

## A Qualitative, Comparative Study of Students' Problem Solving Abilities and Procedures

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### I. Introduction

Currently, two freshmen curricula exist at Rose-Hulman Institute of Technology. This creates a unique opportunity to compare the problem-solving, team training and technology utilization abilities of students who completed the Integrated First-Year Curriculum in Science, Engineering and Mathematics (IFYCSEM) pilot program to the abilities of students who completed the traditional freshman engineering curriculum. This study seeks to **identify** the differences that exist between the techniques of sophomores who were IFYCSEM students and sophomores who were in the traditional first-year curriculum when they are **confronted** with a complex problem in a group setting. This study will also address the link between observed behaviors during problem-solving sessions and students' performance on standardized tests designed to assess problem solving predispositions and abilities.

### II. Project Description

Rose-Hulman Institute of Technology (RHIT) has had a pilot freshman program for the last six years. The Integrated First-Year Curriculum in Science, Engineering, and Mathematics (IFYCSEM) is designed to enhance students' abilities to solve complex problems using computers and active learning. The curriculum also strives to create experiences which parallel those in the workplace. This curriculum is voluntary and **one-quarter** of the RHIT freshman class typically volunteers for the program. In the IFYCSEM curriculum, **all** technical courses in the first year have been integrated into three, twelve-credit courses which are team taught by an interdisciplinary group of faculty. Courses include calculus, physics, chemistry, computer science, **design**, and graphics.

There is special interest in examining the processes used by students in solving complex engineering problems. The study will answer the questions: 1) What processes and tools are used by students when they are confronted with a complex problem in a team setting? 2) Are there differences between students who have been in IFYCSEM and those who have been in the traditional curriculum? 3) If there are observed differences, can they be linked to the different curriculum delivery systems?

### III. Relevant Literature

While literature on problem solving is abundant, the most relevant literature to this proposed study is Carrie **Mullins** and Cynthia J. **Atman's** (1994) "Freshmen Engineer's Strategies for Solving Open-ended Problems" [sic] published in the ASEE Annual Conference Proceedings 1995. The **Mullins** and Atman work "looks at the freshman engineer as a novice problem solver" (p. 220). The researchers characterized the differences between novice and expert problem solvers thus:

Expert problem solving strategies include representing problems at a deep, semantic level devoting



much of their time to understanding the problem and building mental representations of the problem.

Novice problem solvers appear to have fewer pre-formed mental representations, tend to focus on the surface aspects of the problem and spend less time defining the problem. (Mullins and Atman, 1994, p. 220)

In "Gathering Information What do Students Do?" Cynthia Atman, Karen M. **Bursic**, and **Stefanie L. Lozio** (1995) conclude that when asked to solve problems, freshman students, and even seniors, do not spend the required amount of time to gather information. These concerns about the time students spend gathering **information** will be examined in the proposed study.

Also relevant is Pamela Moore, Cynthia Atman, Karen M, **Bursic**, Larry J. **Shuman** and Byron **Gottfried's** (1995). "Do Freshman Design Texts Adequately Define the Engineering Design Process?" in the ASEE Proceedings of 1995. Noting that problem solving and the design process are not synonymous, the authors are **careful** to state that while problem solving is always a part of **the** design process, many problems are **solved** -outside of the design process. However, for many engineering students, the principal **problem-solving** process of the profession--the design process--is never adequately defined:

The content analysis confirms the findings of the literature that there is a lack of consensus about how to define the design process and about the distinction between design and problem solving. . . . the analysis of students' self-assessments illustrates that the steps mentioned **infrequently** in textbooks (Identification of Need, Decision, and Implementation) were **often** not mentioned as being performed by the students. If the students are unaware of the significance of such steps . . . students may never completely understand nor appreciate **all** the elements of the design process. (Moore, et al., 1995, p. 169)

Because of the embeddedness of problem solving in the design process, it is important to evaluate whether or not students in the **IFYCSEM** perform in ways that evidence they have received definitions of problem solving that are adequate enough for them to **operationalize** into problem solving methods.

#### IV. Methodologies and Modes of Analysis

This study focused on in-depth evaluation of the behavior of sixteen students in a problem-solving setting that closely parallels the work environment of engineers. Eight students will be chosen from the Rose-Hulman sophomores who completed the IFYCSEM program. The IFYCSEM students will be chosen to approximate a "typical sample" based on their predicted index, earned grade-point averages at the end of their freshman year, and scores on the California Critical Thinking Skills Test ©, and the California Critical Thinking Dispositions Inventories ©. The comparison groups will consist of eight sophomores who completed the traditional program. All sixteen students received letters asking them to participate in this project and **notifying** them that they would be paid a stipend.

Students enter the **IFYCSEM** voluntarily and may therefore differ from the "typical" student population in the traditional program. To minimize the differences between the groups, the comparison group of students from the traditional curriculum were matched to the **IFYCSEM** students on predicted index, earned grade point averages and test scores on the California Critical Thinking Skills Test ©, and the California Critical Thinking Dispositions **Inventory** ©.

The predicted index was chosen because it has been found to be the best single indicator of success at **Rose-Hulman**. The predicted index, along with the earned grade point average, will enable the matching of



students based on perceived potential as well as actual performance as indicated by grades received. The California Critical Thinking Tests measure students abilities and dispositions toward critical thinking.

The California Critical Thinking Skills Test measures student's abilities in five areas: 1) *analysis* means comprehension and expression of meaning or significance as well as identification of inferential relationships; 2) *evaluation also* has dual meaning--it means assessment of the credibility of statements or representations and the logical strength of **inferential** relationships as well as to state and **justify** the results of one's reasoning; 3) *inference* means to **identify** and secure elements needed to draw reasonable conclusions; to form conjectures and hypotheses, to consider relevant information and deduce consequences 4) *deductive reasoning* means the assumed truth of the premises necessitates the truth of the conclusion: it is not logically possible for the conclusion to be false and **all** the premises true; and 5) *inductive reasoning* means an argument's conclusion is warranted, but not necessitated, by the assumed truth of its premises.

The **California** Critical Thinking Dispositions Inventory measures *truth-seeking, open-mindedness, analyticity* (being alert to potentially problematic situations, anticipating possible results or consequences, and **prizing** the-application of reason and the use of evidence even if the problem at hand turns out to be challenging or difficult) *systematicity* (being organized, orderly, focused, and diligent in inquiry), *self-confidence, inquisitiveness, and maturity.*

By matching students on these criteria, the individual differences in problem-solving skills as measured by these tests will be minimized. The Meyers-Briggs Type Indicator data will be also used to establish groups which are similar in personality and type preference, thus minimizing the influence of group dynamics.

A panel of RHIT professors consisting of an equal number of faculty who have taught in the IFYCSEM curriculum and those who have only taught in the traditional curriculum will select, by consensus, an open-ended problem that they believe is solvable by students who have completed either of the first-year engineering curricula.

It will be important to place students in a "real world" situation where they will make decisions about how to get the job done independent of instruction. There will be no professors present and students will not be instructed to organize their work in any particular way or to use any certain "tools." It will be of principal interest whether the IFYCSEM students choose to employ the techniques of teaming and technology utilization that have been emphasized in the IFYCSEM curriculum, or chose to employ other techniques.

Students will be placed into four groups, two groups of students who have completed the IFYCSEM and two groups of students who completed the traditional freshman program. There will be four members per group in separate rooms with identical technological resources available for the problem-solving session. The students will engage in the problem-solving session simultaneously to minimize differences in the testing environment and access to information. Each session will be video-taped for analysis.

Following the session, the students will be asked to respond to their experience in writing using guided questions. They will be individually debriefed and questioned about their experience. They will be asked about where they think they acquired the skills and procedural tools they used. This information will be used to confirm the observations made on videotape and for triangulation. Because each student is an individual with a wide range of experiences, it is not possible in a human situation to control the extent to which a difference seen among groups, can automatically be attributed to specific curricula. By triangulating observed



data with student interviews, researchers will be able to explore students' impressions about their abilities to solve problems and ask students where they believe they acquired the knowledge and techniques that helped them solve the problem. Among the questions students will be asked will be whether they have ever received team training, what their previous experience with technology has been, what kinds of problem-solving instruction they have received, and how many opportunities they have had to practice solving open-ended problems. It is believed that with this information, links between observed student behavior and their curriculum experiences can be supported.

The dialogue recorded on the videotape will be transcribed and the session analyzed using qualitative evaluation methods and the "C-Video" program for textual coding of videotape. The tape recordings from the debriefing session will also be transcribed and unitized. Data will be analyzed by unitization and categorization using the "constant comparative method" as outlined in Lincoln and Guba's (1995) Naturalistic Inquiry.

## V. Impact on Education

This study hopes to accomplish several things which will contribute to improvement in curriculum reform. It will provide a context for discussing problem-solving methods used by students, examine the impact of innovative curricula in the areas of team training, the use of technology, and the use of open-ended exercises on sophomore engineering students' ability to solve complex problems. It will inform faculty regarding these methods so that they may better understand the learning process as it relates to **problem-solving** and inform them regarding teaching strategies in the classroom which promote **successful problem-solving** processes. By including a group of sophomores who have moved from the **IFYCSEM** curriculum to the traditional curriculum, the impact of the curriculum over time can also be examined and reported. This study will also provide valuable information about the efficacy of the **IFYCSEM** pilot program in achieving its goals relating to problem solving.

## VI. Reporting of Results

The study will take place during March, 1996 and the results of the study will be reported in a presentation at ASEE 1996.

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