

EDUCATIONAL OUTCOMES OF THE INDUSTRY/UNIVERSITY COOPERATIVE RESEARCH PROGRAM: A FOLLOW-UP ASSESSMENT OF GRADUATE STUDENTS

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The purpose of this follow-up study was to examine and contrast the perceptions of graduates with and graduates without significant involvement in an NSF Industry/University Cooperative Research Center (IUCRC).

Ten of the 31 IUCRCs established prior to 1986 were studied. Two groups of graduates were studied; a group of 112 IUCRC graduates and a group of 138 non-IUCRC graduates from similar graduate programs in the same institutions.

Results suggest that graduates who have had significant involvement with an IUCRC consistently report more positive graduate experiences than non-IUCRC graduates. Means of 14 of the 17 comparable survey items were higher for the NSF center graduates than they were for graduates in the Comparison Group. The result of a sign test based on this fact indicated that the IUCRC graduates were significantly more positive about the value of their graduate education than were graduates in the Comparison Group.

Center graduates were significantly more likely to highly value their graduate training than graduates in the Comparison Group for: 1) establishing associations with researchers in the field and with industry representatives; 2) aiding in learning about research in industrial settings; 3) participating in applied research; 4) developing communication and teamwork skills, and; 5) gaining a broader perspective of research. Center graduates were significantly more likely to respond that the research opportunities provided by Center activities were of more value than other research opportunities than non-Center graduates were with respect to departmental opportunities.

The purpose of this follow-up was to examine and contrast the perceptions of graduates with and graduates without significant involvement in an NSF Industry/University Cooperative Research Center (IUCRC). The primary dependent variable was views regarding the value of graduate education expressed by IUCRC and non-IUCRC graduates from the same ten universities. Following the survey, a selected sample of center graduates was interviewed via telephone in an attempt to obtain a more in-depth understanding of their views regarding the strengths and weaknesses of their center-related educational and research experiences and to document any recommendations they might have had for improving the IUCRC experience.

Need for the Study

As technology becomes increasingly important in the production of goods and services, engineers will continue to be an essential part of the production equation (Pool, 1990). By direct inference, science and engineering education will also remain an essential component. Erich Bloch (1990) recently wrote that science and engineering education must become more organized, multidisciplinary and cooperative, that graduate programs must be expanded and strengthened, and that universities, industry and government must increase cooperative basic research efforts and associated research opportunities for students. In short, he called for doing a better job of bridging the gap between industry and universities by supporting multidisciplinary science and engineering centers on university campuses. To the extent that the NSF's IUCRC Model is one means to such ends, it becomes important to more fully understand the impacts that such centers have on graduate student development.

Prior to this study there had been no systematic multi-center follow-up of IUCRC graduates. Virtually nothing had been documented about the impacts of center-related educational and research experiences on graduates' career opportunities, research productivity or personal development. Likewise, little was known about IUCRC graduates' views regarding the degree to which their original expectations for center involvement were met, or about their views regarding any strengths and weaknesses of their center's educational/research experiences programs for students.

METHODS

Center Recruitment

Thirteen of the 31 eligible IUCRCs were randomly selected and invited to participate in the study. Twelve of the 13 IUCRC center directors agreed for their centers to participate in the study. The remaining 18 centers were not approached. Ten (83%) of the 12 recruited centers provided names of their graduates to the study team. The 10 participating centers included:

Georgia Institute of Technology (Material Handling Research Center)
Lehigh University (Chemical Process Modeling and Control Research Center)
Lehigh University (Center for Innovation Management Studies)
University of Massachusetts (Center for Industry Research on Polymer)

North Carolina State University (Center for Communication and Signal Processing)
Northwestern University (Center for Engineering Tribology)
Pennsylvania State University (Center for Dielectric Studies)
Rensselaer Polytechnic Institute (Center for Interactive Computer Graphics)
Rutgers University (Center for Ceramics Research)
University of Washington (Center for Process Analytical Chemistry)

The Instruments. Two follow-up questionnaires were developed; one for the IUCRC Graduate Group and one for the non-IUCRC or Comparison Group. Each of these survey forms contain items focusing of graduates perceptions of their: professional preparation; professional skills; the comparative value of their center-related or, in the case on the non-IUCRC graduates, their department-related activities, and; employment and demographic information. Survey items were build upon those used by Gidley and Gray (personal correspondence, 1988), St. John (personal correspondence, 1989),as well as inquiry lines and item formats previously developed by the principal investigator (Scott, 1985, 1986).

The Subjects. _The IUCRC Graduate Group was made up of the 112 graduates whose names were provided to the study team by the ten participating IUCRCs. Ninety-eight (88%) of the 112 returned completed forms. The Non-IUCRC Comparison Group consisted of 138 graduates from similar graduate programs in the same institutions who had not had IUCRC involvement. Fourteen (10%) of the 138 non-IUCRC graduates who were qualified for inclusion in the Non-IUCRC Graduate Group refused to complete a survey form. Therefore, only 124 forms were mailed. Seventy (56%) of the 124 forms mailed were returned completed. Because of the 10% refusal rate, however, the overall response rate for the 138 graduates that met the criteria for inclusion in the Non-IUCRC Graduate Group was 51%.

Telephone Interviews. Twenty (20) respondents to the mail survey from the IUCRC Graduate Group were selected for further study via telephone interviews. The purpose of these post survey telephone interviews was to obtain more detailed information from selected graduates than would have been possible with the survey alone. Ninety-five percent of those approached for a telephone interview agreed to be interviewed.

Confidentiality

The initial phone contacts with the center directors, as well as the initial study participation and telephone interview contacts with potential respondents emphasized that all information collected as a result of this study would be held in the strictest confidence and that in no communication or report would any center-specific or graduate-specific data be identifiable.

RESULTS

The IUCRC Graduate Group and the Comparison Group were comparable in terms of gender, age, year for completion of their baccalaureate degree, the year they achieved their first full-time postdoctorate employment, and first year earnings after graduation. Center graduates tended to have fewer years of involvement than the comparison group with their respective center or departmental activities. Center graduates were offered employment by a average of 3.0 companies while the non-Center graduates were offered employment by a average of 2.3 companies ($t = 2.1$, $df = 144$, two-tailed: $p < .05$).

Center graduates and the Non-Center comparison group graduates responded to 17 comparable survey items that represent three broad categories. These were professional

participation, professional skills and the comparative value of their Center/Department educational experiences. All items had 7-point response scales.

All significant differences were in the direction of the IUCRC Graduate Group. Means of 14 of the 17 comparable survey items were higher for the NSF center graduates than they were for graduates in the Comparison Group. A non parametric sign test based on this fact indicated that the IUCRC graduates were significantly more positive ($p > .05$) about the value of their graduate education than were graduates in the Comparison Group.

The first set of 5 items (Professional participation) asked the respondents to indicate their opinion regarding the value of their work with the Center or, in the case of the Comparison Group, their Department in terms of providing them with opportunities for: establishing useful associations with university faculty, with researchers in the field, and with industry representatives, as well as for learning about research in industrial settings and for participating in applied research. An unweighted Professional Participation Composite Score (PPCS) was computed by summing the numerical values of the response options to these 5 items. The IUCRC Graduate Group's PPCS was significantly different in a positive direction ($t = 6.8$, $df = 176$, two-tailed: $p < .000$) from the Comparison Group. Center graduates were significantly more likely to emphasize the value of their Center's activities for establishing associations with researchers in the field ($t = 3.9$, $df = 166$, two-tailed: $p < .001$) and with industry representatives ($t = 8.7$, $df = 166$, two-tailed: $p < .001$) than the Comparison Group respondents were to emphasize the value of departmental opportunities. Graduates of IUCRCs were also significantly more likely to emphasize the value of center activities for aiding in learning about research in industrial settings ($t = 5.5$, $df = 166$, two-tailed: $p < .001$) and for participating in applied research ($t = 3.9$, $df = 165$, two-tailed: $p < .001$) than the Comparison Group respondents were to emphasize the value of departmental opportunities for aiding in learning about research in industrial settings.

The second item grouping (Professional Skills) consisted of 6 items that asked the respondents to indicate their opinion regarding the extent to which their Center-related or, in the case of the Comparison Group, their Departmental experiences met their expectations regarding development of the following skills and knowledge: gaining technical knowledge, gaining knowledge about the current state of the field, learning practical 'tricks of the trade' useful for conducting research, developing communication skills, developing teamwork skills and for gaining a broader perspective of research. An unweighted Professional Skills Composite Score (PSCS) was computed by summing the numerical values of the response options to these 6 items. The IUCRC Graduate Group's PSCS was significantly different in a positive direction ($t = 2.2$, $df = 177$, two-tailed: $p < .003$) from the Comparison Group. Center graduates were significantly more likely to view Center opportunities as helpful than were graduates in the Comparison Group. Center graduates viewed opportunities as more helpful for developing communication skills ($t = 4.1$, $df = 166$, two-tailed: $p < .001$), teamwork skills ($t = 2.1$, $df = 166$, two-tailed: $p < .05$), and for gaining a broader perspective of research ($t = 3.4$, $df = 166$, two-tailed: $p < .001$).

The third item grouping (Comparative value of Center/Department Activities) contained 7 items. The first three asked respondents to indicate how their participation in the

Center's/Department's program compared to the rest of their educational activities. The items related to other research opportunities, other outside work/internship experience, and participation at professional meetings. An unweighted Comparative Value Composite Score (CVCS) was computed by summing the numerical values of the response options to these 3 of these 7 items (4 of the items did not assess comparative value). The IUCRC Graduate Group's CVCS was significantly different in a positive direction ($t = 2.1$, $df = 152$, two-tailed: $p < .04$) from the Comparison Group. Center graduates were significantly more likely to respond that the research opportunities provided by Center activities were of more value than other research opportunities ($t = 2.7$, $df = 157$, two-tailed: $p < .01$) than were non-Center graduates. Within this item grouping respondents were also asked: whether their experience working in the Center/Department had increased their chances for career development; how central to their professional goals and interests was their work in the Center/Department; how they would rate the quality of time spent at the Center/Department, and; the degree to which they felt that their time spent at the Center/Department had been valuable and worthwhile. Center and non-Center comparison graduates did not differ significantly with respect to these four items.

Comparisons of the Ten Most and the Ten Least Satisfied IUCRC Graduates

In order to categorize the overall opinion of center graduates about associations with IUCRCs, the response values of the all parallel survey items (demographic items were excluded) were summed to form an unweighted overall composite score. The 10 center graduates who expressed the most favorable opinions and the 10 center graduates who expressed the least favorable opinions were then selected for further examination. These two groups of center graduates did not differ significantly in terms of age, number of company interviews completed, nor in the number of companies which subsequently offered employment. Ninety-five percent of the selected survey respondents agreed to be interviewed by telephone.

Since the selections of the top 10 and bottom 10 center graduates had been made on the basis of the composite score, which was based on the 17 common survey items, the fact that the groups were significantly different on all 17 items ($p < .001$) was not surprising. It is important to note, however, that while the survey responses of individuals in the bottom center graduate group were clearly less positive regarding the value of their graduate training than were the responses of those in the top center graduate group, their survey responses were definitely more neutral than negative.

With the note at the end of the preceding in mind, inspection of the interview responses by three study team members, revealed few notable differences between the two extreme groups of center graduates. It is very difficult, almost impossible in fact, to correctly categorize the telephone interviews on the basis of the interview texts as either top group (very positive view of center experience) or bottom group (less positive, more of a neutral view of center experience; certainly not a negative view). This suggests that response style on the mail survey may account for the separation between the top and bottom groups rather than distinctly different qualitative impressions of center-related activities. A response style

explanation would also be consistent with the positively skewed direction of the center graduates' responses.

The only theme in the telephone interview texts that the three readers agreed was identifiable had to do with often expressed desire of graduates to have had more substantial contact with center research faculty. This theme, while neither universal nor predictive of membership in either the top or bottom group, generally involved access to center faculty. It was variously expressed either as a lack of faculty availability, not enough contact with their faculty advisor(s), or too little interaction with and knowledge of what center faculty, other than their main faculty advisor, were doing.

Limitations. Involvement in an IUCRC may not have been the major cause of the differences observed between the Center Group and the Comparison Group. The relatively low response rate for the Comparison Group may have been a source of bias effecting both the reliability and the validity of the comparisons. Selection bias could have resulted in more capable graduate assistants having been recruited for the center's graduate assistantships. Reduced levels of financial support and more difficult subsistence concerns for non-IUCRC students during graduate education may have been confounding factors. As a result, response and/or selection bias and/or confounding due to unexamined independent variables may have had major implications for the validity of these results. The degree to which such considerations may have played a role in the reported findings cannot be determined from the existing dataset. On the other hand, if they could be reduced or more adequately controlled for, then the utility of the findings could be increased. Even if these sources of bias and the confounding factors were eliminated, whether these results would generalize to involvement in other types of research centers in these or in other institutions cannot be determined from these data.

DISCUSSION AND CONCLUSION

This study provide a cross-sectional, retrospective assessment of the impressions of graduates from 10 IUCRCs of their previous involvement in an NSF cooperative research center and their associations with their center's industrial sponsors. It examined graduates' perceptions, not their capabilities. It contrasts views of IUCRC graduates with views of similar graduates from the same institutions who had not had major involvement in an IUCRC.

Results clearly indicate an association, though not necessarily a causative one, between major involvement in an NSF Industry/University Cooperative Research Center during graduate education and positive views regarding the value of related experiences. Center graduates from 10 IUCRCs that had had major involvement in an IUCRC reported more positive perceptions than did graduates from the same institutions who had no such involvement in the centers. The non parametric sign test, perhaps the most robust of all of the statistical tests, pointed to major differences between the IUCRC Graduate Group and the Comparison Group. Over 50% of the differences between the IUCRC Graduate Group and the Comparison Group were statistically significant. All statistically significant differences

were in favor of the IUCRC Graduate Group and most were large enough to be of practical significance as well.

The possibility exists that involvement in an IUCRC may not be the major reason for the observed differences. Response and selection bias, as well as differences in graduate's levels of financial support while in graduate school may also have influenced the results. The degree to which these limitations reduced the validity of these results, cannot be determined from the existing dataset. The consistency and magnitude of the results, however, were such that it is unlikely that these limitations had a major impact on the conclusions.

The central purposes of IUCRCs is to promote and improve industry/university cooperative research, to foster more effective technology transfer and, in the process, to increase the competitiveness of American industry. While graduate education is a central mission of universities, improving graduate training is not one of the central reasons for the existence of NSF IUCRCs. The fact that results of this study suggest that IUCRC graduates' consistently report a more positive graduate experience than non-IUCRC graduates should, therefore, be gratifying both to science educators and to the National Science Foundation.

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