent some of the new areas that students were able to experience and use in designing team developed projects.

Table 1. Description of Modules

Module	Specific Theoretical Content	Major Activities
Coffee Maker	**energy, heat/mass transfer, fluid flow**	**Design and build a coffe maker**
Chromatography	extraction, chromatography, spectroscopy	Solve a murder mystery by identifying a victim's poison
Room Acoustics	sound, absorption, reverberation	Determine acceptable reverberation times for concert halls, chamber halls, theaters, and opera houses
Bridge Design	statics, strength of materials	Design and build a bridge
Problem Solving	mass/energy balance, surveying, electricity	Design an in-ground swimming pool with appropriate piping; using data acquired in class, compute the power dissipated by a resistor

The purpose of this article is not to elaborate on each learning module [more information about the modules may be found in Kendricks and Ponton (2001)], but rather to provide information with respect to assessment via self-report instrumentation administered to the spring semester students before and after taking the course. While such a small group study is not amenable to quantitative-based generalizations, nonetheless the students' comments do provide insight into the minds of secondary school students with respect to the engineering course. Perhaps such qualitative information may be of use to other persons interested in developing successful high school courses in engineering.

Method

Permission to conduct human subject research was granted to the first and second authors by The University of Mississippi Institutional Review Board. At the beginning of the spring semester, an *Assessment Consent Form* was distributed to all students for the appropriate parental signatures. After all consent forms were returned to the OHS teacher, the teacher administered the pretest (Appendix I).

Acquiring the consent forms and administering the pretest occurred within the first week of the semester.

One week before the end-of-semester final examinations, the first author visited the class to administer the posttest (Appendix II). Note that the posttest as presented in Appendix II has been slightly modified in that questions 3 through 12 actually presented the student with about 1½ inches of blank space for their responses. Also, students were asked by the researcher to change the names of two modules to *Plant Chromatography* and *Designing a Bridge* to more accurately reflect the content of these modules (the original names are not shown in Appendix II).

Another modification to both Appendices is that the actual assessment instruments requested the last four digits of the student's Social Security Number (located in the header of each instrument) to facilitate pairing of pre and posttest responses. To preserve anonymity, the first author maintains all administered forms and solely compiled the data for summary interpretation. As per the American Psychological Association guidelines, all raw data will be kept for a minimum of 5 years after article publication (American Psychological Association 2001). Both pre and posttests were deemed face valid by the researchers as the items measure only what they purport to measure without respect to any underlying construct. The sole purpose of these instruments is to provide qualitative descriptive information; therefore, there is no constellation of items that would correlate in a manner consistent with content validity. Each item was designed to be open-ended to provide insight into the opinions of the students with respect to engineering, the course, and the course's effects on them. No risks (physical, psychological, social, etc.) to the subjects were anticipated as a result of completing the instruments. In presenting the results of the surveys, the six students will be referred to as students A through F.

Results

Do you want to study engineering in college? [Pretest/Posttest]

Table 2 presents a comparison of the pre and posttest with respect to the question *Do you want to study engineering in college?* (Refer to the Appendices for a complete description of the Likert response scale.) As indicated in Table 1, only students A, C, and D had an interest in studying engineering before taking the course. After the course, student A's marginal desire (a score of 5) changed to a neutral position while both students C and D maintained their desire. Interestingly, the largest change occurred with student F who went from a neutral position to a distinct desire to study engineering. Also seen in the table is a change in student E from a neutral position to a marginally negative desire to study engineering. These data indicate that the class composition was not solely representative of students with preconceived notions of studying engineering in college. Students without a decided desire to become engineers generated many of the positive comments that will be highlighted later in the article.

Table 2. Student Responses to Item 1

Student	Pretest	Posttest
A	5	4
B	4	4
C	6	7
D	6	6
E	4	3
F	**4**	**6**

Do you believe that you are capable of studying engineering in college? [Pretest/Posttest]

Presented in Table 3 are the pre and posttest comparisons to the question *Do you believe that you are capable of studying engineering in college?* As the data indicate, the students are highly self-efficacious with respect to engaging in an engineering course of study. Although student responses attesting to the rigor of course will be highlighted later, the demands of the course did not negatively affect the student perceptions of self-capability as reflected by the posttest results. This is an important result because as Ponton et al., (2001) assert “self-efficacy [i.e., perception of self-capability] plays an important mediating role [in cognitive motivation] because goals are selected based upon subjective probabilities of successful accomplishment” (pp. 250-251). Thus, the high level of self-efficacy displayed by the results presented in Table 3 indicates that all of the students would choose to pursue a major in engineering if they had the desire to do so.

Table 3. Student Responses to Item 2

Student	**Pretest**	**Posttest**
A	7	7
B	5	6
C	6	6
D	7	6
E	6	7
F	6	7

What are your views on engineering as a profession? [Pretest]

The students identified several themes associated with the engineering profession: (a) “well paid position for above-average persons” (student A); (b) “very interesting” (student B); and (c) “hard to get a degree in. . . but I will enjoy it when I learn what it is about” (student D). Student F asserted:

It’s a well-respected profession. When someone tells you that they [sic] are an engineer, you think they are pretty smart. I think I would like to be an engineer because I like to build things and figure out how things work. It’s hard work but fascinating when you understand.

This response is somewhat interesting because student F responded in the pretest to Item 1 with a neutral response. Thus, the response to this pretest question indicates that student F was considering engineering as a profession before taking this course.

In general, the students do appear to have a general image of the engineering profession as “a worthwhile career” (student E) with regard to interest, money, and social respect. Also, a perception exists that engineering is an intellectually challenging field to enter into. However, none of the students responded to this question with any information that indicated they knew specifically what engineers actually do. One goal of this course was to enlighten students to the breadth of the profession.

Has this course changed your desire to study engineering in college? If so, how? [Posttest]

As could have been predicted from Item 1 (see Table 2), most of the students (A through E) responded to this item that the course did not change their desire to study, or not study, engineering in college. The only exception was student F who responded as follows:

> Yes. Before I took this course, I thought that I wanted to be a doctor and go to medical school, etc. Now, however, I want to study engineering in college. We studied some things, esp. [sic] the chemical engineering things that 'sparked' my interest.

Some responses did indicate that the course was used by the students to better understand engineering. Student B asserted "I took this course to just see what engineering is really about [as] I just thought it would be something new" and student C stated "it [the course] has not changed my desire to study engineering but it helped me come to the conclusion of what [engineering] fields I am and are [sic] not interested in."

Has this course changed your views on your capability to study engineering in college? If so, how? [Posttest]

The results presented in Table 3 certainly indicate that the students strongly perceived themselves capable of studying engineering in college. The results from this item were overwhelmingly consistent with Table 3 with five of the students explicitly responded with a "No." Although student C remained highly efficacious (see Table 3) and was the only student not responding explicitly with a "No," this student responded as follows: "This course helped me realize how hard engineering really is." This response may indicate that the course authentically presented the rigor of engineering study but not to the point of instilling self-doubt in the students' perceived capability. As indicated earlier, such self-doubt in capability could deter future choices of activities.

Student F responded as follows: "I felt that I probably could study it [i.e., engineering] if I had wanted to. The course did make me <u>want</u> [sic] to study it , though." Consistent with the data presented in Table 2, student F appears to be interested in studying engineering as a result of this course.

Has this course changed your views on engineering as a profession? If so, how? [Posttest]

While students B, C, and D did not profess different views of the profession as a result of taking this course, students A, E, and F did. Student E responded “[the course] showed me more things that engineers do & [sic] introduced me to different fields of engineering” and student F stated “at first I thought that engineering was a very limited profession, but now, I see that there are nearly limitless possibilities for engineers.” The course appears to have accomplished a very important goal of introducing the students to the diverse activities that engineers engage in.

Has this course changed your views on any other high school classes? If so, how? [Posttest]

The responses reveal that the experience of taking this course contrasts greatly from other courses these students have taken. Student A responded “some of my other (Chemistry) classes now seem far too inflexible and graded too much on useless details rather than good comprehensive knowledge”; student B responded “I actually have to work hard and listen [in engineering class] to get a good grade”; student E replied “other classes do not usually require as much from you & [sic] many are less interesting & [sic] hands-on”; and student F stated

> Now that I have taken this course, I see that there are courses out there that can stretch my mind and challenge me. Through this course, I have seen, for example, how boring some of the normal math classes are.

While students A, B, and E did not indicate an interest in studying engineering in college (see Table 2), they nonetheless appear to have grasped some of the salient characteristics of an engineering course of study, i.e., rigor, flexibility, and “comprehensive knowledge.” Certainly, these students are in a better position to make an informed choice when deciding upon an ultimate vocation.

Has this course changed you as a learner? If so, how? [Posttest]

The majority of the students felt that they had changed as a learner because of this course. Indicative of the rigor associated with engineering, student B stated “I have to take time outside of school to actually learn the material” while student E asserted “it [the course] forces you to pay attention & [sic] keep up during class.” This certainly has implications in preparing students for a collegiate path. As student D stated, “it [the course] has shown me how things will be done in college.” Although student F did not indicate a change as a learner, this student did state, “this course caused me to learn more.”

Has this course changed your problem solving capability? If so, how? [Posttest]

The development of critical thinking in problem solving through the study of engineering was a major factor in generating an interest by the school system to offer the introductory course. Engineering, as a scientific discipline, is highly focused on the development of innovative solutions to complex problems. Such problems are typically decomposed into realizable sub problems where insights in the sub problems are derived using multi-disciplinary sources of information. The solution to the original complex problem is then developed through the logical synthesis of information gathered from physical and mathematical principles as well as from experimentation. This process facilitates problem-based learning and aids in the development of the critical thinking skills useful to virtually every specific academic discipline as well as to life in general. Thus, the study of engineering can be the vehicle for developing critical thinking skills that transcend the discipline of engineering itself.

The majority of students indicated that they felt they had changed as problem solvers because of this class. The two major themes indicated were becoming more careful in developing solutions and having to think more when solving problems. As student D asserted “I think it has [i.e., changed problem solving capability] by making me write down all the steps and going over them more carefully” and student F stated, “I feel that engineering has stretched my problem solving capability. It forced me to think harder and use my mind to solve difficult problems.”

Was there any particular aspect of this course that you particularly liked? If so, what was it? [Posttest]

While the students did enjoy different specific aspects of the course, the major theme from the responses was an enjoyment of “hands on” activities. Student C stated, “I really enjoyed making the coffee maker and bridge because I like building things & [sic] adding my own details” (Figure 1 shows a student enjoying his bridge), while student F asserted

I particularly liked and enjoyed the study we did on chemical engineering w/ [sic] the GC [gas chromatograph] and spectrophotometer. This unit was very fun, and it was something new for me. In fact, I enjoyed it so much that I think that I want to study it in college.

With regard to the pedagogy and the use of several team activities to facilitate critical thinking, student A professed to enjoy “the relaxed, but still constructive, atmosphere.”

Figure 1. A student relaxing on his bridge.

Was there any particular aspect of this course that you particularly disliked? If so, what was it? [Posttest]

There was no major theme with the responses to this item. Individual students did not like particular topics such as mass balance (student C), chemistry (student D), and electricity (student E) while both students A and B did not like the mathematics. But student B understood the importance of mathematics in engineering by the statement “I hate math, but that [i.e., mathematics] is a huge aspect in engineering.” Student F did not dislike any particular content area but did state, “The only negative point I can think of was that it [the course] went a little slow. I think the class should have gone at a little faster pace.”

The comments are indicative of individual preferences and differences. Thus, the responses do not warrant any particular change in the course’s content material at this time. However, the course developers (particularly the first and third authors) are planning to develop new modules in the future thereby continuing to broaden the students’ understanding of the breadth of engineering.

Would you recommend this course to another student? Why or why not? [Posttest]

The majority of students indicated that they would recommend the course to their peers. Student B responded “this class makes you a better student in so many ways”; student C stated “if the [potential] student has the slightest interest in engineering they sould [sic] take this course because it could help them realize if this is the profession they would like to pursue"; student D responded "I think it [the course] will help them do better in other classes in problem solving, write-ups, and studying"; and student F stated "I thought the course material was excellent. . . . I would especially recommend it [the course] to any study [sic] who feels a little bored in their normal classes. This course causes you to be stretched."

Is there anything else that you would like to comment on concerning this course (please elaborate)? [Posttest]

As expected, a question this broad did not reveal any common themes among the students. Individual students recommended the following: (a) the removal of grades based upon contests between teams (student A), e.g., in the designing/building a bridge module, a contest was held that awarded points between various teams based upon the amount of weight each respective bridge could withstand (see Figure 2); (b) an increased level of planning to permit more time for the *Designing a Bridge* module (student C); (c) more hands on activities and field trips (student D); and (d) more prerequisites, particularly chemistry (student F). While more prerequisites will not be added because a goal for this course is to be as accessible as possible to all students, the comments of students A, C, and D will be considered for next year's offering.

Figure 2. A bridge after failure (notice fallen weights).

In numerical order where number 1 represents your favorite engineering module, please assign a number to all of the engineering modules that you covered in the semester. [Posttest]

The responses to this item are presented in Table 4. By a simple summation of the rankings, the students preferred the modules in the following order: (1) *Designing a Bridge*; (2) *Designing a Coffee*

Maker; (3) *Plant Chromatography*; (4) *General Problem Solving*; and (5) *Controlling Room Acoustics*. This result is not surprising as the top three modules contained hands on activities that the students have already professed as preferring in Section J. *General Problem Solving* had some simple hands on experiments in electricity while *Controlling Room Acoustics* was completely devoid of such activities. The results of this item suggest that *Controlling Room Acoustics* should be modified to contain a hands on activity.

Table 4. Student Responses to Posttest Item 13

Student						
Module	**A**	**B**	**C**	**D**	**E**	**F**
Designing a Coffee Maker	2	2	1	2	5	3
Plant Chromatography	3	5	2	5	1	1
Controlling Room Acoustics	4	4	4	4	4	5
Designing a Bridge	1	1	5	1	3	2
General Problem Solving	**5**	**3**	**3**	**3**	**2**	**4**

Discussion

Based upon the student responses, the major outcomes of the course were achieved: (a) the development of an understanding of the field of engineering to permit an informed academic/vocational choice by the students; (b) the enhancement of academic skills due to the rigor of cross disciplinary problem solving; and (c) the fostering of critical thinking in problem solving skills that are important regardless of ultimate vocations pursued. The students gained an appreciation for the breadth of engineering professions, the rigor associated with the study of engineering, and an appreciation for the "comprehensive knowledge" required in solving engineering problems. Fortunately, the rigor of engineering study did not significantly alter the high level of self-efficacy that each student brought to the course.

Persons interested in designing a similar course should consider developing hands on activities that build upon theoretical topics. The students participating in this introductory course overwhelmingly enjoyed using content knowledge and creativity to solve real world problems via team-based activities. The rigor of engineering study should not be avoided as the students in this study welcomed and in some cases appeared to enjoy the academic challenge.

While the prerequisites were minimal for the highlighted course, it is suggested that this practice be followed in order allow as young a student as possible the opportunity to develop an interest in engineering. When such an interest is developed early in a high school program, curricular choices can be made to better prepare the student for a future collegiate course of study. For the most part, this course successfully introduced topics from science and mathematics when such information was necessary in understanding the direction of the learning module.

Conclusion

The major conclusions of this research are that students enjoy (a) hands on activities; (b) academic challenge as found in engineering; (c) group activities; and (d) using knowledge as the basis for creative thinking. The results of this qualitative investigation may serve as the foundation for research directed toward creating tenable generalizations that will serve as definitive models upon which to design similar courses.

The self-reported statements from the students who participated in the *Introduction to Engineering* course indicate that the course was a worthwhile project and should be continued. It is important that such projects be assessed to determine positive outcomes and needed modifications. While courses created and offered in other locations may develop assessment measures based upon specific needs, the assessment instruments presented in this article have provided important insights for this research. The authors encourage any future high school course developers to use, at their discretion, the assessment materials presented in this article.

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APPENDIX I: PRETEST ASSESSMENT SURVEY

Introduction to Engineering Pretest Assessment Survey

Please respond to the following items as honestly and completely as possible. For questions 1 and 2, please circle one number from 1 to 7 that best represents your response. For question 3, please provide your response below the question in the space provided (continue on the back of the survey form, if necessary).

Your candid responses will help the Oxford High School and Ole Miss faculty and staff improve the Introduction to Engineering course for the benefit of future students.

Thank you for your time in completing this survey.

1. Do you want to study engineering in college?

1	2	3	4	5	6	7
Definitely No			Neither Yes nor No			Definitely Yes

2. Do you believe that you are capable of studying engineering in college?

1	2	3	4	5	6	7
Definitely No			Neither Yes nor No			Definitely Yes

3. What are your views on engineering as a profession?

APPENDIX II: POSTTEST ASSESSMENT SURVEY

Introduction to Engineering Posttest Assessment Survey

Please respond to the following items as honestly and completely as possible. For questions 1 through 2, please circle one number from 1 to 7 that best represents your response. For questions 3 through 12, please provide your response below the question in the space provided (continue on the back of the survey form, if necessary).

Your candid responses will help the Oxford High School and Ole Miss faculty and staff improve the Introduction to Engineering course for the benefit of future students.

Thank you for your time in completing this survey.

1. Do you want to study engineering in college?

1	2	3	4	5	6	7
Definitely No			Neither Yes nor No			Definitely Yes

2. Do you believe that you are capable of studying engineering in college?

1	2	3	4	5	6	7
Definitely No			Neither Yes nor No			Definitely Yes

3. Has this course changed your desire to study engineering in college? If so, how?

4. Has this course changed your views of your capability to study engineering in college? If so, how?

5. Has this course changed your views on engineering as a profession? If so, how?

6. Has this course changed your views on any other high school classes? If so, how?

7. Has this course changed you as a learner? If so, how?

8. Has this course changed your problem solving capability? If so, how?

9. Was there any particular aspect of this course that you particularly liked? If so, what was it?

10. Was there any particular aspect of this course that you particularly disliked? If so, what was it?

11. Would you recommend this course to another student? Why or why not?

12. Is there anything else that you would like to comment on concerning this course (please elaborate)?

13. In numerical order where the number 1 represents your favorite engineering module, please assign a number to all of the engineering modules that you covered in the semester.

Engineering Module	Number
Designing a Coffee Maker	________
Plant Chromatography	________
Controlling Room Acoustics	________
Designing a Bridge	________
General Problem Solving	________