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AN ANALYSIS OF THE EFFECTIVENESS OF BRIDGING OF FUNDAMENTAL COURSES IN THE FIRST YEAR

An Interactive Qualifying Project Report
submitted to the Faculty of
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by

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Abstract

The "bridging model" is a new teaching model developed to help students make connections between basic mathematics and science concepts learned in early courses and the utility of those concepts in the students' major disciplines. This study assessed the effectiveness of the "bridging model" based on students' performance in courses and change in students' attitudes towards engineering and science. The Tukey statistical test of the difference of the means for multiple populations was used to conduct our analysis on both the course performance and attitudinal survey data. Student performance was assessed by comparison of exam and final course grade data from courses taught first without and then with bridging.

The analysis of the bridge from Calculus III to Introduction to Programming in C shows that students who were bridged performed significantly better on exams in t6he bridged-to courses in the bridged year. The results of the bridge from Calculus III to Chemistry III showed no significant increase in student performance. The Linear Algebra bridge to students' majors demonstrated significant improvements in students' performance on the final exam. The data shows no significant decline in performance of the students in any population.

The students' attitudes were assessed using the Pittsburgh Engineering Attitude Survey. The survey was administered to students before the fall semester and after the spring semester of the freshman year to assess attitude changes after a year of coursework which may have included bridging. The survey results demonstrated increases in bridged students' self-confidence in their problem solving abilities, and basic engineering knowledge and skills. Bridged female students showed a positive change in their

impression of engineering. Non-bridged students did not show any significant attitude change.

We believe that our results demonstrate that the bridging model is a viable and worthwhile format for course development. The format seems to offer students a way to learn material more in depth without detracting from their learning. It also seems to have a positive effect on students' attitude towards engineering and in no case does bridging detract significantly.

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1 Introduction

The curriculum of Worcester Polytechnic Institute (WPI) has had an outcomes orientation since the inception of the WPI Plan. Under the WPI Plan, students integrate classroom studies with research projects conducted on campus and around the world. Since the Plan's implementation almost thirty years ago, it continues to focus on the development of the competencies of students through team-based and real-world experience. This method of education is actually very unusual since most of the time people think about how one does in individual classes, as opposed to how one is able to perform when confronted by a complex problem. By assessing what students know and can do, overall effectiveness of the educational program, not just the aptitude to study and return information on a test, can be examined.

In addition to the WPI Plan, a new model was developed in response to a self-assessment study conducted at WPI. In the summer of 1996 WPI held its first Future Search Conference, an assessment program that solicited input from the stakeholders participating to help direct curriculum reform. WPI students reported that they saw the first two years of course work as very separate and compartmentalized. Students also reported that while they can master concepts in a mathematics course, they have great difficulty applying these concepts to problem solving in science or engineering (Miller, 1996). These findings agree well with those at universities across the United States which also showed that students do not perceive that the topics learned in basic courses link to topics in later coursework. The feedback showed that students fail to see how knowledge of basic concepts furthers their understanding of their major field of study. In an attempt to address these issues and as a first step toward developing WPI's curriculum to meet the requirements of the ABET Criteria (see 2.3.1), some members of the faculty have begun to develop curricular and conceptual bridges between pairs of courses in mathematics, physics, chemistry, biology, and engineering. These courses are designed to link material common to both courses in order to increase learning and understanding of fundamental concepts for improved learning in later coursework, and to develop interest through application of more fundamental subject matter.

1.1 Objectives

The goals of this Interactive Qualifying Project are twofold:

- To determine whether or not the "bridging model" is an effective method of increasing student learning of fundamental concepts in either or both of the "bridged-from" and "bridged-to" courses.
- To discover if taking bridged courses affects the attitude students have towards engineering, science, their knowledge, and their abilities.

We have developed two forms of analysis to assess the bridging model. The first analysis evaluates students' performance on standard evaluations like exams and final course grades. This data has been analyzed to determine if bridged courses have any effect on students' overall performance and learning. In the second analysis we administered attitudinal surveys to freshmen students to measure changes in students' attitudes over the course of their first year. These two measures will demonstrate any difference in student performance after exposure to bridging and how this learning method may have affected their attitudes towards engineering and their own abilities.

It is our hypothesis that the bridging of courses is an effective tool for learning and positively affects students' attitudes about engineering and science.

1.2 Terminology

It is important to cover some basic terminology that will be used throughout this report. We will use words like AP, Non-AP, bridged, non-bridged, bridged-from, bridged-to, term, A99, D99, etc. within the document. Therefore, this will be a section to reference for any specialized terminology.

Term — The word term refers to the seven-week unit of time that WPI students spend on each course. WPI students participate in four, seven-week terms over the course of one academic year, that is, two terms per semester. In each term students take three courses. Term A is the first term in an academic year (the first fall term), B is the second, C is the third, and D is the fourth. The normal method for writing about a term is to place the last two digits of the year just after the letter. For instance A99 refers to the first fall term of the 1999-2000 academic year.

AP, Non-AP — AP (for "Advanced Placement") means that a student has taken calculus III in the first term of his/her freshmen year. Most students start the freshman year in Calculus I or II, and students with AP credit can start in Calculus III. Although a student with AP credit might start in Calculus I, II, or IV, we are using this term as a shorthand way to refer to students who started in Calculus III.

Bridged, Non-Bridged — Bridged refers to a population that participated in a bridged course. For instance in one comparison there are four groups. The three control groups did not participate in a bridged course and therefore are labeled as Non-Bridged.

The experimental group did participate in a bridged course and is therefore labeled Bridged.

Bridged-from, Bridged-to — Bridged-from refers to the course where bridging was implemented to specifically link to material in another course. For instance, Calculus III is a course where bridging was implemented to link to Introduction to Programming. The bridged-from course is Calculus III. Introduction to Programming, on the other hand, is the bridged-to course. The curriculum of the bridged-to course is not altered in any way, but it is the course to which the bridged-from course links course content.

2 Background

2.1.1 The Foundation

The WPI Plan is a project-based system, a flexible, exciting, and academically challenging program aimed at helping students learn *how to learn*. Within this system, there are some underlying principles that make the WPI experience unique. First, the curriculum stresses that students have hands on experience with open-ended problems that professional scientists and engineers face in their daily work. Secondly, there is a commitment to the development of team interactions through group projects. Third, the curriculum calls on students to develop a skill set based on fundamental concepts. Fourth, the students are shown the impacts of technology on global society. This provides the basis for understanding and learning within a student's chosen field. These objectives have driven the WPI Plan for over 25 years.

WPI has had a great deal of success with the ideas and policies that have been developed under these guidelines. The university has created cooperative educational environments in many different aspects of the WPI experience. Classes in mathematics, science, and engineering develop teamwork through short and long term projects. The Interactive Qualifying Project and the Major Qualifying help students to develop skills for working in teams on long term, "real world" projects. This means motivating students by providing them long term project opportunities of their own choosing. In most cases, these projects are completed successfully because the students have a positive attitude about the project.

Gauging students' understanding of fundamental concepts and ideas is much harder than assessing their performance solving a problem. It is quite possible for one to hypothesize that if students are leaving WPI in high demand for the skills they possess, then they must have a firm grasp on the fundamental concepts that they have learned. On the contrary, many studies and self-reports from WPI students show that students do not fully understand the integral part that prerequisite courses play in later course work.

It is not hard to see how this problem occurs. In an introductory course, students are taught in the "language" of that discipline. In a mathematics class, the concepts of the mathematics are taught in the "language" of mathematics by working out examples spoken of only as mathematics problems. This is as opposed to physics, which uses the fundamentals of calculus to solve problems in the terms of physicists. Therefore the basic mathematics may be glossed over or not noticed at all in the physics course. Those students not in a certain major lose a lot of the concepts as the language used to teach the subject matter changes once they leave that particular department. This forces the students to relearn the same concepts in a different language before being able to apply what they have already learned. Each discipline must now re-teach the basics instead of developing students' understanding.

The bridging of courses seeks to find ways to teach the basic concepts of a discipline not as well known to students by using a language that is more familiar to students. For example, explaining the use of first and second derivatives in terms of the position, velocity, and acceleration vectors, or in terms of the van der Waals equation, gives the discussion validity in another discipline. This in turn should allow students to return later to a problem in chemistry and know how to find the characteristics of a chemical potential by looking at the properties of derivatives of the van der Waals equation. The connection between understanding what the derivative tells you and that it makes sense to check the first derivative to find the desired information is something students are expected to connect on their own in traditional non-bridged courses.

2.1.2 Evidence for Change

Failure rates of freshmen at WPI are concentrated in the most fundamental disciplines. For example there is a failure rate of around 24% for all Calculus I students in the first term of the freshmen year. There is also a high failure rate in the advanced freshman physics courses Classical Mechanics and Electricity & Magnetism. This is surprising considering that most of the students who take these courses have high aptitudes in math and science and were outstanding students in high school. So what has happened to this seemingly perfect relationship between good students and challenging coursework?

There is a school of thought that says performance in the freshman year is dependent on how a student views what is being presented to them. For instance, some believe that students learn better if they are presented with material that is familiar to them even if it requires them to solve a problem that would have seemed foreign before.

Take, for example, a student majoring in Mathematics, who is taking calculus. This student will most likely be very motivated to learn new mathematics. Now look at a student majoring in Computer Science and try to give him the same problem in calculus. What will he/she learn from it if his/her attitude towards the calculus class is that it is not computer science? Presumably he/she will not be interested in the course. Hence, will this student begin a homework problem with the same amount of desire to completely understand it as did the Mathematics major? Probably not.

With this in mind, let us assume this attitude towards classes outside of one's major is common at WPI. This is a good assumption because we find that people interested in the most fundamental disciplines, i.e. mathematics and physics, are the smallest populations in the WPI student body. These are the students we have observed to use their fundamental understanding in other courses more readily. There are many more students interested in majoring in Mechanical Engineering, Electrical Engineering, Civil Engineering, Chemistry, Chemical Engineering, Computer Science, Biology, and Biotechnology in each class year than in Mathematics or Physics. We expect that these students will use their fundamental understanding less in coursework outside of where they learn it. This presents the educators in these departments with a need to develop the students' motivation for the use of fundamental concepts. Hence, they need to portray fundamental concepts in a way that students can easily grasp.

Motivating a student to use something not in their immediate area of interest can be very difficult for faculty. The trick is to find a way to bring it into the realm of the students' interests. For example, the simple harmonic oscillator (SHO) represents a simple system based on fundamental concepts developed in differential calculus as it is represented by an ordinary differential equation. From the SHO different complex physical systems, such as a circuit made up of a resistor, inductor, and capacitor combination (RLC circuit) found in many Electrical Engineering problems, can be modeled. An RLC circuit is modeled by a second order differential equation and it has some very fundamental properties and solutions seen in the solution to the SHO. At first, however, it is difficult to see the SHO in an RLC circuit because the SHO is usually taught using the pendulum in a grandfather clock example. The connection between a pendulum, the design of a suspension system, and the bonding of two atoms is not so obvious to most students, but it is very apparent, to an expert in that discipline, what the pendulum means in an engineering problem. To the expert, it is the natural choice for explaining differential systems in engineering.

Other examples of these same connections between disciplines abound throughout first and second year courses. Examples include:

- The divergence theorem creating volume and surface integration -- seen both in Electricity and Magnetism and Calculus IV
- Path independence of line integrals, same two courses
- Solutions of second order ODE's [ordinary differential equations] -- already discussed here
- Dot products, projections and cross products (vector techniques) -- in both [Classical Mechanics] and [Calculus III]
- The process of iteration -- seen in both CS2005 [DATA STRUCTURES AND PROGRAMMING TECHNIQUES] and MA1023 [Calculus III] (sequence and series) (Davis, 1999).

It will take a large amount of work on the part of a faculty member to motivate the typical WPI student to gain a fundamental understanding of the SHO. To help the student achieve the desired level of learning, the faculty member is forced to spend more time in and out of class teaching and reviewing the topic, which keeps him/her from pursuing scholarly endeavors. Taking a faculty member from scholarly work makes the faculty as a whole less productive. This decreases the amount of research completed and grants awarded to faculty of the university as a whole, and is not an acceptable tradeoff for WPI. This is a university dedicated to the teaching of undergraduates, but it is also a competitive academic institution, which needs to be attractive to excellent researchers.

2.1.3 The Davis Educational Project

As WPI was faced with no immediate solutions to motivate students and increased overall faculty productivity, WPI was granted a five year, $800,000 award from the Davis Educational Foundation for the development of a test model to increase educational quality and productivity (Miller, 1998). This grant was distributed to the WPI faculty through mini grants for the redevelopment of first and second-year courses. The essential elements of course redesign were: increased student responsibility for learning, use of cooperative learning (CL), use of project-based learning, better use of faculty time, and the use of peer learning assistants (PLA's) (Miller, 1998).

This model was the beginning of what has evolved into today's very successful mathematics curriculum, where the use of PLA's to teach students in first and second year courses (Calculus I, II, III, IV, Linear Algebra and Differential Equations) has had a very positive impact. PLA's are students who are hired to facilitate conference sections to review material that the students enrolled in a particular class have questions about. The large class size in these courses creates a need for a large number of PLA's in the Mathematics Department. Having many PLA's results in a large amount of feedback on how students are handling the material. Also, the large number of first and second year students enrolled in mathematics courses provides a large experimental population for evaluating the effect of changes to teaching of the curriculum.

The PLA system has also been implemented in other departments in a variety of ways. Professor Susan Vick, of the Humanities and Arts Department, uses PLAs as tutors for students working on Sufficiency projects. This was a very innovative model where both PLAs and Sufficiency students reported increased learning and satisfaction. This program also significantly decreased Prof. Vick's advising time. The Mechanical Engineering Department used PLA's to help facilitate work on problems in lecture and conference. The Civil Engineering Department developed the PLA role for a computer simulation lab. Surveys revealed a marked increase in the number of students taking this course that plan to major in Civil Engineering as a result of this experience (Miller, 1998). Departments have had varied success with the PLA implementation.

The major result of the peer-assisted cooperative learning (PAC) course development project was a significant positive effect on student grades. Course grades in the last two years of students' WPI careers, retention rates, and graduation rates were also shown to be higher due in part to the PAC courses. PAC courses also resulted in major self reported benefits for the PLA's (Miller, 1998). Most faculty reported a significant amount of time saved using the PAC model (Miller, 1998). The PAC model is also cost effective, in that it has developed a means of creating greater student learning with less faculty time input. This leaves the faculty member with more time to pursue professional aims.

The PAC courses and departments have continued to operate under the PAC model even after the Davis Foundation funding expired. The Davis Project has resulted in substantial scholarship for participating faculty including 22 papers in professional journals, 30 professional presentations, 1 book, and 4 externally funded grants. The benefits have also promoted the limited adoption of this model at institutions such as MIT, The University of Illinois, at Champaign-Urbana, and the University of New Hampshire, at Durham (Miller, 1998).

2.2 The Bridging Concept

2.2.1 Fundamental Flaw

There is one problem that the PAC model has not been able to address; the inability to create change in students' attitudes towards the material to facilitate learning. It was necessary to interest students in appropriate prerequisite material that was required for later courses in the major. This is not a small problem. Considering the Davis Project's objective was to decrease the time that faculty spent teaching first and second-year courses, any new teaching tools should be able to increase student learning, thus decreasing the time faculty need to spend on a given course.

2.2.2 Finding a Fundamental Solution

The solution to the problem of motivational increase was to begin a project to study the effectiveness of bridging courses in the first and second years. Bridging courses is a method of teaching complementary material within two courses in order to motivate learning, while still covering all of the essential topics of each course. This entails the development of homework problems and projects in the language of the bridged-to discipline that also reinforces the fundamental concepts being taught in the bridged-from course.

If a student were taking both Classical Mechanics and Calculus III in the same term, course bridging from the Calculus course would entail using calculus problems that were similar to physics problems. The intent is to explain the concepts being learned in calculus using the language of physics. This common language should help to bridge the gap between the classes. This connection of material has been hypothesized to have a positive effect on students' attitude towards the material.

As the inception of this study a grant was written to the National Science Foundation titled "Building Bridges in the First Two Years: Making Connections Among Introductory Mathematics, Science, and Engineering Courses," for a two year research project to develop and implement the course bridging model. The grant was approved for funding for the academic year 97-98 and has been implemented since in mathematics courses including Calculus III, Calculus IV, Linear Algebra, and Differential Equations. These courses were all previously adapted to the PAC model to create a more effective learning system. Now the focus was to adjust the model to include bridging to create positive attitude change towards the material presented in the courses.

2.2.3 Course Bridging

Course bridging is designed to address a common set of well-known faults in the first two years of science and engineering education. These faults include:

- Students see introductory mathematics and science courses as having little apparent relation to one another or to their professional goals.
- Skills essential to academia and to the workplace -- communication, problem solving, working in groups, information gathering, and synthesis -- are not consciously nurtured (Miller, 1996).

Over time, individual disciplines have worked on these, but have struggled to create a positive attitude change in the students. The course bridging initiative is intended to help students realize that the fundamental concepts in prerequisite courses are central to their major disciplines. Group projects and individual assignments demonstrate the use of fundamental concepts to solve problems in other disciplines. "They also help to improve skills in information retrieval, teamwork, communication, and problem solving, which are key to a student's future success. These outcomes are being measured through data collection throughout the project to assess the value that potential bridging could offer" (Miller, 1998).

2.2.4 The First Bridging Model Components

The project needed material to bridge one course to another. These materials were developed in advance of the project. The following is an example of a problem that a student would be asked to solve in a course bridged from calculus to chemistry (Miller, 1996).

> Example 1: The simplest equation of state is that of an ideal gas:
> $PV= nRT$
> Where P (pressure), V (volume), and T (temperature), are the variables of interest. The remaining parameters are n, the number of moles in the volume, and R, the universal gas constant.
> A more realistic equation for state is the van der Waals equation
> $(P+(an^2)/V^2)(V-nb)=nRT$
> Here, a and b are constants that depend on the identity of the gas in the volume.
> The purpose of this project is to use Calculus and the computer to explore and illustrate some of the properties of this equation of state. Here are some questions to guide you along.
>
> 1. Solve for the pressure as a function of everything else. Fix n, R, T, and plot versus volume for each equation of state. When do the models agree most closely? What are some of the key differences between the two models? You will have to choose units and values for a and b in the van der Waals equation. (You can find a table of values in your chemistry book.) Experiment with different temperatures and different ranges for P and V in your graphs.
> 2. The chemistry text states that "as V becomes large...the van der Waals equation of state approaches and eventually becomes the same as the

equation of state for an ideal gas." Explain this claim in terms of a limit. (Hint: Go to your chemistry text and look up compressibility factor.)

3. The van der Waals equation has some strange properties at low temperatures (and/or low volumes and pressures). Look at P as a function of V for different values of T to illustrate these properties. Use what you know about derivatives (first and second) to analyze the behavior. (Study at least two examples--carbon dioxide (CO_2) and chlorine (Cl_2) are nice.)

Keys to designing the problems in bridging courses include the following: The project should have a range of structure, from well-defined initial tasks to somewhat ill-defined questions which allow (require) that the students make creative choices.

The project should require teamwork in a natural way. Activities should be linked so cooperation is important. The project must require that students collect information from outside the primary discipline. In this case, it would be a chemistry text or a chemistry expert. These experts could be specifically designated chemistry faculty, the student's current chemistry instructor, or specially trained interdisciplinary PLAs. The topic must be current in more than one course. In this case, the van der Waals equation was introduced in Chemistry I (CH1010) before curve analysis was discussed in Calculus I (MA1021). This is accomplished by comparing course syllabi for Calculus I-IV, Chemistry I and II .

Most of the students who enter WPI with Advanced Placement credit enter into the sequence of Calculus III, IV and either Chemistry I, II or Physics I, II in their first semester. This self-selecting group was small, but also large enough to look at in a preliminary study for bridging. Development of exercises for the group was fairly easy, since both physics and chemistry use calculus to solve problems in their subject matter. Physics and Chemistry courses were also necessary prerequisites for most students' major fields of interest, and most students in Calculus III were also enrolled in either Classical Mechanics or Chemistry.

This small population of AP students had a high failure rate in the Physics I & II bridged-to courses, and were specifically chosen for the first bridged course. This setup allowed the faculty to connect courses in which students were simultaneously enrolled. It allowed for the preliminary study, by Professor John Goulet, of how helpful bridging might be. The effectiveness of this link is the first item that this IQP has set out to evaluate.

The NSF grant also allowed development of an infrastructure to help faculty interested in bridging their own courses. The infrastructure consists of a "Bridge Planning Group," and web pages to help disseminate information. A few WPI faculty have adopted the bridging often accompanied by rethinking of their own teaching techniques. The existing bridge resource materials offer easy to access syllabi, multiple course descriptions, and a wide variety of opportunities for facilitating the linking of different courses.

2.2.5 Bridged Course Experiments

In the first bridging projects connections were made from one course to another course in another discipline. As the project has progressed, bridging has evolved from just calculus to physics to include calculus to physics, calculus to chemistry, calculus to computer science, biology to chemistry, etc. Some of these course bridges seem to have resulted in improvements in the students' learning. Students seem to have gained a more fundamental understanding of concepts after bridging. But we can only speculate that this improvement is because students have been exposed to the bridged material. This interpretation comes from assessments made by both the WPI faculty members involved in the course bridging and by Valerie M. Crawford, M.A., an externally hired professional evaluator who evaluated each of the bridging experiments.

Although course bridging appears to work, it does not suggest that it will work in all cases. In the evaluations made by Valerie Crawford, students performed better than the non-bridged students of the same aptitude from previous years on some exams in the bridge between Calculus III (Prof. Goulet) and Classical Mechanics (Prof. Phillies). The students that were bridged in this study were not bridged completely throughout the duration of the two courses because of some non-complementary course materials. There were significant improvements in the bridged students' performance on the first two exams in PH1111 over that of the control group, but on the third exam, the mean score of the bridged group was below that of the control group. This is most likely a result of the un-bridged part of the course occurring before the third exam.

In Professor Heinricher's Calculus III bridge to Modern Physics, there was an increase in the failure rate in Modern Physics upon the initial implementation of bridging. The bridged-to material was relativity and modern physics, which is very abstract material for most students. Although the mathematics in Calculus III bridged to Modern Physics are the same as those bridged to Classical Mechanics, the applications in Modern Physics are more complex and algebraically harder to deal with. Not having simple examples to bridge to, it is very likely that bridging to modern physics was very hard for the students. Finding material to cover in both courses that was complementary and understandable was difficult.

Professor Miller and Kildahl's bridge between Introduction to Biological Macromolecules (Biology) and Molecularity and Structure (Chemistry) was also not successful. The results showed no significant difference in the bridged student's scores in comparison to non-bridged students. The problem here could be that the bridge was not made explicit to the students, meaning that the bridging material was "slipped into" assignments, but was never specifically discussed in class. Homework sets for the bridged population contained more explicit chemistry problems than did the homework sets of the control population. With adjustment and different treatment, these courses could be managed better to provide more positive results.

2.2.6 Bridging of the Three Courses

In this project, we have looked at three different bridges. The first is a bridge from Calculus III to Introduction to Programming in C. Students in Calculus III who were also enrolled in Introduction to Programming were given calculus homework assignments in which they were directed to write a computer program to solve a calculus problem. These problems were integrated with standard calculus problems.

The second bridge was made from Calculus III to Chemistry III. This bridge was similar to the first bridge that we looked at. All the students of this bridge in Calculus III were also enrolled in Chemistry III. the difference in this bridge is that Calculus III is taught to the bridged population in term A and Chemistry III is taught to the same population in term C of the same academic year. This allows us to test the effectiveness of non-simultaneous bridges as opposed to simultaneous ones.

The third bridge was a general bridge to students' major disciplines. Students in Linear Algebra were asked to complete a number of group projects that contained problems students were likely to see in their major. These projects emphasized the mathematics as well as the engineering problems.

In all of these bridges, students were evaluated with standard examinations as well as projects and homework. Each of these bridges also had a control course taught in the previous year. All of the students enrolled were freshmen on the year they took a course. The students in the Calculus III courses were taught in separate sections. These sections follow a common syllabus, but students involved in one bridge do not share a section with students in another. These commonalties across bridges allowed us to look at three different types of bridging (simultaneous, non-simultaneous, and to major) and make comparisons between them.

2.3 Assessment

Assessment of the educational process is a key factor in curricular development. Through the evaluation of students' performance and attitudes, we are able to identify elements of the present curriculum that will help students the most as well as those that are ineffective. Over time, the evaluation of each part of the curriculum can lead to a better understanding of what it is that helps students gain the best understanding of the material they learn. It is through such assessments that WPI has been trying to develop better courses for its students.

2.3.1 Outcome Assessment at WPI

Concern about students' development of skills and knowledge that are useful in real-world problem solving situations led WPI to the development of the Competency Exam, which was, until about 1970, a degree requirement for graduation. For students, this was three days of written and oral examinations in their major. When the Plan was first developed, there were no distribution requirements for students to follow. Each student and advisor were free to develop a selection of courses that was tailored to the student's intended degree and special interests. For instance a student of Mechanical Engineering might specialize their coursework to concentrate in the design of machines rather than techniques of manufacturing. Within this system, the exam made sense since it determined the student's competency and could be used as a measure of the outcome of four years of work.

This form of academic review was not a standard of the accreditation system then used by the Accreditation Board for Engineering & Technology (ABET). At the time the Plan was conceived, the ABET accreditation was more of an exercise in counting the number of courses a student had completed. A visiting accreditation team would determine if each criterion could be met in its facilities, faculty, and students. For example, they would pull all the transcripts for the graduating Electrical Engineers and count the number of physics courses they had taken. If there were a sufficient number of courses per student for most of the graduating Electrical Engineers, then WPI would pass that part of the accreditation process. Without an institutionally determined course distribution for each major it was not always easy to pass such checks for reaccreditation. So finally, after many debates over the correct necessary requirements for accreditation, WPI imposed distribution requirements.

Use of the Competency Examination as an overall assessment of the student's competency for graduation was kept for a few more years. But with mounting pressure from families, faculty, and students WPI decided to discontinue the use of the Competency Examination. This did not end the outcomes based degree requirements, though. The WPI degree requirements still include three projects based on teamwork, open-ended problem solving, and professional communication. The project form has produced graduates who are in high demand as high quality engineers and scientists entering the workforce.

The WPI experience, though, has had an impact on the next generation of ABET assessment criteria. The new ABET Criteria 2000 takes an outcomes assessment approach to the evaluation of the engineering curricula of today. The new model of assessment will follow from the previous, by looking at things that have been criteria before, e.g.: student performance after graduation, faculty, facilities, and financial support. But the new Criterion 3, "Program Outcomes and Assessment" is very different and almost ambiguous. Criterion 3 is reproduced below from "How Do We Measure Success?" a publication of the American Society for Engineering Education.

> **Criterion 3. Program Outcome and Assessment**
>
> Each program must have an assessment process with documented results. Evidence must be given that the results are applied to the further development and improvement of the program. The assessment process must demonstrate that the outcomes important to the mission of the institution and the objectives of the program are being measured. Evidence that may be used includes, but is not limited to, the following: students portfolios, including design projects; nationally normed subject content examinations; alumni surveys that document professional accomplishments and career development activities; employer surveys; and placement data of graduates.
> Engineering programs must demonstrate that their graduates have:
> a) An ability to apply knowledge of mathematics, science, and engineering;
> b) The ability to design and conduct experiments as well as to analyze and interpret data;
> c) An ability to design a system, component, or process, to meet desired needs;

> d) An ability to function on multidisciplinary teams;
> e) An ability to identify, formulate, and solve engineering problems;
> f) An understanding of professional and ethical responsibilities;
> g) An ability to communicate effectively;
> h) The broad education necessary to understand the impact of engineering solutions in a global/societal context;
> i) A recognition of the need for and an ability to engage in lifelong learning;
> j) A knowledge of contemporary issues; and
> k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (ASEE, 1998).

The heart of this criterion is that the institution applying for accreditation must show students' competency in the areas listed. Does the university have a way of assessing the overall performance of students that represents accurately what the student knows and can do? To do that, the university must develop its own methods for determining the outcomes of the students' passage through the educational program. These evaluations are then used to determine whether the programs of the university are meeting the overall academic and professional needs of the students so that they will be competitive and useful in the job market for many years. The emphasis here is to determine if feedback from the results of the outcomes assessment is being used to improve the existing programs. This is not an easy task, especially if one is used to the usual counting approach to assessment. But this approach does shift much of the weight of development of assessment measures onto the university and faculty. It creates a need for the ongoing assessment to increase the effectiveness of teaching. This criterion pushes the university to not only look at the number of students graduating and taking high paying jobs, but also to look at whether their graduates will continue to be effectively prepared in the future. Is the education in the classroom pushing the students to their potential by offering them interesting problems to solve? It makes the university accountable to the student and to parents to produce education that does not lose its value as the world changes.

2.3.2 How Well Do We Prepare Our Students?

What is interesting within our focus on the freshman year and bridged course effectiveness is the question, *"How well do we prepare our students to understand the intimate linkages among basic concepts implied by parts a and e of criterion 3?"* Over a small interval of time, one can see if information from one class is being applied to solve problems in another. This means looking at things like performance in Math and Physics, Calculus and Chemistry, Calculus and Computer Science, Physics and Electrical Engineering, etc., and comparing student data to see if basic skills learned in one course affect a student's ability to solve problems in another.

2.3.3 Does Bridging Help to Improve Students' Attitudes Toward Learning?

Once we know whether or not the students' understanding increases through bridging courses as opposed to the traditional methods of teaching, we can begin to further ask, *"Does bridging help improve students' attitudes toward learning?"* The answer to this question comes in understanding the development of attitudes in the freshmen enrolled in the bridged courses. What happens to a student's attitude towards engineering and science, the basic disciplines of physics, calculus, chemistry, biology, communication, and computers, and how they feel about their own abilities as students when they begin to better see the connection between fundamental material in calculus and problems they need to solve in a computer programming or chemistry class?

This leads us to the question of how to assess the effectiveness of bridging on grade performance and attitude change in the freshman year. By hypothesizing that students will enjoy learning the material presented in a bridged curriculum more than in a standard curriculum, we can guess that they will walk away with a greater understanding and increased positive attitude about their skills.

2.3.4 What Do We Measure In Order To Test This Hypothesis?

There is a body of research concerned with attitude assessment in engineering students. Recent work by Dr. Besterfield-Sacre asks these questions: why is there stagnation in the number of graduating engineers, why is there attrition in engineering education, and what causes the change in performance level after the freshman year? Her work identifies some key features of how students react to their educational environment.

Attitudes of freshman engineering students change over the course of their first year. The type and quality of educational program that the students experience can affect these changes. Consequently, an accurate assessment of both the attitudes that students bring to the university and the attitude changes that occur over the course of the year can provide an effective means to evaluate freshman engineering programs (Besterfield-Sacre, 1996).

Table 2.1 Methods of Evaluating Engineering Students Attitude Change

Method	Engineering Examples	Comments
Closed-form Questionnaires	Impressions of the engineering fields, enjoyment of working on teams, Self-assessed competencies upon graduation.	Easy to administer, can be given to a large number of individuals.
Essay Questions	Engineering exams that request the individual to comment on the engineering ethics of a particular situation.	Easy to administer, hard to assess.
Ethnographic Studies	Observing teamwork on a project. Observing the cultures and environments that students experience.	Very time consuming.
Focus Groups	Feedback of academic and personal experiences.	Time consuming, typically conducted on a few groups with small number of individuals per group.
One-on-one Interviews	Exit interviews of students leaving an engineering program.	Time consuming to administer and analyze the data, typically give to a small number of individuals.
Portfolios	Document students' perceptions about their engineering program.	Difficult to assess.
Student Journals	Feedback of academic and personal experiences.	Allows for student reflection and self-evaluation, hard to assess.
Verbal Protocols	Document individual student approaches to solving engineering design problems.	Time consuming to administer and analyze, conduct a small number of individuals.

Dr. Besterfield-Sacre used a pre-survey to determine the initial attitudes of students entering the engineering curriculum and a post survey to determine the change in students' attitudes toward engineering, their own abilities and preparedness, and the academic institution. A team of researchers from the University of Pittsburgh has performed this assessment process continuously over the course of a six-year period. They have shown that the use of pre- and post-surveys can accurately identify students who will perform well and those who will not. Using these surveys, the researchers have been able to direct resources to students who most need them. They have also begun developing models to help predict which students will succeed easily and which will need help to stay within the engineering field (Besterfield-Sacre, 1996).

In the research at the University of Pittsburgh, the development of assessment materials was one of the first priorities in the investigation. Their interpretations of different methods of assessment are depicted in table 2.1 (Besterfield-Sacre, 1998). The research team determined that the amount of time available to administer an effective survey with a pool large enough to be statistically significant was very limited. Hence, they concluded that a closed form questionnaire was a practical method for evaluating student attitudes (Besterfield-Sacre' 1998). Although the ability to thoroughly research complex issues is compromised by this method, the need for conclusive data to show a general problem is necessary for a first run of evaluation. Once this is complete, more complex issues can be addressed with forms of analysis more suited to specific questions.

In this project, the understanding of how the process of bridging relates to the attitudes of freshmen is vital. A goal of curriculum development is usually to increase student interest and learning by more effective teaching techniques. When a student's interest in a subject is piqued, he or she is apt to perform better and learn more.

Our experiment measures the attitudes of students before and after they have taken a bridged mathematics course, i.e. Calculus III, Linear Algebra, or Differential Equations, and compares them to students who have not taken any bridged courses in their freshman year. In this measurement, if the bridging method has had a positive effect on students' views of engineering then our survey will show that students have a higher opinion of their skills when they complete a sequence of bridged courses.

2.3.5 Pittsburgh Engineering Attitudes Survey

For this reason the Pittsburgh Engineering Attitudes Survey, developed by Dr. Besterfield-Sacre et al., was chosen to assess changes in student's attitudes over the course of the freshmen year. The survey, located in Appendix A, contains 50 questions. The first section, questions 1 through 28, assesses students' perception of engineering and science. Each question in this section has five possible answers: Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. The second section, questions 29 through 35, pertains to students' perception of their own abilities in calculus, physics, chemistry computers, English, writing, and oral communication. The possible answers to these questions are: Not Strongly Confident, Not Confident, Neutral, Confident, Strongly Confident. The third section, questions 36 through 50, is made up of questions about a students' self-perception of their abilities at problem solving, engineering, working in groups, and adequate study habits. The questions for this section are the same as for the first. The following table represents the information presented here.

To analyze the surveys that have been completed each of the entries is must be coded with a number 1 through 5 depending on the response, 1 for strongly disagree through five for strongly agree. Once this is done the statistical weights for each answer must be multiplied by the answer to give the correct normalization factor to each response. The weights for the each question, provided to us by Dr. Besterfield-Sacre, are located in Appendix A. Once the weightings are calculated then all the weighed responses in a group are summed. Each survey now has a number representing each of the 13 groups of questions. Within each group the mean and the variance are calculated for the whole population. With this information two populations can be compared by using a test to measure the difference in the means of each group in the two populations.

Table 2.2 The 13 groups of questions in the Pittsburgh Engineering Attitude Survey

Section	Survey Questions Group Descriptions
Section 1	
Questions 1-28	1. Perception of the work engineers do and the engineering profession
	2. General impressions on engineering
	3. Financial influences for studying engineering
	4. Perception on how engineers contribute to society
	5. Enjoyment of math and science courses
	6. Engineering perceived as an exact science
	7. Family influences for studying engineering
Section 2	
Questions 29-35	8. Confidence in basic engineering knowledge and skills
	9. Confidence in communication and computer skills
Section 3	
Questions 36-50	10. Problem solving abilities
	11. Engineering attributes
	12. Working in groups
	13. Adequate study habits

These are the 3 sections and 13 general groups represented by the questions in the Pittsburgh Engineering Attitudes Survey. Each of the questions on the survey is contained in one of these groups. Changes in student attitudes are looked at on a group by group basis. (Besterfield-Sacre, 1999)

3 Methodology

3.1 Experimental Design

The objectives of this experiment are again:

- To determine whether or not the "bridging model" is an effective method of increasing student learning of fundamental concepts in either or both of the "bridged-from" and "bridged-to" courses.
- To discover if taking bridged courses affects the attitude students have towards engineering, science, their knowledge, and their abilities .

We collected data on students' grades in bridged and bridged-to classes to assess students' performance on the traditional exams. Through our statistical analysis, we determined if there is a measurable increase in performance that is attributable to the bridging model. In the second of the two experiments we administered the Pittsburgh Engineering Attitude Survey to WPI students at the beginning and end of their freshman year to determine if there is a change in students' attitudes resulting from exposure to bridging. The collection of data and format of statistical analysis that we have chosen is discussed in detail within this chapter.

3.2 Student Grade Data

The goal of the analysis of the student grade data is to determine if the "bridging model" curriculum is an effective method for increasing student learning of fundamental concepts in both the bridged-from course and in the bridged-to course. To accomplish this, an analysis of the students' performance on standard examinations that are consistent from year to year is necessary. Consistent data are not always available in a study like this; therefore, only data that can be controlled will be considered.

3.2.1 Data Collection

Professor Goulet collected the data from the faculty members involved in the study. The data and the faculty members whom supplied it are listed here in table 3.1.

Table 3.1 Courses and terms in which student grade data was taken

Professor	Department	Bridge	Terms
Prof. Phillies	Physics	Principles of Physics Mechanics/ Calculus III Bridge	A98
Prof. Jasperson	Physics	Introduction to Physics Mechanics/ Calculus III Bridge	A98
Prof. Beall	Chemistry	Chemistry III/Calculus III Bridge	A98, B98, C99
Prof. Kildahl	Chemistry	Chemistry III/Calculus III Bridge	A98, B98, C99
Prof. Glaser	Chemistry	Chemistry III/Calculus III Bridge	A98, B98, C99
Prof. Delaney	Chemistry	Chemistry III/Calculus III Bridge	A98, B98, C99
Prof. Grecu	Computer Science	Introduction to Programming/Calculus III Bridge	A97 & A98
Prof. Heinricher	Mathematics	Principles of Physics Mechanics/ Calculus III Bridge	A98
Prof. Goulet	Mathematics	Calculus III/CH, PH, CS, & General	A98
Prof. Goulet	Mathematics	Linear Algebra/General Bridge	C98, C99

Student grade data was collected from the faculty members listed here for each of the bridges. The course that each professor taught is listed first in the column labeled *Bridge*. Each of the terms that data was collected is also represented in the *Terms* column.

The faculty members provided student grade data. These data usually included the scores on each exam and each student's final numerical grade, but some data only contained final course grades.

Professor Goulet coded the data prior to releasing it to us. The coding is used to differentiate between bridged and non-bridged students without revealing their identities. The names and social security numbers of individual students were stripped and replaced by a designation of a "yes" or were highlighted for bridged students. Those who were not bridged were given a "no" designation or not highlighted. Each set of data used only either yes/no or highlighting. In doing this the students' names and any other identifying information were stripped away so that the data set was anonymous. In some cases one class would have to be separated into several parts to be compared to its corresponding bridged-to group. These cases were sorted out before the data was coded.

The data on student grades covered the bridged courses shown in table 3.1. From the data collected we were able to use the Chemistry III/Calculus III bridge, Introduction to Programming/Calculus III bridge, and the Linear Algebra/General bridge data in our analysis. The last five bridges had incomplete data sets. Data was not collected from the previous year and therefore the Calculus III class lacks a control group. Any comparative analysis of the bridges was not feasible without control data. These unusable data have been recorded in the appendix, and are not discussed in the data analysis. A complete listing of student grade data can be found in Appendix B.

3.2.2 Control Data

Table 3.2 The Experimental and Control Courses in each Bridge

Courses	Term	Control/Experimental	Term	Control/Experimental
CH1010	A98	Control for CH1030 C99		
CH1020	B98	Control for CH1030 C99		
CH1030	C99	Experimental		
CS1005	A97	Control for CS1005 A98	A98	Experimental
MA2071	C98	Control for MA2071 A98	C99	Experimental
MA1023	A98	Experimental		

The table gives a brief overview of the courses and the role that they play in the analysis. There is an experimental population in each course and one or multiple controls depending on the course.

Table 3.2 shows each course in the data set and what the data are used for. Each experimental population has a corresponding control population. The Introduction to

Programming (CS1005) and Linear Algebra (MA2071) populations have traditional control groups, which means that the course was taught similarly in the previous year with the exception of bridging. It is therefore, assumed that there have been no significant changes that may have adjusted the amount learned significantly in the years prior to the implementation of course bridging.

The Chemistry control group is not a traditional control. Since the chemistry curriculum for the 1998-99 academic year had been changed significantly the Chemistry III (CH1030) course from C98 is not comparable to that of C99. Therefore, because the Calculus III in A98 bridged-to Chemistry III in C99 it was necessary to make Chemistry I & II (CH1010 & CH1020), in A98 and B98 respectively, the control groups. This means that students would be expected to perform significantly better in Chemistry III than in Chemistry I or II if bridging significantly affected performance in Chemistry III. Hence, Chemistry I & II are valid, although, nontraditional controls.

3.2.3 AP/Non-AP Comparison

We have devised four comparison groups. They are: AP students in the control course, Non-AP students in the control course, AP students in the experimental course, and Non-AP students in the experimental course. We are using the terms AP and Non-AP to separate students who have tested out of Calculus I & II with advanced placement credit from high school, and started their freshmen year in Calculus III. These AP students in the experimental year are the first group to have been bridged and they need to be distinguished from other students so that they may be compared with AP students form the previous year who were not bridged. Those students whom have started in

Calculus I & II may also have high aptitude, but for the purposes of this study we have given them the label Non-AP as they did not take Calculus III in the first term of their freshman year and did not have the opportunity to be bridged. The Non-AP students in the control and experimental years are used to determine if there is a significant difference in how the course was taught or graded between the control class and the experimental.

3.2.4 Formatting the Student Grade Data

The data we received was not standardized. Each class is graded based on how the faculty member teaching the course decides is best. Therefore, it was necessary normalize the data, i.e., adjust it all to the same scale, so that we could use statistics to analyze it. The usable student grade data is displayed here in Table 3.3, showing the final formats used in our analysis.

Table 3.3 Format of Data from each Course

Linear Algebra	Question by Question on Final Exam
Chemistry	Exam-by-Exam & Final Letter Grade for the Course
Computer Science	Exam by Exam

The data recieved for each course varied and therefore we normalized the data from each course in different ways so that it could be compared.

3.2.4.1 Linear Algebra

To begin the analysis, the data had to be formatted such that it could be manipulated. The Linear Algebra data was in the form of how many points each student scored on each question on the final exam. The number of points possible was also given. The problem is that although the problems in the control and experimental groups were identical, the number of points they were worth was not. Therefore, we divided the number of points each student scored by the number of possible points for that question. This normalized the data by converting it into percent form, which could be compared.

3.2.4.2 Chemistry

The data from the Chemistry Bridge were collected as exam-by-exam data from some faculty members, and as final letter grade data from other faculty members. This presented a problem of determining the best method of coding. Since the bulk of the data was in exam-by-exam form, the subset that was not could have been ignored. This was not feasible because there were many different faculty members teaching Chemistry I, II & III. With a range of faculty comes a range of teaching styles and therefore, deleting any portion of the students would lead to an incomplete analysis. Therefore, to include all the data we used the final letter grades for each Chemistry course. The difference in exams is also not an issue in the Chemistry III bridge, because the final grades encompass all the examination materials in the course. Also any exam given in Chemistry I is different from any exam given in Chemistry II or III, because each course contains different material. Any significant difference in difficulty any two exams is, therefore, irrelevant

This made each data point either A, B, or C. Any failures (NR's or No Record grades) were neglected due to the fact that we cannot determine why a student received a failing grade based on the data we received. If a student were to have dropped the class without notifying the registrar and therefore failed then it would not make sense to compare how well that student did compared to a student who attended lectures and received an NR based on the quality of their work. The A, B, C data was then coded on a four point scale. A's were coded as 4, B's were coded as 3, and C's were coded as 2. This scheme allowed us to analyze the final grade data mathematically. With the Chemistry data that we have we can compare the Non-AP populations in each course to determine if the overall evaluation method between each course is significantly different. If any of the Non-AP comparisons between Chemistry I, II, & III are significantly different then Chemistry I & II are not a suitable control population in this experiment.

3.2.4.3 Computer Science

The data from the Computer Science bridge was given as a percent of total correct on each of three exams for each student. The problem with this data was that we could not control for the difference in the exams from one year to the next. Professor Grecu did not use the same exams from year to year and tells us that there could be a difference in the level of difficulty from the control and experimental years. Therefore, to normalize the data the mean for each year was calculated by taking the average score for each year. The standard deviation from the mean of all the exams was then calculated by taking the square root of the variance of each student from the mean. The control and experimental groups were calculated separately. This normalization places both populations on the same scale allowing each population to be compared to the other.

3.3 Attitude Survey

The attitude survey used in this study was the Pittsburgh Engineering Attitude Survey (Besterfield-Sacre, 1998). The survey is presently being used in a national study of engineering students to assess the change in students' attitudes toward engineering, science, and students' perception of their own abilities, over the course of their freshman year. We have adopted this survey to look for any changes in the attitudes of WPI students over the course of the freshman year. The survey was administered to bridged and non-bridged students from AP and Non-AP populations. The analysis has been performed for all responses from the freshmen, students in the five engineering majors (Mechanical Engineering, Electrical Engineering, Chemical Engineering, Civil Engineering and Computer Science), and the women who completed the survey.

3.3.1 Survey Administration

The survey was first administered in term D99. The students whom we wished to compare were the AP students who had taken Calculus III in A98 and the AP students who had taken Calculus III in A99. Normally students would take the survey during orientation and then again late in second semester. This would have meant surveying the students who took Calculus III in A98 in August of 98, before our project started. Due to the time constraints of this study the Freshmen in A99 were surveyed to provide a baseline for comparison. Therefore the experimental group was composed of the students taking Linear Algebra or Differential Equations in D99 who had taken at least one bridged course. The control group was composed of the students in D99 who did not take a bridged course in their freshman year. We assume that the administration of this survey to two separate populations will not yield any significant differences as the survey is normally administered to the same population twice, once as an entrance survey and then again as an exit survey in the freshman year. We also assume the composition of the freshman class does not vary significantly from year to year.

3.3.1.1 Term D 99 Survey Administration

In D99 surveys were administered to students in Linear Algebra and Differential Equations. Linear Algebra students were given the survey as they entered class and were asked to fill out this survey for an IQP group doing a study on WPI students. The students were told that this was an anonymous survey that would have no bearing on the grade they would receive. They were asked to supply the last four digits of their student ID number so that we may separate them into groups. They were instructed to fill in all the sections except for the "School Number" and "School Code" sections. This IQP team administered these surveys directly to the students.

In Differential Equations surveys were given to each of the PLA's to administer with instructions on how to administer the survey. The PLA's in each section told the students that this was for an IQP doing research on WPI students. The students were then told that this was an anonymous survey that would have no bearing on the grade they would receive. They were asked to place the last four digits of their student ID number so that we may separate them into groups. They were instructed to fill in all the sections except for the "School Number" and "School Code" sections.

3.3.1.2 Freshmen Orientation Survey Administration

In August 1999 the same survey was administered to the incoming freshmen of the class of 2003. The Orientation Leaders (OL's) administered the survey to the students in their orientation group. The OL's in each section told the students that this was for an IQP doing research on WPI students. The students were then told that this was an anonymous survey that would have no bearing on any grade they would receive. They were asked to place the last four digits of their student ID number so that we may separate them into groups. They were instructed to fill in all the sections except for the "School Number" and "School Code" sections.

3.3.2 Data Collected

In administering the Survey we received data from students in all class years. The data collected in term D99 were organized so that responses from freshmen of the class of 2002 were separated out. Any surveys that were not complete or that could not be categorized were deleted from the study. Out of those groups in D99, 7 surveys were removed because the students reported majors of Management, Management Information Systems, Society and Technology, or Other. These majors are not considered to be engineering or science majors and therefore were deleted from the groups before analysis. The remaining surveys were then separated into AP and Non-AP groups by matching the last four digits of each AP student social security number with a list of the last four digits of the social security number for each student who took Calculus III in the first term of their freshman year. The list we used did not contain any information that could identify a student, as it was just a list of four digit numbers.

The data collected from the administration of the survey in August 1999 at Freshman Orientation was only from freshmen and transfer students. Transfer students were removed from the data set. The surveys were separated into groups according to students who were taking Calculus III in their first term or students who were not. The problem encountered with the administration of the surveys was that although the OL's had explicit instructions as to how to administer the surveys most of the OL's did not administer the survey. Out of 30 orientation groups only 11 survey packets were returned and only 7 contained completed surveys. Hence, out of 700 freshmen the survey was only administered to only 148 freshmen. Of those completed surveys 8 were removed as students reported non-engineering and science majors, and 2 were removed for missing biographical information needed to determine their class year or age. Table 3.4 summarizes the number of surveys and numbers removed in each population.

Table 3.4 Overview of how the Freshmen Survey Data collected was sorted

Population	Estimated Num. of Students Total Pop.	Total Num. Of Students Surveyed	Total Num. of Students Removed	Reason Students were Removed	Total Num. of Students Removed	Reason Students were Removed
AP A99 (class of 2003)	156	27	2	Not Eng/ Sci Major		
Non-AP A99 (class of 2003)	~544*	121	6	Not Eng/ Sci Major	2	Missing Bio Information
AP D99 (class of 2002)	230	60	4	Not Eng/ Sci Major	4	Upper-classmen
Non-AP D99 (class of 2002)	~470*	63	3	Not Eng/ Sci Major		

The table lists the approximate total population, number of students who completed surveys, the number of responses that were removed and the reason for removal of the Freshmen surveyed.
*** The estimated number of students in the total population for the Non-AP population is determined by subtracting the average total number of freshmen, about 700, and then deleting the number of students in the AP population.**

Data that is not represented in table 3.4 is sophomores, juniors, seniors, special students, transfers, and high school students. All of the survey responses that fall into these categories are not of interest to our study and were set aside. This data has not been coded as the survey data from the freshmen have, and therefore will not appear with the freshmen attitude survey data in Appendix C. Also, it will not be discussed in the analysis, as it is not relevant to our research.

3.3.3 Formatting the Attitude Survey Data

Each of the responses on the survey was coded, and the data were recorded in four files. The files were organized into a spreadsheet and the statistical weights for the survey, provided by Dr. Besterfield-Sacre, were applied to each answer. The weighted responses to each question were summed with each of the other questions in each group for each individual survey. The sums of the weighted responses for each group were then averaged together over all the surveys. The averages that resulted were the average responses for the population. The variances and numbers of responders to each group of questions were also calculated. The complete survey and weights can be found in Appendix B. The 13 sections are presented here in table 3.5

Table 3.5 The Populations that were Compared in the Analysis of Attitude Change.

Population	Control or Experimental	Compared to what Pop.?	Reason
Non-AP A99	Control	Non-AP D99	To create a baseline of un-bridged data.
Non-AP A99	Control	AP A99	To check for differences in bridged and non bridged students before participation in bridging.
Non-AP D99	Control	AP D99	To check for differences in the attitudes of bridged and non-bridged students after participation in bridging.
AP D99	Control	AP D99	To look at differences in bridged students' attitudes after a year taking at least one bridged course.

The Freshmen who enrolled in Calculus III in A98 and A99 are the AP population for each year. Those that did not are the Non-AP population. The table outlines why comparisons are made between the populations.

Once the process of separating the data for analysis was complete the data for each group of questions was then compared using the Tukey test. This test was employed to determine if there was a significant difference in the mean of each population's response to each group of questions. The populations that were compared are summarized in table 3.6.

The Tukey test allows for the comparison of each of the populations on a normalized scale based on those populations being compared. This allows us to determine if any of the populations differ significantly in their responses within any of the groups of questions.

3.4 Statistical Analysis

The method we chose for the analysis was a test of variance among all. For example, when comparing the students in Chemistry I with the students in Chemistry II and the students in Chemistry III all the populations were considered simultaneously. This approach shows any difference in Chemistry I and Chemistry II data, Chemistry I and Chemistry III data, and Chemistry II and Chemistry III data using a normalized scale that is specific to the data set. This analysis is necessary because it allows us to compare three separate groups of students, whose learning was not evaluated in exactly the same way. Discrepancies in the evaluation occur when the exam changes from one year to the next. Comparison of the difference in the means is a reliable method to compare the data we have.

To begin the analysis all the data is organized into comparison groups. For each population the number of data points, N, the mean, $\overline{X}$, and the variance, S^2, must be determined. The population size is given by

$$N = \sum_{i=1}^{h} student_i \qquad \textbf{Equation 3.1}$$

where h is the last student in a population, and i is an index. The mean grade within each population is determined by the sum of all students' numerical grades over the population size, N.

$$\overline{X} = \frac{\sum_{i=1}^{h} grade_i}{N} \qquad \textbf{Equation 3.2}$$

The variance within each population is then determined by

$$S^2 = \frac{\sum_{i}^{h} (X_i - \overline{X})^2}{N} \qquad \textbf{Equation 3.3}$$

which is just the sum of the difference between each grade, X, and the mean of the population, $\overline{X}$, squared and divided by the population size, N. The variance represents the distribution of data about the mean. If the variance is small most of the data points were very close to the mean. When the variance is large the range of answers is also very large. For instance, if there were five possible answers to a question, *a, b, c, d, e,* then a large variance about the mean of *c* would mean that there were a number of responses for *b* and *d* and a few for *a* and *e*. If the variance were small and the mean was c then most of the responses would be *c*, a few would be *b* and *d*, and probably none would be *a* and *e*.

Now, to compare the different populations based on the variance in each population, the Tukey test for multiple comparisons of *K* populations is used (Gopal,1993). This test determines the extent to which the means of each population vary in comparison to the means of other populations in the analysis.

To use the Tukey test, first the number of degrees of freedom, *D*, must be calculated. The number of degrees of freedom is found by taking the sum of all of the population sizes and subtracting the number of populations in the comparison.

$$D = \left(\sum_{i=1}^{K} v_{population} \right) - K_{populations}$$ **Equation 3.4**

Next the total variance of all of the samples is calculated by

$$\Psi^2 = \frac{\sum_{i=1}^{K} ((N_i - 1)(\text{variance}_i))}{D}$$ **Equation 3.5**

where Ψ^2 is the total variance of all of the samples found by summing over the size of i^{th} population minus one times the variance of the i^{th} population, and then dividing by the number of degrees of freedom.

"q" is the standardized range which is found in a table (Gopal,1993) that lists q by the number of populations and the degrees of freedom for the Tukey test. The normalizing parameter, n, is found by taking the number of populations divided by the sum of one over the population size for each group in the sample as shown here

$$n = \frac{K_{pop.}}{\sum_{i=1}^{K} 1/N_i}$$ **Equation 3.6**

where K is the number of populations, i is an index, and N is the number in the i^{th} population.

The limit of the absolute difference in the means is W. If the value of the absolute difference of the means is greater than W then the means are significantly different. If it is less than W then the means are not significantly different. W is calculated by

$$W = \frac{q * \sqrt{\Psi^2}}{\sqrt{n}}$$ **Equation 3.7**

where q is the standardized range, Ψ^2 is the total variance, and n is the normalization parameter.

This statistical analysis was used on all the data to compare the populations in both the student grade data and the attitudinal survey. To do the analysis we chose an uncertainty of $p \leq 0.05$.

4 Results & Analysis

4.1 Student Grades Analysis

The student grade analysis contains the analysis of the Computer Science bridge, the Chemistry III bridge and the Linear Algebra bridge. These three bridges represent the three presently used methods of bridging, simultaneous bridges, non-simultaneous bridges, and general bridges to major, respectively. In this section each is analyzed to determine its effectiveness teaching students about fundamental concepts and their linkages to other disciplines.

4.1.1 Computer Science Bridge

In the computer science bridge, students were separated into AP and Non-AP populations in each year, 1997 and 98. The students taking Introduction to Programming in C (CS1005) in A97 were the Non-AP control group for AP students taking CS1005 in A98. The bridged students were the subset of students in CS1005 in A98 who were also AP students. This description is represented here in table 4.1

Table 4.1 Division of control and experimental groups in the Computer Science Bridge data

Population	Con./Exp.	Population is a control for:	
A97 Non-AP	Control	A98 Non-AP	A97 AP
A97 AP	Control	A98 AP	
A98 Non-AP	Experimental	A98 AP	
A98 AP	Experimental		

The table shows how the four populations in the CS1005 bridge were separated, and what population each population was a control for.

In table 4.2 each of the populations is compared with each of the other populations. *V* is the total number of subjects in the comparison *W* is the limit of absolute difference in the means, and *X* is the absolute difference in the means.

Table 4.2 Results of the Tukey test on the mean of students' three exam scores for the Computer Science Bridge

Measures	A98 Non-AP vs. A98AP	A97 Non-AP vs. A98 Non-AP	A97 AP vs. A98 AP	A97 Non-AP vs. A97 AP
V	217	400	49	232
W	8.071	3.946	10.844	8.446
X	**11.580**	**8.291**	**12.409**	7.462
Sig. Diff.?	yes	yes	yes	no

Using the Tukey test to look at each student's mean score for the course we find that the Non-AP students in 97 and 98 are significantly different from each other. The failure of the control test means that no conclusions about bridging can be drawn. Since the A97 and A98 AP students are also significantly different we believe that an exam-by-exam analysis is needed to interpret the data correctly.

The control groups, A97 Non-AP and A97 AP did not have significantly different overall scores on the three exams (Table 4.2). But when the A97 and A98 Non-AP students are compared we can see that there is a significant difference in the performance of the two populations, X = 8.291 with W = 3.946. The A98 Non-AP performance was higher than that of A97 Non-AP students. This means that the two populations are not the same and because of this continued analysis is difficult. The fact that the A97 and A98 AP populations are also significantly different leads us to believe that the examinations given in each year were possibly significantly different or that the awarding of points was possibly altered in some statistically significant way. The thing that is very encouraging is that the scores of the A98 Non-AP and AP populations are also significantly different. The A98 AP population has a significantly higher mean score than both the A98 Non-AP and the A97 AP. Since the A97 AP and Non-AP comparison is not significantly different, this lends to the idea that either the analysis is masking something by looking at the overall scores for all the populations or that the analysis is not rigorous enough.

This led us to analyze the data on an exam by exam basis to determine if something was being overlooked in the analysis. The students in each year were given three exams. Therefore, we analyzed the data for each exam separately and compared all the groups again using the Tukey test to determine if there was a significant difference between the populations on a test by test basis. When each of the groups was evaluated on a test by test basis and then compared it was seen that, with the exception of the A98 AP and A98 Non-AP groups, all of the populations had no significant difference from one another on a test by test basis. This allows us to examine the difference in the A98 populations, as all the control comparisons are not significantly different.

Table 4.3 Results of the exam by exam analysis for A98 AP vs. A98 Non-AP students using the Tukey test for the Computer Science Bridge

Measure	Exam 1	Exam 2	Exam 3
V	217	217	217
W	0.54	0.54	0.53
X	0.45	**0.70**	**0.78**
Sig. Diff?	no	**yes**	**yes**

These results show that there was a significant increase in the overall performance on the second and third exams for AP students in A98 over that of Non-AP students in the same year. The comparisons of the other groups show no significant difference in the absolute difference in the means. This means that on an exam by exam basis the bridged students learned and retained more as time went on.

As seen in table 4.3 above, the first test these two populations did not have significantly different scores whereas on the second and third exam the populations become significantly different. There is also a noticeable trend in the increase of the difference in the means. For exam two the $X = 0.70$ for $W = 0.54$,, whereas, on exam three $X = 0.78$ for $W = 0.53$. This shows an increasing spread in the difference of the means between the AP and Non-AP students in A98. This suggests that students retained more information over the course of the term. As the AP students' scores increased like this, we believe this shows that this bridge has been effective in teaching fundamental concepts that can be applied effectively in another discipline.

4.1.2 Chemistry

The Chemistry students were separated first into AP and Non-AP students in each course: Chemistry I, II, & III. They were then compared to each other by using the Chemistry I & II Non-AP groups as a control for the Chemistry III Non-AP group. The Chemistry I & II AP groups were a control for the Chemistry III AP group. This comparison is represented here in table 4.1.

Table 4.4 Division of control and experimental groups in the Chemistry bridge data

Population	Con./Exp.	Population is a control for:	
Non-AP 1010	Control	Non-AP 1020	Non-AP 1030
Non-AP 1020	Control	Non-AP 1010	Non-AP 1030
Non-AP 1030	Experimental		
AP 1010	Control	AP 1020	AP 1030
AP 1020	Control	AP 1010	AP 1030
AP 1030	Experimental		

The table shows how the six populations in the Chemistry bridge were separated, and what populations each populations was a control for.

The analysis of the final grade data showed no significant difference in the absolute difference of the means between any of the three courses. The comparison was performed first on the Non-AP students in Chemistry I, II, & III using the Tukey test. Then the analysis was performed the same way on the AP students. The results of each comparison are displayed here in Table 4.4.

Table 4.5 Results of the Tukey test on Non-AP and AP populations in Chemistry.

Measure	Non-AP 1010-1020	Non-AP 1010-1030	Non-AP 1020-1030	AP 1010-1020	AP 1010-1030	AP 1020-1030
V	55	27	17	28	19	19
W	0.536463	0.673193	0.746391	0.557822	0.489402	0.450574
X	0.309091	0.185185	0.294118	0.233333	0.210526	0.105263

The table shows that the Non-AP control populations have no difference between them which means that the AP populations can be compared. The AP populations also have no significant difference between the two controls, AP 1010 and AP 1020, which means that they can be compared to the experimental population, AP 1030. The results show that AP 1030 students' performance is not significantly different than both AP 1010 and AP 1020 performance. Therefore our data does not support the notion that bridging to Chemistry III was successful in increasing student learning.

Unless there was an increase in learning in all three Chemistry courses, there was no detectable effect from bridging to Chemistry 3 from Calculus 3.

4.1.3 Linear Algebra

The Linear Algebra (MA2071) students were separated only by year in which they took the course. In the first course, C98, students were not bridged and are therefore the control group. The students in C99 were bridged and are the experimental group. The separate populations are represented here in table 4.6

Table 4.6 Division of control and experimental groups in the Linear Algebra bridge data

Population	Con./Exp.	Population is a control for:
MA2071 C98	Control	MA2071 C99
MA2071 C99	Experimental	

The table shows how the two populations in the MA2071 bridge were separated, and what population each population was a control for.

Linear Algebra in term C99 was not bridged to any specific course. Instead it was bridged to students' majors through group projects with problems designed for each major. Students could pick projects that were not in their major, but we assume that most students selected projects related to their major.

First, in an overall analysis, the Tukey test was used to determine if there was a significant difference in test performance . The results can be seen in Table 4.7.

Overall, there is a small but significant difference in the overall performance of the students in the bridged course taught in C99 as compared to the non-bridged class taught in C98 with a limit $W = 0.0613$ and an absolute difference $X = 0.0666$. The mean in C99 is higher than that of C98, therefore, the results suggest that the bridging to many different majors or interests may be an effective method for bridge course design.

Table 4.7 Results of the Tukey test on the mean of questions 1 through 5 on the Linear Algebra final exam.

Measures	Questions 1-5
V	209
W	0.061378
X	**0.066604**
	Significantly Different

Each student's mean score for the final exam was calculated and then the mean of each class was taken. The Tukey test was used to show that there was a significant difference in the means. The bridged year's mean is higher than that for the non-bridged year. We decided from this that a question-by-question analysis was needed to determine if this difference was due to one or all of the questions.

When the data were further analyzed on a question-by-question basis, the results, shown in Table 4.8, were different than expected from the overall analysis.

Table 4.8 Question by Question Analysis of the final exam in Linear Algebra using the Tukey test.

Measures	Question 1	Question 2	Question 3	Question 4	Question 5
V	209	209	209	209	209
W	0.113	0.122	0.13	0.184	0.178
X	**0.124**	**0.174**	0.033	-0.084	0.051
	Significantly Different	**Significantly Different**	Not Sig. Different	Not Sig. Different	Not Sig. Different

The question-by-question analysis revealed that scores on two of the questions were significantly different, and that in both cases the experimental population scored higher. Of the last three questions students in the experimental population scored higher on the third and fifth questions and only scored lower than the control population on the fourth question. Since the only question in which the bridged students did worse on was not significantly different, this suggests that the bridge was successful in that students performed significantly better as a whole and in 4 out of 5 cases scored better on the final examinations.

For the first two questions the absolute difference was $X = 0.124$ (12.4%) and $X = 0.174$ (17.4%) with $W = 0.113$ (11.3%) and $W = 0.122$ (12.2%) respectively. These were the only two questions upon which students scored significantly better in the bridged class than did the non-bridged students. For the third, fourth and fifth questions the difference in the absolute means was very small and on the fourth question bridged students scored 8.4% lower than that of the non-bridged students, although none of these differences were significant. Questions three, four, and five have absolute differences of 3.3%, -8.4%, and 5.1%, with absolute limits of 13%, 18.4%, 17.8% respectively. Therefore, since the final exams in each year were identical, except in the number of points per question, there is no discrepancy in the level of difficulty to be considered. This leads us to conclude that although it seems that student learning has increased due to bridging, more data is needed to make a definitive determination.

4.2 Attitude Analysis Results

The analysis of the survey data was performed three times. First, it was performed on results from all students who reported engineering and science majors. Second, only the subset of the populations who reported Chemical Engineering, Mechanical Engineering, Electrical Engineering, Civil Engineering, and Computer Science majors were analyzed. Finally, an analysis was performed on the subset of female students who completed the survey. In all cases, pre- and post-freshman year data were compared. The engineering and science students were used to gain an overall picture of attitude change in the freshmen class. The engineering group was looked at to determine if there was any different amount of change within only the engineering majors to whom the survey was most applicable. The female students were singled out because they make up a very small subset of the students represented in the overall analysis. Because the subset of females is small (about 22% of the total) there may be changes in their attitudes that cannot be detected by the overall analysis.

The first group is that of A99 AP and A99 Non-AP students. The comparison of these two populations tells us if there are initially any significant differences in the attitudes students have as they begin their first year. The second comparison is that of D99 Non-AP and A99 Non-AP students. These students show if there is any change in the attitudes of students who have not had any contact with bridging over the course of their freshmen year. Next the D99 AP and A99 AP comparison is made. This comparison shows if there are any changes in students' attitudes over the course of the year when they have taken at least one bridged course. We present the results of the D99 AP and D99 Non-AP comparison last. This is the experimental comparison that should show any differences in attitudes due to bridging. Finally a discussion of the conclusions from the comparisons is made. This is the format used to present each of the three populations that were analyzed: all respondents, engineering majors, and women.

4.2.1 Engineering and Science Majors Population

The analysis of the engineering and science student responses encompassed the comparison of the two control groups from term A99, A99 AP and A99 Non-AP, and the experimental groups from D99, D99 AP and D99 Non-AP. The results of this analysis are shown in the following tables and a discussion of each table follows it.

Table 4.9 Tukey comparison of the A99 AP vs. A99 Non-AP Engineering and Science Majors Population

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
V	136	136	136	136	136	136	136	136	136	136	136	136	136
W	0.285	0.221	0.298	0.359	0.416	0.449	0.471	0.387	0.457	0.346	0.405	0.403	0.466
X	0.093	**0.225**	-0.156	0.065	0.208	0.079	-0.008	0.087	-0.197	0.282	0.120	0.081	-0.098
SD?	No	**Yes**	No	No	No	No	No	No	No	No	No	No	No

There is a significant difference in the second group.

The significant difference in group 2 shows that A99 AP students have a significantly more positive attitude towards engineering than do Non-AP students.

Table 4.10 Tukey comparison of the D99 Non-AP vs. A99 Non-AP Engineering and Science Majors Population

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
V	171	171	171	171	171	171	171	171	171	171	171	171	171
W	0.208	0.165	0.219	0.269	0.303	0.321	0.332	0.262	0.326	0.235	0.281	0.283	0.359
X	0.117	0.106	-0.110	-0.064	0.167	-0.157	-0.039	0.216	-0.006	0.155	0.239	-0.100	-0.014
SD?	No	No	No	No	No	No	No	No	No	No	No	No	No

The table shows the comparison of the A99 Non-AP and D99 Non-AP students. This is a control comparison to check if the two control groups are significantly different. Since there is very little difference in the absolute means the data from different years is comparable.

Table 4.10 shows the comparison of the A99 Non-AP and D99 Non-AP students. This is control to check and see if the two groups are significantly different. If they were in some way significantly different then the two populations of students might not be a very good group for comparison. A significant difference could mean that one group as a whole has had a significant experience, which is seen in one or more of the questions in the survey. Since there is very little difference at all in the absolute means the rest of the data should be comparable.

Table 4.11 Tukey comparison of the D99 AP vs. A99 AP Engineering and Science Majors Population

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
V	75	75	75	75	75	75	75	75	75	75	75	75	75
W	0.311	0.258	0.388	0.489	0.442	0.507	0.552	0.383	0.517	0.350	0.458	0.568	0.480
X	0.050	-0.070	0.057	-0.047	0.054	-0.064	0.018	0.208	0.122	-0.096	0.173	-0.226	0.398
SD?	No	No	No	No	No	No	No	No	No	No	No	No	No

The table shows the comparison of the A99 AP and D99 AP students. There are no differences in the populations due to bridging in this comparison.

Table 4.11 shows the comparison of the A99 AP and D99 AP students. If there were change in attitude due to bridging or anything else in the freshman year, it would be evident in this comparison. As is evident in the table, the differences in the absolute means are well within the limit *W*.

Table 4.12 Tukey comparison of the D99 AP vs. D99 Non-AP Engineering and Science Majors Population

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
V	110	110	110	110	110	110	110	110	110	110	110	110	110
W	0.244	0.203	0.290	0.371	0.350	0.381	0.402	0.271	0.387	0.248	0.329	0.395	0.421
X	0.026	0.050	0.011	0.082	0.095	0.171	0.049	0.079	-0.069	0.031	0.054	-0.045	0.313
SD?	No	No	No	No	No	No	No	No	No	No	No	No	No

The Tukey test was used to determine if there are any differences in the attitudes of the D99 AP and D99 Non-AP populations. In this and each of the following comparison the thirteen groups of questions on the survey were used to look at attitude change. This comparison shows that there is no significant difference in the two populations for any of the attitudes measured.

Table 4.12 shows the comparison of AP and Non-AP students in D99. There is almost no difference in the attitudes of bridged and non-bridged students at the end of the freshman year. Any difference that there is in the absolute means is very small in comparison to the limit *W*.

In Table 4.9 it is evident that the A99 AP students have a significantly more positive attitude towards engineering than do A99 Non-AP students. This is interesting because there is no significant difference in students' attitude towards engineering between D99 AP and D99 Non-AP students (Table 4.12). The average of D99 AP students is still higher than that of D99 Non-AP students although D99 AP students have a slightly, but insignificant lower mean than A99 AP students. Therefore we can conclude that Non-AP students' attitude improves over the course of the year so that D99 AP and D99 Non-AP students have a insignificant difference in attitude towards engineering after a year of coursework.

4.2.2 Engineering Student Population

For analysis of the engineering student population, all students who were not in the engineering disciplines: mechanical engineering, chemical engineering, civil engineering, electrical engineering, and computer science, were removed from the analysis. This analysis was performed to see if the responses of engineering students, to whom the survey was geared, were different from those of the engineering and science population as a whole.

Table 4.13 Tukey comparison of the A99 AP vs. A99 Non-AP Engineering Major Populations

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
V	101	101	101	101	101	101	101	101	101	101	101	101	101
W	0.365	0.261	0.362	0.394	0.478	0.555	0.531	0.485	0.536	0.422	0.471	0.478	0.521
X	0.151	0.231	-0.029	0.080	0.132	-0.012	-0.106	0.212	-0.163	**0.434**	0.358	0.251	-0.181
SD?	No	No	No	No	No	No	No	No	No	**Yes**	No	No	No

There is a significant difference in means for group 10, the problem solving group of questions.

In table 4.13 there is a significant difference in the A99 AP and A99 Non-AP students with respect to group 10, students' perception of their own problem solving ability. A99 AP students reported significantly higher problem solving abilities than A99 Non-AP students.

Table 4.14 Tukey comparison of the D99 Non-AP vs. A99 Non-AP Engineering Major Populations

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
V	137	137	137	137	137	137	137	137	137	137	137	137	137
W	0.240	0.180	0.250	0.283	0.326	0.362	0.361	0.296	0.351	0.263	0.297	0.310	0.383
X	0.093	0.088	-0.143	-0.154	0.162	-0.153	-0.092	0.251	0.024	0.163	0.218	-0.118	-0.005
SD?	No	No	No	No	No	No	No	No	No	No	No	No	No

Attitudes for Non-AP engineers did not significantly change.

Table 4.14 shows no difference in the D99 Non-AP and A99 Non-AP students, and is the same in the overall analysis.

Table 4.15 Tukey comparison of the D99 AP vs. A99 AP Engineering Major Populations

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
V	60	60	60	60	60	60	60	60	60	60	60	60	60
W	0.369	0.286	0.435	0.598	0.512	0.601	0.591	0.444	0.597	0.394	0.531	0.658	0.528
X	-0.018	-0.096	-0.049	-0.152	0.071	0.066	0.113	0.039	0.094	-0.302	-0.106	-0.381	0.473
SD?	No	No	No	No	No	No	No	No	No	No	No	No	No

The comparison of the D99 AP and A99 AP students showed no significant differences in any of groups. Group number 13, although still not significant, shows more than four times the difference in the means of any other group.

Table 4.15 shows no difference in the A99 AP students and the D99 AP students. None of the differences in the mean, *X*, are close to the limit except for the absolute difference in group 13. By comparing the averages we see that the A99 AP Freshmen answered with less self confidence about their study habits on average than the D99 AP Freshmen, but the D99 population had a larger variance, $V = 0.560$ in D99 as compared to $V = 0.361$ in A99. The increase in the variance leads us to believe that although some students keep high quality study skills, many adjust their study habits to their environment. This may have negatively affected their view of their own study habits.

Table 4.16 Tukey comparison of the D99 AP vs. D99 Non-AP Engineering Major Populations

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
V	96	96	96	96	96	96	96	96	96	96	96	96	96
W	0.263	0.212	0.313	0.412	0.378	0.414	0.428	0.286	0.410	0.263	0.343	0.423	0.446
X	0.040	0.047	0.064	0.082	0.042	0.207	0.099	0.000	-0.093	-0.030	0.034	-0.012	0.298
SD?	No	No	No	No	No	No	No	No	No	No	No	No	No

No change in attitudes for engineering majors.

Table 4.16 shows no difference in the D99 AP and D99 Non-AP engineering students, just as in the overall analysis.

The change in Table 4.13 is interesting because the mean reported score for A99 AP and D99 AP students is 4.261 and 3.959 respectively. The other interesting point is that the variance in A99 and D99 decreases from 0.334 to 0.259. The decrease in the means show a trend towards a slight negative change students' perception of their own problem solving abilities over the course of the year. There is also an improvement in attitude, although it is not significant, in the mean response of the D99 Non-AP students over the A99 Non-AP students. The rise in the D99 Non-AP attitude is reflected in the fact that group 10 in the D99 AP and D99 Non-AP comparison is not significantly different. From this information we conclude that there is an increase in Non-AP students' perception of their own problem solving abilities after a year of course work, and possibly a decrease in the attitudes of AP students towards the same.

4.2.3 Female Population

The female population was analyzed separately to determine if there are any changes in the attitudes of females that would be masked because they make up only twenty-two percent of the population. In this analysis we were looking for trends that did not match the trends found in the overall analysis. This information should begin to develop a picture of how female students might react differently to bridging than the student body in general.

Table 4.17 Tukey comparison of the A99 AP vs. A99 Non-AP Female Populations

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
V	31	31	31	31	31	31	31	31	31	31	31	31	31
W	0.484	0.554	0.615	1.012	1.163	0.967	1.384	0.748	1.181	0.699	1.013	1.016	1.365
X	-0.016	0.256	-0.321	-0.207	0.419	0.357	0.301	-0.144	-0.645	-0.029	-0.464	-0.435	0.362
SD?	No	No	No	No	No	No	No	No	No	No	No	No	No

Both populations started with similar attitudes.

Table 4.17 does not show any significant changes in attitude, which is not consistent with the analysis of all engineering and science students. In the engineering and science analysis the general impression of engineering was significantly different between A99 AP and A99 Non-AP students. The A99 AP students impression was higher. This was evident by a significant difference in group 2, in table 4.9 where x = 0.225 and W = 0.221. Here in table 4.17, x = 0.256 and W = 0.554. This shows that it is the male population of AP students that has a significantly higher impression of engineering than their non-AP counterparts at the beginning of their freshman year..

Table 4.18 Tukey comparison of the D99 Non-AP vs. A99 Non-AP Female Populations

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
v	42	42	42	42	42	42	42	42	42	42	42	42	42
W	0.349	0.354	0.357	0.640	0.648	0.514	0.703	0.408	0.679	0.444	0.706	0.581	0.755
x	0.133	0.068	-0.025	0.010	0.106	-0.076	0.119	0.167	0.064	-0.035	0.074	-0.051	-0.071
SD?	No	No	No	No	No	No	No	No	No	No	No	No	No

No attitudinal change observed.

Table 4.18 does not show any significant changes in attitude. This helps to add validity to the conclusion that increased self-confidence in the knowledge of skills and engineering (group 8), and mechanical, technical, applicable, and design inclination (group 11) is possibly attributed to bridging. The results represented here are also consistent with the results received in the comparison of all engineering and science majors and all engineering majors. This fact suggests that conclusions about increases in AP student attitudes can be drawn from each of the analyses as the Non-AP control groups each show non-significant differences. Therefore the Non-AP populations give a basis for comparison of the AP populations.

Table 4.19 Tukey comparison of the D99 AP vs. A99 AP Female Populations

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
V	8	8	8	8	8	8	8	8	8	8	8	8	8
W	0.714	0.472	1.478	0.954	1.369	1.810	2.823	0.858	1.644	0.829	0.837	2.289	1.474
X	0.333	0.254	0.233	0.587	0.088	-0.417	-0.305	**0.882**	0.487	0.593	**1.232**	0.269	-0.417
SD?	No	No	No	No	No	No	No	**Yes**	No	No	**Yes**	No	No

Change in attitude for groupings 8 and 11.

In table 4.19 there are two points where the female D99 AP female students had a significant positive change in attitude. The first change is in female students' view of their knowledge and skills in engineering, group 8. This is expected as the comparison of the A99 AP females and A99 Non-AP females, shown in table 4.20, is not significantly different, whereas, the D99 AP and D99 Non-AP females is. The D99 AP females report a higher confidence level than do the D99 Non-AP females. Therefore, the results suggest that it is possible that the change in attitude comes from bridging. The fact that there is no significant difference in A99 Non-AP and D99 Non-AP females, as seen in table 4.19, supports that conclusion.

The second positive change seen in table 4.19 is in group 11, which deals with engineering attributes including mechanical, technical, applicable, and design inclination. The results show that the female students' perception of their own technical skills are increased over the course of the year which included taking at least one bridged course. The mean response of the D99 AP females compared with the A99 females increased by more than 1 point from 3.149 to 4.831 respectively. A99 Non-AP and D99 Non-AP students' confidence levels were about the same, as can be seen in table 4.18. This suggests that the female students taking bridged courses significantly increased their perception of their own abilities, most likely as a result of the bridged courses.

Table 4.20 Tukey comparison of the D99 AP vs. D99 Non-AP Female Populations

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
V	19	19	19	19	19	19	19	19	19	19	19	19	19
W	0.666	0.555	0.743	1.000	0.866	0.844	1.182	0.511	1.032	0.728	1.213	1.151	0.958
X	0.184	0.443	-0.063	0.369	0.400	0.017	-0.123	**0.571**	-0.222	0.598	0.694	-0.115	0.017
SD?	No	No	No	No	No	No	No	**Yes**	No	No	No	No	No

Increase in engineering knowledge confidence.

Table 4.20 shows a significant difference in group 8. D99 AP students reported a significantly increased confidence level in engineering knowledge and skills over the Non-AP students in D99.

5 Conclusions & Recommendations

5.1 Performance Evaluation

OBJECTIVE I

- *To determine whether or not the "bridging model" curriculum is an effective method of increasing student learning of fundamental concepts in both the initial bridging course and in the bridged-to course.*

The focus of our analysis was twofold. In the analyses that we have performed we have looked at the performance of students in the bridged-to course or the bridged-from course. We present here our final conclusions regarding student grade performance based on the following findings.

5.1.1 Calculus III - Computer Science Bridge

In the Calculus III/Introduction to Programming bridge students we found that students performed better on the second and third exams in the bridged-to course, Introduction to Programming. Students who were bridged were A98 AP students. These students performed significantly better than the A98 Non-AP students. The difference in the means of each exam also increased over time, which suggests that the A98 AP students learned how to apply fundamental concepts as the courses progressed simultaneously. Therefore, we conclude that, in this case, the data suggests bridging increased student learning and understanding of fundamentals, which was evidenced in the bridged-to course.

5.1.2 Calculus III - Chemistry III Bridge

Calculus III bridged to Chemistry III had a different implementation. The Calculus III course was taught in term A98, and the Chemistry III course was taught in term C99. The analysis showed that there was no significant difference in the final grades students received in any of the Chemistry courses within either the AP or Non-AP populations. As Chemistry III was the bridged course we conclude that this bridge was not effective in increasing student learning and understanding of fundamentals in the target class.

5.1.3 Linear Algebra Bridge

In the Linear Algebra bridge in A98, the mathematics course utilized problems from other disciplines in the form of group projects to demonstrate mathematical concepts. The course was not bridged to any specific class, but was bridged in such a way that students should be able to see where the concepts in the Linear Algebra course fit into their major. In this class, we saw significant improvement in the scores on the first two questions of the Linear Algebra final examination in the bridged year. The results also show non-significant increases in performance on two of the three remaining questions on the final exam. Our conclusion is that this bridge was successful in increasing students' understanding of fundamental concepts in the bridged-from course. We draw this conclusion knowing that the examinations were identical in each year, and that the only addition to the course was the use of projects specific to each student's major.

5.1.4 Simultaneous, Non-Simultaneous & Non-Specific Bridges

The question of what is the most effective form of bridging still remains. In this study we have seen simultaneous course bridging, course bridging separated by two terms, and nonspecific bridging which has no specific bridged-to course. From the results we have obtained it is not a simple task to discern which is a more effective method of bridging. We can clearly state that the non-simultaneous bridge between Calculus III and Chemistry III was not successful in increasing performance in the Chemistry III course. We do not have control data on students' performance in the Calculus III bridge to Chemistry and therefore cannot draw any conclusions about how chemistry material affected students' learning of calculus.

As evidenced by the results of the Calculus III / Computer Science bridge we believe that simultaneous bridging is an effective method for increasing learning in the simultaneously bridged-to course. Again there is no data with which to make conclusions on student performance in the Calculus III course.

Finally, we feel that the Linear Algebra non-specific bridge was successful in that in its first implementation students' test scores rose over those in the non-bridged course. Since only two of the five questions had significantly higher scores we are not sure whether this is due in some way to grade inflation or to different graders in different years. Therefore we believe that there is not enough evidence to show that this form of bridging is successful at increasing student learning and understanding of fundamental concepts in the bridged course.

In comparing the three forms of bridging we believe that for the bridged-to course the simultaneous bridge is the most effective form of bridging. It is unclear if it was the lack of adequate control groups, or if there were other circumstances that led to the failure to see significant differences in the bridge to Chemistry III. Either way we believe that more data needs to be taken to properly determine if non-simultaneous bridging is effective or not. Non-specific bridges also seem to be effective in the bridged-from course, but more data is also needed before a final recommendation can be made.

5.1.5 Other Bridging Outcomes

In June 1999, professors Paul Davis, Mikhail Dimentberg, John Goulet, Judith Miller, and Steve Pierson compiled an interim report for the National Science Foundation (NSF) Institution Wide Reform project. Within this report, the WPI faculty members discussed the positive and negative outcomes of bridging and how the bridging model could be evaluated and implemented more effectively. In terms of students' grade performance, students in "all bridges involving MA [Mathematics] courses, better performance was noticed in the [bridged-from] course (MA) in the form of lower [failure] rates. In the PH-EE [Physics to Electrical Engineering] bridge, students did not perform differently in the PH [bridged-from] course but better performance was noted in the relevant material in the EE [bridged-to] course. In MA-PH [Mathematics to Physics] and MA-CS [Mathematics to Computer Science] bridges [(a bridge we have analyzed in this report)], performance also improved in the [bridged-to] courses (PH and CS)" (Davis, 1999)

Comparing the information in the report to our analysis of the three bridges we looked at, it seems that there is good agreement with our findings. Both our analysis and the NSF report found that students improved in the Introduction to Programming course from the Calculus III/ Introduction to Programming bridge. In the report, Prof. Pierson's Physics/ Electrical Engineering bridge also showed improved performance in the bridged-to course, which is reflected in our analysis of Introduction to Programming. The report does not have any mention of how students performed in general or non-simultaneous bridge, although it does say that "[bridged-from] and [bridged-to] courses need not necessarily be offered in the same term" (Davis, 1999) This leads us to believe that there is more data that may show this but from our analysis there is no significant effect when courses are taught non-simultaneously.

5.1.6 In Summary

Based on all the student grade data presented here and the assessments of the faculty members involved in other bridges we conclude overall the "bridging model" helps students in the bridged-to course learn and connect more fundamental concepts and the utility of those concepts than traditional courses. We feel the data presented in the Computer Science bridge clearly shows a marked improvement in bridged student performance. From the results of the Linear Algebra course and that of the reduction of failure rates noted by the mathematics faculty it is our belief that bridging helps students in the bridged-from course learn fundamental concepts as well. This data set for the bridged-from course analysis is not sufficient to draw a definitive conclusion, and further data collection is needed to solidify the claim.

5.2 Attitude Evaluations

OBJECTIVE II

- *To discover if the "bridging model" affects the attitude students have towards engineering and science, their knowledge, and their abilities after having taken a bridged course or the sequence of bridged courses.*

5.2.1 Engineering and Science Majors

In the analysis of the Engineering and Science major population, we found that AP students start the year with a significantly more positive attitude towards engineering than the Non-AP students. The results of the comparison of the D99 AP and D99 Non-AP populations show no significant differences in student attitude towards engineering. Comparisons between the A99 AP and A99 Non-AP populations and their D99 counterparts show no significant change over the course of a year. In fact, D99 AP students gave less positive responses than did A99 AP students. D99 Non-AP students gave a more positive response than A99 Non-AP students. This means that overall, the A99 AP and D99 AP population's attitudes toward engineering decreased. This is not what would be expected, but could be evident because the population is made up of engineer and science students and it is possible that the non-engineers are masking the engineers' responses. This is not true though. When the analysis was done with only engineering students, there was no significant difference at all for group two between any of the populations. Hence, it would seem that an analysis of the science student population is needed to further understand where this difference in the A99 AP and A99 Non-AP comes from.

5.2.2 Engineering Student Population

The results from the engineering student population showed that the difference in all AP and Non-AP students' attitude toward their own problem solving abilities decreased over the course of the year. This again demonstrates a decrease in the AP students' attitude response and an increase in the Non-AP students' responses in D99 Non-AP as compared to the A99 Non-AP populations. As students' skills in problem solving are shown to increase in the Calculus III/Introduction to Programming bridge, it seems that this is presently an isolated case. Although there may be other data to explain the decrease in AP students' attitudes, we believe more data is needed before a better judgment can be made.

Comparing the results of engineering and science majors and just engineering majors with respect to group 2, it is evident that the science students are actually causing the significant difference. We find it interesting that the science majors would cause the A99 AP population to be significantly different from the A99 non-AP population in group two. This could be explained by more research, but we speculate that it is because the Non-AP student population's attitude increases more over the course of the year than the AP population's attitude decreases. Overall, we note that the engineering student population has no significant difference from the engineering and science student population.

5.2.3 Female Population

Analyzing just the female students from the engineering and science major population, we found that, unlike the engineering and science major population, there was no significant difference in group two for the A99 AP and A99 non-AP students. This confirms that the female students do not significantly contribute to the difference in group two for the A99 AP and A99 Non-AP engineering and science students.

The two areas that differed significantly for D99 AP females above A99 females were knowledge of skills in engineering, and self-perception of their technical skills. The D99 AP females answered more positively in both categories than their A99 counterparts. This shows that female students' attitudes were positively affected by bridging. Although this is only shown significantly in two categories, we see that of all the other groups in table 4.19, that in only three groups does the D99 AP population report a less positive attitude than the A99 AP students, and none of the less positive responses are close to being significantly different. Also, in comparing D99 AP and D99 non-AP students, we see that female students in the D99 AP population have a significantly more positive response to knowledge of skills in engineering. This further substantiates our belief that bridging significantly affects the attitudes of female students. The only drawback to this data is that the populations of female students in each population (A99 AP, D99 AP, A99 non-AP, and D99 non-AP) are small. This could lead to outliers having a significant effect on the results. We do not believe this to be the case here.

5.2.4 Does Bridging Help to Improved Students' Attitudes Toward Learning?

Through our analysis we find that the bridging model has had certain isolated effects on students' perception of engineering, their own skills, and their own abilities. We found that the Non-AP control population showed no significant attitude changes at all over the course of a year. We also found that there were differences in attitude change between male and female respondents. There were no significant negative changes in attitude over the course of the freshmen year whether bridged or not. This fact is interesting because although it is not desirable to have students' attitude decline it is also not likely that none of the attitudes should have declined by a statistically significant amount.

Again in the June 1999 report to the National Science Foundation faculty found that overall attitudes toward material seemed to improve. Professor Dimentberg found Mechanical Engineering students, "to be more interested in his course material," in the mechanical engineering course bridged from mathematics (Davis 1999). Professor Goulet described his "observed qualitative change among Linear Algebra students as 'close to overwhelming.' He also observed that the 'educational quality' of his conversations with students was elevated from 'what score they needed on what exam to get a C' to 'how the material relates to their other course(s)'" (Davis, 1999). The only case yet to demonstrate a decline in students' attitudes after participating in a bridged course was the Physics IV/Electrical Engineering bridge conducted by Professor Pierson. "Pierson found that attitudes toward interdisciplinary work of both the control and [experimental] groups declined over the course of the term. He suspects that the ratings declined from beginning to end partly because he built high expectations for the course, and partially because the last third of the course (immediately preceding the survey) was not bridged due to topic mismatch between the two courses. Therefore, [Pierson believes,] students may have felt the high expectations were not met" (Davis, 1999).

With the quantitative data collected in our study and the qualitative observations of faculty members, we believe that bridging seems as though it may have a positive effects on all students who take bridged courses. We are certain that taking bridged courses have positive effects on female students based on both surveys and opinions expressed in the report to NSF. With none of the survey data showing any significant decrease in attitude and with just one reported instance of decline in students' attitudes observed by faculty there is sufficient support to say that bridging is effective in increasing students' own interest in courses and engineering due to bridging. Hence, we recommend that the students who were surveyed in August of 1999 be resurveyed before the close of the 1999-2000 academic year. It is important to test this group to verify that the conclusions that have been drawn using the Pittsburgh Engineering Attitude Survey are correct.

5.2.4.1 Female Students

It seemed that female students were the population most affected by the bridging process. The female students showed positive attitude change in their impression of engineering. This is important to note considering that WPI and other engineering programs are trying to recruit and retain more and more female students. For a student's impression of engineering to be positively affected could lead to the retention of a student who would have left engineering. This is a measure that could be very important in retaining female students. Further examination that could draw a correlation between impression of engineering and retention as a result of these findings is encouraged.

5.3 How well do we prepare our students to understand the intimate linkages among basic concepts implied by parts *a* and *e* of criterion 3 in the ABET 2000 Criteria?

In the ABET 2000 Criteria for engineering technology parts a and e of criterion 3 specifically state that institutions must show students' ability to apply knowledge of mathematics, science, and engineering, and ability to identify, formulate, and solve engineering problems. These two points are another way of saying that students must have a fundamental understanding of basic material that they can effectively apply to all the steps needed for solving engineering problems. As the "bridging model" was developed to bridge the use of fundamental concepts from the most basic courses to the courses where those fundamentals are utilized it is important to ask how effectively this linkage has been demonstrated.

Looking at the results of both the student grade and attitudinal survey analyses it is not convincingly evident that students understand the linkages in the fundamentals learned in each course. The analysis of the student grade data demonstrates to us that students do learn the fundamentals of calculus and are able to apply them in computer programming. This practice in applying the fundamentals of calculus to programming has resulted in a significant increase in performance over the course of the bridge. But this is the only course where we are able to draw this conclusion from our data. From the analysis of the Linear Algebra and Chemistry bridges we do not have enough information to make a conjecture about whether or not students can truly see the linkages between fundamental ideas in each discipline. Professor Goulet's "conversations with students, it is clear to him that students were impressed at the effort he was investing in order to tailor the course to meet their needs (*i.e.* majors)" (Davis, 1999) shows evidence that some students are seeing a link to their other courses, but the claim does not substantiate a general trend. Hence, we still think that only more data will be adequate to draw a conclusion.

5.4 Will Bridging Be an Effective for Achieving ABET Accreditation Standards?

Although we had hoped to be able to definitively answer this question, we cannot. We would like to believe that as an institution WPI is continuously moving to prepare students to meet these challenges. From the data we have it is evident that if course bridging is to be a method to facilitate this then the development of the bridging model needs to be a long-term goal. Further evaluation is needed, but preliminarily we believe that course bridging has the potential to help meet the new accreditation criteria set down by ABET.

5.5 Recommendations for Future Work

We recommend that course bridging be further developed as we believe that it has the potential to develop the understanding of how interconnected the fundamentals of one subject are to another and how a fundamental understanding allows one to learn more about complex subject matter in other disciplines. As bridging is developed we suggest that comparing the new student grade data with the existing data set to better monitor the development of bridging. This will allow the faculty developing the model to understand better how the model is affecting students.

5.5.1 Student Grade data

We also recommend development of a more controlled experiment. For instance if one faculty member could teach both courses in a bridge for three to four years then the exams and the teaching style could be controlled for. This would lead to more meaningful analysis of student grade data. This may be unfeasible due to the way that the university systems work. Therefore we encourage a closer tie between bridged-from and bridged-to faculty members. With a commitment to the study of the bridging model by the instructors of both courses we think that more consistent data will result which has less possible error. The NSF report emphasizes the adoption of more standardized and formalized evaluation materials (Davis, 1999). If this could be achieved in both the bridged courses the incomplete data sets found in many of the bridging experiments would be minimized.

5.5.2 Attitude Evaluation

In terms of the Pittsburgh Engineering Attitude Survey we highly recommend that it be implemented again as a post-survey for the class of 2003 and then as pre- and post-surveys for the class of 2004. The post survey should be implemented for the class of 2003 because our administration of the survey as a post attitudinal survey to Freshmen in the class of 2002, and then as a pre-survey to freshmen in the class of 2003 is unusual for this survey. Actually as far as we know it has never been done with the Pittsburgh

Engineering Attitudes Survey. Therefore, although we assume, for our purposes, that there are no significant effects from this administration, it is possible that there are. Reissuing the survey and analyzing the data would determine if our assumption was valid. Administering the pre- and post-survey to the freshmen of 2004 would allow WPI to see if the survey can provide usable feedback about the attitude change that students have about engineering, and their perception of their own abilities. The NSF report also points out that a standard set of attitude measures is needed in all courses, and preferably both pre- and post-course. We believe that this Pittsburgh survey may prove useful in developing an overall bridged curriculum in the first two years, as the survey is designed to measure short-term attitude changes in freshmen. Further, there are surveys being developed and tested to gauge attitude change in the sophomore and junior years that compliment the freshman survey. A suite of standard surveys could help assess the effects of a bridged curriculum in the first two years.

5.5.2.1 Survey Administration

We suggest that more direct supervision be applied in the administration of the surveys to students, especially when surveys are administered through freshmen orientation. Since most of our surveys were never returned we believe that if students need to take this survey at freshmen orientation then someone who is administering the tests should be present to follow up with orientation staff to track down all completed surveys.

5.5.3 Future Research

5.5.3.1 Analysis of GPA data

One form of analysis, which we did not do, was an analysis of GPA data. We believe that the GPA data would be a good way to determine how students fared over the course of their freshmen year. This measure allows one to look at students from a yearlong perspective and from a traditional grading scheme. Therefore, students are evaluated in a standard method, which has a large quantity of control data. We believe that the analysis of this data along with the attitudinal data should allow future researchers to determine the outcome of a student's freshmen year by developing models around GPA and initial attitudes. The NSF report says that looking at the same data may be able to relate participation in bridged courses with overall student performance (Davis, 1999). The combination of these two idea could lead to a system to pick out students at risk of failing or leaving engineering due to dissatisfaction. Resources could be directed to these at risk students to both help the student and to reduce attrition from WPI.

5.5.3.2 Extra Data

There is a body of data remaining after we have made our inquiries into the attitudes of Freshman at the end of the year in the data collected on the Sophomores, Juniors, and Seniors who took Linear Algebra and Differential Equations. This has resulted because we wanted to single out the freshmen for our study. This data on upper classmen has been set aside as data for another IQP group. This will give the researchers a starting point for more data collection, as we did not assess the attitudinal change of upperclassmen.

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Appendix A: Pittsburgh Engineering Attitude Survey

The Pittsburgh Engineering Attitude Survey has been reproduced with the permission of Dr. Mary Besterfield-Sacre. Dr. Besterfield-Sacre is a faculty member at the University of Pittsburgh in Pittsburgh, Pennsylvania. The original survey has been altered slightly to better suit the needs of this study and WPI.

In this section we have also included the breakdown of the questions on the survey into the 13 groups and the statistical weights for each question.

This information has been presented here so that others may reanalyze the data presented here. The further use of the survey and statistical weights for any other purpose but the analysis of the data presented in this volume is prohibited. The Pittsburgh Engineering Attitude Survey is under copyright and written approval is necessary prior to use.

Pittsburgh Engineering Attitudes Survey

This is a survey to elicit Engineers' opinions and feelings about engineering. Please do not spend more than 25 minutes to complete the questionnaire, so work as quickly as you can. (Remember, these are your own personal attitudes, not your friend's.) Your responses will remain anonymous. Complete the following information as instructed.

Student Number Only last 4 digits

[redacted]								
O0	O0	O0	O0	O0	O0	O0	O0	O0
O1	O1	O1	O1	O1	O1	O1	O1	O1
O2	O2	O2	O2	O2	O2	O2	O2	O2
O3	O3	O3	O3	O3	O3	O3	O3	O3
O4	O4	O4	O4	O4	O4	O4	O4	O4
O5	O5	O5	O5	O5	O5	O5	O5	O5
O6	O6	O6	O6	O6	O6	O6	O6	O6
O7	O7	O7	O7	O7	O7	O7	O7	O7
O8	O8	O8	O8	O8	O8	O8	O8	O8
O9	O9	O9	O9	O9	O9	O9	O9	O9

Age

O0	O0
O1	O1
O2	O2
O3	O3
O4	O4
O5	O5
O6	O6
O7	O7
O8	O8
O9	O9

School

O0	O0
O1	O1
O2	O2
O3	O3
O4	O4
O5	O5
O6	O6
O7	O7
O8	O8
O9	O9

Ethnicity

- O African American
- O Asian Pacific
- O Hispanic
- O Native American
- O White Caucasian
- O Other

School Specific Code

O0	O0	O8	O12
O1	O1	O9	O13
O2	O2	O10	O14
O3	O3	O11	O15

Gender

- O Male
- O Female

Enrollment Status

- O Under Grad
- O Special Student
- O Mass. Academy

Transfer Student

- O No
- O Yes (< 1 year)
- O Yes (> 1 Year)

Major

O ME	O CH/BC
O EE	O BB/BBT
O CM	O PH
O CE	O MA
O CS	O MG/MIS
O ST	O OTHER

Year

- O Freshman
- O Sophomore
- O Junior
- O Senior

For each statement about engineering please fill in the number that corresponds to how strongly you disagree or agree with the statement.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I expect that engineering/science will be a rewarding career.	O 1	O 2	O 3	O 4	O 5
2. I expect that studying engineering/science will be rewarding.	O 1	O 2	O 3	O 4	O 5
3. The advantages of studying engineering/science outweigh the disadvantages.	O 1	O 2	O 3	O 4	O 5
4. I don't care for this career.	O 1	O 2	O 3	O 4	O 5
5. The future benefits of studying engineering/science are worth the effort.	O 1	O 2	O 3	O 4	O 5
6. I can think of several other majors that would be more rewarding than engineering/science.	O 1	O 2	O 3	O 4	O 5
7. I have no desire to change to another major (biology, English, chemistry, art, history, etc.).	O 1	O 2	O 3	O 4	O 5
8. The rewards of getting an engineering/science degree are not worth the effort.	O 1	O 2	O 3	O 4	O 5
9. From what I know, engineering/science is boring.	O 1	O 2	O 3	O 4	O 5
10. Engineers/Scientists are well paid.	O 1	O 2	O 3	O 4	O 5
11. Engineers/Scientists contribute more to making the world a better place than people in most other occupations.	O 1	O 2	O 3	O 4	O 5
12. Engineers/Scientists are innovative.	O 1	O 2	O 3	O 4	O 5
13. I enjoy the subjects of science and mathematics most.	O 1	O 2	O 3	O 4	O 5
14. I will have no problem finding a job when I have obtained an engineering/science degree.	O 1	O 2	O 3	O 4	O 5
15. Engineering/Science is an exact science.	O 1	O 2	O 3	O 4	O 5
16. My parent(s) are making me study engineering/science.	O 1	O 2	O 3	O 4	O 5
17. Engineering/Science is an occupation that is respected by other people.	O 1	O 2	O 3	O 4	O 5
18. I like the professionalism that goes with being an engineer/science.	O 1	O 2	O 3	O 4	O 5
19. I enjoy taking liberal arts courses more than math and science courses.	O 1	O 2	O 3	O 4	O 5

Statements 1-28

Grp	Number	Statement	Normalized Weight
1	12	Eng are inn	0.166
	22	Eng fix wor	0.164
	25	Eng are cre	0.163
	28	Technology	0.143
	17	Eng is respe	0.135
	18	Like profess	0.128
	27	Enjoy figuri	0.101
2	1	Expect eng	0.124
	2	Expect stud	0.121
	4	Don't care f	0.120
	3	Adv. outwei	0.114
	7	No desire to	0.114
	8	Rewards of	0.113
	5	Future bene	0.104
	9	Eng boring	0.100
	6	Other major	0.090
3	23	Eng guarant	0.301
	14	No problem	0.289
	21	Study eng f	0.206
	10	Eng well pa	0.204
4	20	Eng improv	0.519
	11	Eng make w	0.481
5	19	Enjoy libera	0.525
	13	Enjoy math/	0.475
6	15	Eng exact s	0.516
	26	Eng precise	0.484
7	24	Parents wan	0.586
	16	Parents forc	0.414

Statements 29-35

Grp	Number	Statement	Normalized Weight
8	30	Physics abil	0.244
	32	Eng ability	0.233
	31	Calculus abi	0.224
	29	Chemistry a	0.169
9	**35**	**Computer**	**0.130/0.161**
	33	Writing abil	0.422
	34	Speaking ab	0.416

Statements 36-50

Grp	Number	Statement	Normalized Weights
10	50	Enjoy diff w	0.247
	49	Enjoy open-	0.244
	38	Creative thi	0.177
	42	Confident ir	0.169
	40	Strong prob	0.163
11	47	Mechanicall	0.303
	48	Technically	0.294
	36	Know what	0.202
	44	Good at des	0.201
	41	**Friends stu**	*
12	43	Prefer study	0.385
	37	Group bette	0.363
	45	Have not en	0.252
13	46	Confident ir	0.501
	39	Need more t	0.499

13 Groups of Questions

1 Perception of the Work Eng. Do ant the Eng. Profession
2 Gen. Impressions on Engineering
3 Financial Influences for Studying Eng.
4 Perception on how Eng. Contribute to Society
5 Enjoyment of Math and science courses
6 Eng. Percieved as an exact science
7 Family Influences for Studying eng.
8 Confidence in basic eng. Knowledge and skills
9 Confidence in Communication and computer skills
Problem solving abilities
Eng. Attributes
Working in groups
Adequate study habits

Score range for answers

5 is more positive response 1 is less positive

Appendix B: Student Grade Data

The Student Grade Data is located on the disk found in the jacket of this report.

Appendix C: Pittsburgh Engineering Attitude Survey Data

The student Pittsburgh Engineering Attitude Survey data is located on the disk found in the jacket of this report. There are three separate files.

1. Overall_Analysis.xls

Contains the overall analysis of the reported material.

2. Eng_Major_Analysis.xls

Contains the analysis of only the engineering majors sampled.

3. Female_Analysis.xls

Contains the analysis of only the female students who were sampled.