CONTENT ANALYSIS OF UNDERGRADUATE RESEARCH STUDENT EVALUATIONS

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ABSTRACT

To examine the educational effectiveness of the undergraduate research experience, a content analysis was conducted on 183 randomly selected free-form evaluation letters (1-4 pages long) written during the period 1985 to 1995 by undergraduate research students in engineering and the sciences. Students perceived their learning to be greater through research than through ordinary classes. They reported increased technical skill, ability to act independently, insight into graduate study and career possibilities, understanding of the value of team work, ability to work with setbacks and/or ambiguity, desire to learn, ability to think creatively and/or synthetically, self confidence, communication skills, and understanding of where "knowledge" comes from.

I. INTRODUCTION

With its call to "make research-based learning the standard" for the education of undergraduates in research universities, the influential Boyer Commission Report (1998) brought a major national focus on undergraduate research within US higher education. The National Science Foundation named undergraduate research as a critical component of its core strategy for integrating research and education (National Science Foundation 2000). Faculty mentors agree that undergraduates gain significant educational benefits from a research experience (Gates et al., 1999; Kardash, 2000, Zydney et al., 2002). The public, however, may maintain some skepticism about educational value added to undergraduate education by the research experience, noting "Research by Undergraduates Proliferates, But Is Some of It Just Glorified Homework?" (Reisberg, 1998). If undergraduate research is to serve as the cornerstone for a reform of undergraduate education, it would be helpful to identify what the educational benefits of the experience are and to document their existence.

University of Delaware Undergraduate Research Program

The University of Delaware, a research-extensive institution with about 15,000 full-time undergraduates enrolled in 122 degree programs, has sponsored a university-wide Undergraduate Research Program since 1980. In one of its sub-programs, "Science and Engineering Scholars," which has operated since 1985, participants receive a research scholarship that enables them to work full-time for ten weeks during the summer following their sophomore year as a junior collaborator on a faculty mentor's research project. The students are expected to gain increasing independence throughout the summer so that by the end of the summer, they will be genuinely contributing to the research program. They then continue their research during the junior year, which concludes with a Scholars poster session, in which the Scholars present scientific posters they have prepared on the projects to which they have contributed. Some of the participants continue with undergraduate research until they graduate, often as authors of senior theses and/or as co-authors with their faculty of professional research publications. Others conclude their research participation in June of their junior year.

II. EVALUATIONS USED

Science and Engineering Scholars are required to write extensive, thoughtful evaluations of the summer portion of their experience in addition to providing shorter answers on questionnaires at the end of academic-year terms. The students submitting the end-of-summer evaluations used in this study did not have a form or questionnaire to complete; rather, they were requested to describe their experience discursively, evaluating its impact on their learning. The evaluation expected from the students was described in the following words:

> *This evaluation letter remains completely confidential. Its purpose is to aid the development and improvement of the Science and Engineering Scholars Program. Your letter should report briefly on the technical progress of your work, on the educational and personal aspects of the undergraduate research experience, and on your registration plans for the fall term. You should comment as frankly and specifically as possible on your personal and professional growth as a result of participation. You should be specific about the nature of the faculty supervision, help, moral and financial support received. You should give the Undergraduate Research Program suggestions for improving the workings of the Science and Engineering Scholars Program, where possible.*
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> *We are especially interested to know how students judge their research experience as a component of their undergraduate education. How does what they learn in undergraduate research compare to more standard course work? Would they want to see more time made available in their schedule for research or similar activities? Do they sense that undergraduate research assistance is genuinely encouraged by all units within the University?*

Based on your experience thus far, would you recommend that the summer portion of the Science and Engineering Scholars Program be continued as is?

The original purpose of these evaluations was formative. They enabled the program coordinators to evaluate the program's effectiveness as it was developing, to intervene with individual assistance where needed, and to plan program improvements. However, since a large number of these evaluations were collected over many years and since they had been retained, the evaluations were also usable as the basis for a summative evaluation of the Undergraduate Research Program's effectiveness. Response from program participants in submitting the required letters was nearly 100%; thus, results could be taken as representative of participants' experience in the program when they are mid-way through their undergraduate careers.

Research Questions

The evaluations were used to address these research questions:

1. How effective did students perceive the experience of learning through research to be when compared to the experience of learning through course work?

2. What specific skills or abilities were perceived by students to increase as a result of the research experience?

Since the evaluations were discursive and open-ended and were not prompted by questionnaires, omission of a category did not necessarily indicate the perception of no skill increase in that area. Thus, the content categories that were evident in this analysis should be taken as suggestive rather than definitive and should be compared to results from other facets of the overall assessment of the Undergraduate Research Program.

The University of Delaware RAIRE studies

The content analysis reported herein comprises one part of a multi-faceted evaluation of the University of Delaware's Undergraduate Research Program, an assessment funded by a National Science Foundation RAIRE [Recognition Award for the Integration of Research and Education] award, which was granted to the University of Delaware in 1997.[1] This large-scale evaluation was designed to address the national need to study the educational effectiveness of the undergraduate research experience.[2] Other facets of the evaluation included a survey of alumni in all fields, a survey of science and engineering faculty, and a five-year longitudinal study of currently enrolled science and engineering undergraduates.[3]

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[1] http://www.udel.edu/RAIRE

[2] This material is based upon work supported by the National Science Foundation under Grant No. 9620082. Any opinions, finding, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

[3] The findings of the other facets are available in Bauer, K.W. & Bennett, J.S. (in press) and Zydney, A.L., et al (2002). As of September 2002, the longitudinal study is being written.

III. METHOD

This content analysis examined 183 letters, each 1 to 4 pages in length. The letters were randomly selected for every third year from over a ten-year time period by taking all evaluations written by the sophomore participants in the Science and Engineering Scholars Program in each of four years as follows:

1985-86---44 evaluation letters
1988-89---47 evaluation letters
1991-92---43 evaluation letters
1994-95---49 evaluation letters

Following Holsti's (1969) suggested criteria for categorization, a rater unfamiliar with the Undergraduate Research Program worked with a sample of letters to develop content categories related to our two research questions. These were reviewed by the Undergraduate Research Coordinator to ensure that they reflected the purposes of the research. The rater then used the categories to code each of the 183 evaluation letters for the presence of the content items. As a cross check, as second rater coded 50 of the letters using the same content categories. The inter-rater reliability coefficient was .65.

IV. RESULTS

Research Question 1: How did students value the research experience in comparison to course work?

In order to assess how the Scholars felt that the learning experience provided by their summer research compared overall to their learning through standard course work, three subcategories of comments were coded for each evaluation letter to see whether the student indicated that research was (1) equal in value to standard course work, (2) less valuable than standard course work, (2) more valuable than standard course work. Of the 183 students studied, 154 (84%) had written a comment that corresponded to one of these three subcategories.

Table One compares results for those 154 students who addressed the comparison between undergraduate research and standard classroom learning. For the major groups, percentages are based on the number of students within each major group who addressed the comparison. The actual number of students represented by the percentage is in parentheses below the percentage.

Table One:
Research in Comparison to Course Work
(Percentages are of those letters that included this category.)

Research learning greater	73%	(113)
Equal	25%	(39)
Course learning greater	1%	(2)

As shown, the large majority, 113 students, felt that they had learned more through the research experience than in standard courses. The students supplying this comment represented 62 % of the total letters and 73% of those who commented on the comparison.

Some students felt liberated by the realism of their research experience; for instance, an electrical engineering student reported, "My research experience allows me to be independent, flexible, creative, etc. It truly presents a challenge to myself that I have yet to find in any standard course." Many students expressed no dissatisfaction with course work, but tried to explain how the research experience differed from and complemented it, sometimes using descriptive terms like "joy" and "wonderful." For instance, an entomology student said, "It is a challenge to be presented with a [genuine] problem in experimental design and a joy to come up with a solution that works." A chemistry student commented, "There is nothing quite so wonderful as sitting down and puzzling out and working over something that has never been done before. The classroom can teach abstract and creative thought, but only the research lab can show you how to rein abstract thought into a real and working solution to a problem."

In addition to those students who reported that they learned more through research, another 39 students felt that their learning in research was as valuable as that in courses but of a different kind; the students making this comment represented 21% of the total evaluation letters and 25% of those commenting on the comparison. Two individuals, representing 1% both of the total and of the students commenting on the comparison, felt that they learned more through course work than through research

Research Question 2: Specific Learning Content Categories

Almost all of the students (96%) described at length the advanced technical skills they had learned through their research assistance. These skills were what many of the students expected to gain when they sought the research experience, and they were proud to report that they had measured up to or exceeded their own expectations in this area. The reported gains were sometimes accompanied by a statement describing increased general self confidence, as in the following comment by a physiology student, which was

coded for two comment categories, (1) increased technical skill, and (2) increased self-confidence: "Of greatest importance to me was the training in and performance of delicate small animal surgery. At the onset of the program I thought these skills were beyond the scope of my abilities; however, through careful supervision, my confidence and ability have grown tremendously." Overall, 28% of the students commented directly on their generalized increased self-confidence.

Other skills mentioned were: increased general ability to think creatively and/or synthetically (mentioned in 32% of the evaluations), improved ability to act independently (mentioned by 57%) and increased ability to work with situations involving ambiguity and setbacks (mentioned by 37%), as in this evaluation, which was coded for all three of these comment categories:

> It was…a new experience to do work that hasn't been done before as opposed to course work where students have performed all of the labs before, taken all the same tests, etc. I began to feel much more responsible for what I'm doing as there was no one to turn to and say, "This didn't work, what do I do?" Instead, my professor was saying to me, "If it didn't work, what happened?" In answering this question, I became familiar with chemical literature and other sources of information available. I also had to be creative and try new methods, reactions, conditions, etc. Since I didn't have a grasp on what was wrong, I couldn't have a closed mind as to how to fix it. That feeling of working with unknowns was not easy to handle especially for a student who usually has a command of her work.

Nearly half of the students (45%) commented that the research experience had given them important insight into the world of graduate study, thus aiding their own career decision. For instance, "I also learned a great deal about graduate school from the students I was working with. I have seen how much work it is, what a commitment it is. There is as large a difference between college and grad school as there is between high school and college. When I do go to graduate school, I will be going with the right frame of mind, knowing what to expect."

Forty-five percent of the students also commented on a new understanding of the importance of collaboration in research, not only with graduate students and their faculty sponsors, but also with technicians, industrial scientists and engineers, and others.

About one third (32%) reported an increased desire to learn because of their research, as did one chemical engineering student, who outlined an ambitious plan of intended course work following his summer, explaining how his research experience was now guiding his studies: "This research was at least 1,000 times more intellectually stimulating than any course work I've ever done. Reading papers concerning my research (activated carbon) got me interested in other environmental engineering areas such as water chemistry and hazardous waste detoxification. I really became hungry for any information regarding environmental work."

About a quarter of the evaluations (24%) mentioned improved communications skills gained from professional presentation of research. For instance, one student reported: "I have learned how to speak at the professional and technical levels with my peers as well as my superiors, and I feel confident discussing the various aspects of the research" with both faculty and industry professionals. A quarter (24%) also said they had gained a new understanding of where ideas and theories in their field came from and a recognition of the tentativeness of scientific findings.

Table Two below summarizes the frequency of the content categories describing educational gains resulting from the undergraduate research experience.

Table Two:
Skills and Abilities Content Categories

Content Category	N	Percent of total evaluations
Increased technical skills	176	96%
Increased ability to act independently	104	57%
Insight into graduate school	82	45%
Insight into value of teamwork	78	43%
Ability to work with ambiguity/obstacles	67	37%
Ability to think creatively/synthetically	59	32%
Increased desire to learn	59	32%
Increased general self-confidence	51	28%
Improved communication skills	44	24%
Deepened understanding of where "knowledge" comes from	44	24%

V. DISCUSSION

Analysis of evaluation letters reveals that rising juniors at the end of a ten-week summer research experience perceived themselves to have made important gains in their undergraduate education. Most felt that they had learned more through conducting research than they had learned from regular course work. The increased learning was of two kinds, cognitive and technical, on the one hand, and behavioral on the other. Since students were writing open-ended evaluations, inventing their own categories of responses, it can be assumed that the categories that appeared most frequently were those at the forefront of the students' minds. It is also reasonable to assume, however, that if they had been given a questionnaire with all ten categories listed, some would have indicated that they had made gains on those areas even if, when composing an undirected letter, they had not commented on that form of learning.

Many students acknowledged beginning the summer feeling uncertain that they would be able to accomplish all that would be expected of them; thus, it is not surprising that 96% wanted to report that they had indeed learned to perform complex investigative tasks well and that 57% remarked on a newfound ability to act independently. The next most frequently remarked forms of learning were closely related to the research communities in which they worked, with slightly under half remarking that they had learned by experience the importance of effective teamwork, and approximately the same number reporting insight gained into the graduate school experience. Over one-third of the students reported a new ability to work with the setbacks and ambiguities inherent in the research endeavor, and almost the same number said they developed new abilities to think synthetically and to think and act creatively. These advances were paralleled in frequency by a reported increased desire to learn. Finally, about a quarter of the letters referred to significantly improved communication skills and an overall deepened understanding of the tentative nature of research conclusions, suggesting a more sophisticated epistemology.

V. LIMITATIONS AND FURTHER STUDY

The evaluations used for this analysis represent only students who worked full time in undergraduate research for the summer following their sophomore year. In order to obtain another perspective on such students' learning, it would be interesting to expand the study to examine the evaluations submitted by faculty supervisors of the undergraduate researchers during the same randomly selected years, to compare their perceptions to those of the students. In order to examine learning perceived by students who did not have a summer's immersion in research, it would be possible randomly to select evaluations written over the same ten-year period by students who participated in undergraduate research for only one or two semesters but did not have the summer immersion experience.

To further test the content categories found in this study, it would be possible to put the content categories into a questionnaire format that would then be administered to students in the same summer program over a period of several years, checking to see how frequently the content categories would be claimed to characterize a student's experience.

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