Active Research Experience for Undergraduates Increases Students' Motivation and Academic Performance

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Abstract

An active research experience is one of the most effective ways to attract talented undergraduates and retain them in careers in science and engineering. At NJIT, the (REU) Research Experience for Undergraduates program provides educational experience for undergraduate students through specially designed active research projects. This allows students to experience first-hand how basic research is carried out, and to contribute substantially to the undertaken research. In its first year of operation, (NJI-TOWER) New Jersey Information Technology Opportunities for the Workforce, Education and Research project funded 39 students to conduct their research projects during the 2000-2002 academic years. Those 39 students also received access to NJIT equipment and facilities. After completion of the projects, the REU awardees presented the results of their efforts with their research mentors to the university community.

While student presentations were considered to be qualitative outcomes, quantitative analyses were conducted on students' academic performance. Retention rates, cumulative grade point averages (GPA) and overall academic persistence measured by ratio of earned and attempted credit hours were analyzed. Students and their supervisors were also surveyed on their satisfaction with the REU experience. Other educational outcomes such as obtaining graduate education and employment have been measured.

To analyze the impact of REU on academic achievement, a quasi-experimental design was applied. Pure experimental design was not possible because students could not be randomly assigned to experimental and control groups. Thirty-nine recipients of the NJI-TOWER REU awards composed the experimental group and 230 NJIT students were included in control group. The results of quasi-experiment can be considered valid due to the size and matching characteristics of the control group.

The t-tests on experimental and control groups' retention, cumulative GPA and ratios of earned and attempted credit hours showed statistically significant difference between two groups. Survey responses from both faculty and students confirmed that REU has increased students' motivation and interest towards research.

Introduction and literature review

Active participation in real-life research has always been considered a high motivation for the undergraduates. According to NSF Report "Shaping The Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology "America's undergraduates – all of them – must attain a higher level of competence in science, mathematics, engineering, and technology… (make sure that) all students who enter advanced training at the professional level are well and broadly trained; and that the process of learning does not end with the classroom. "[1] The NSF studies prove that research experience during the undergraduate years is highly valued by the employees: "… (J)ob experience would appear to be the most salient factor to employers.[2]" Jeanne L. Narum says that being involved in research as an undergraduate challenges students to be able and willing to move beyond their comfort zone … beyond the safeties of the past as they explore, experiment, and create new knowledge … these experiences also give students other skills and capacities (Narum 2002).[3] The Boyer Commission on Educating Undergraduates in the Research University Report expresses the idea even stronger, saying that "The research universities need to be able to give to their students a dimension of experience and capability they cannot get in any other setting, a research experience that is genuine and meaningful. They should turn out graduates who are well on the way to being mature scholars, articulate and adept in the techniques and methods of their chosen fields, ready for the challenges of professional life or advanced graduate studies" (The Boyer Commission Report 1998).[4]

The Kellogg Commission Report, *Returning to Our Roots* (Kellogg's Report 1998), when discussing the issue of the "engaged university," states that student's experience should be enriched by bringing research and engagement into the curriculum: "…"(L)earning is not a spectator sport. Independent learners are active, not passive. We must insist that students take responsibility for their own learning and introduce many more of them to research, as collaborators with faculty and graduate students and as seekers and inventors of new knowledge in their own right."[5]

In 2000-2002, the research experience for undergraduates (REU) program at NJIT was funded by the New Jersey Information-Technology Opportunities for the Workforce, Education and Research (I-TOWER) grant, and provided educational experience for NJIT undergraduate students through specially designed active research projects. That allowed students to experience first-hand how basic research was carried out, and to contribute substantially to the undertaken research. This paper describes the REU process and analyzes students' outcomes related to the REU.

Undergraduate Research Projects

NJI-TOWER first circulated a request for competitive proposals among NJIT students and faculty in November 2000. It resulted in fifteen projects involving 16 students, with one collaborative team, winning $2,000 honoraria for their research during the spring 2001 semester. In 2001-2002 academic year, the number of students participating in REU had increased to 23. On April 30, 2001 and on May 3, 2002 the REU awardees participated in poster sessions displaying their work, the results of their interaction with faculty and/or other research mentors and use of the facilities and professional development opportunities. Table 1 provides the list of students' projects.

Table 1: Undergraduate research project titles.

No	*TITLE*
1	*Network Health Monitoring System*
2	*Analysis and Modeling of Ion Implantation Methods for Ultra-Shallow Junctions in Silicon.*
3	*Robustness of Digital Watermarking.*
4	*Using Sequence-Dependent Aspects of DNA to Predict Binding Pattern of Amiloride*
5	*Mobile Agents for the Web*
6	*Modeling and parameter identification of electroretinograms to improve their diagnostic utility in clinical ophthalmology*
7	*Encoding Literary Objects for Archiving and Presentation in a Digital Medium*
8	*Computer Modeling & Physiochemical Study Of The Halogenated Analogs Of Common Drugs*
9	*Low Cost Web-Based Alarm System*
10	*Computer Modeling And Animation Of A Galton's Board*
11	*Robotic/AGV Computer Integration Project*
12	*Hardware MP3 Player (Playback From IDE/ATAPI Drive)*
13	*Identifying Specific Facial Region Using Facial Data In Stereolithographic (.Stl) File Format*
14	*Production Lines In Semiconductor Manufacturing*
15	*A Microprocessor I/O Expander Chip*
16	*Pro ECG Virtual Simulator*
17	*Modeling Of Electrical Activity Of A Neuron Using Neurolucida, CVAPP, And Genesis*
18	*Differential Tolls For Motorists (Value Pricing)*
19	*Comparative Study Of Four Theories Of Propagation And Scattering In Rough Metal Surface And A Bounded Two-Layer Model Of Vegetation Using Transport Theory*
20	*Computer Simulations Of Liquid Crystalline Polymers And Polyelectrolytes.*
21	*Distance Learning Study*
22	*Implementation Of Importance Sampling With The Semi-Regenerative Method To Analyze Large-Scale Systems.*
23	*Fuzzy Clustering Of Object Data And Relational Data.*
24	*T1 Wide Area Network Protocol Analyzer*
25	*Common Cancer Drugs: Computer Modeling And Phyphysiochemical Study Of The Halogenated Analogs*
26	*Case Study Of The Software Engineering Process As It Relates To Group Collaboration And Problem Solving*
27	*Resilient Packet Ring Access Protocol*
28	*A Computational Approach To The Search For A Treatment For Cocaine Abuse*
29	*Simulation For A Universal, Dynamically Adaptable And Programmable Network Router For Parallel Computers*
30	*Enhancing Access To IT For Persons With Disabilities.*
31	*A Methodology For Web-Based Interactive Laboratory*
32	*A Voice Controlled Text-To-Speech Web Page Reader.*
33	*Imaging And Image Processing Of Combustion Of High-Energy Density Al-Mg-H Compounds*
34	*Robotic/AGV Computer Integration Project*

During the students' presentations, the projects were discussed and evaluated by the students' peers, faculty and researchers. The discussions were mostly linked to the technical aspects of the projects, their importance for the field, and feasibility of implementation. The authors' goal was to analyze whether the REU experience had any impact on students' academic achievement, which included retention rates, cumulative GPA, and overall academic performance measured by ratio of earned and attempted credit hours. Other educational outcomes such as obtaining graduate education and employment were also measured. Students and their supervisors were surveyed on satisfaction with the REU experience.

Research Design

To analyze impact of REU on academic achievement, a quasi-experimental design was applied. Pure experimental design was not possible because students could not be randomly assigned to experimental and control groups. The recipients of the NJI-TOWER REU awards composed the experimental group and 230 NJIT students with matching demographic characteristics and academic background who took similar courses were included in control group. The group comparison was conducted based on the selected indicators of academic performance which included grades for program-specific courses, cumulative GPA and ratio of earned and attempted hours. The groups' characteristics were first analyzed before REU started to see if the groups were compatible. After that, the authors analyzed the groups' end-year performance after REU.

Grades for Program-Specific Courses, Cumulative GPA and Ratio of Earned and Attempted Hours for REU and Control Groups

1. **2000-2001 group.**

   2001 REU and control groups' grades for program specific courses, cumulative GPA and ratio of earned and attempted academic hours

First, the performance of two groups was compared before REU started. Student *t*-test showed a slight difference between the cumulative grades for program-specific courses of the experimental and control groups; however, the difference was not statistically significant. (The two-tailed P = 0.1076; t = 1.7648, df = 122 and standard error of difference = 0.262). Overall, data show that the groups had similar academic performance in the semester preceding the project. The finding makes it reasonable to assume that both experimental and control groups had equal chances to succeed academically before REU started (Table 2).

Table 2: Cumulative GPA for REU and control groups in Fall 2000.

	Control	REU
Mean	2.91764	3.34258
SD	0.88628	0.56552
SEM	0.08489	0.16325
N	109	15

Table 3 compares Spring 2001 average program-specific grades, after the REU projects were finished. The *t*-test showed that the RUE students performed better; however, the difference was statistically significant at a slightly lower than generally accepted level: (t = 1.8444, df = 118; the two-tailed P-value equals 0.0677).

Table 3: Program specific average grades for REU and control groups in Spring 2001

	Control	REU
Mean	2.63877	3.22483
SD	1.06167	0.84292
SEM	0.10361	0.24333
N	105	15

Table 4 analyzes student s' overall academic performance by Spring-2001. Student *t*-test showed statistically significant difference in performance between REU students and control group (t = 1.9659, df = 118 standard error of difference = 0.265; the two-tailed P value equals 0.0514).

Table 4: Cumulative GPA for the control and REU groups by Spring-2001.

	Control	REU
Mean	2.63877	3.2942
SD	1.06167	0.6277
SEM	0.10361	0.1812
N	105	15

As an additional measure of academic performance, ratios of earned and attempted hours were compared for the REU group and selected control group. The groups were first compared before the research experience. Student *t*-test did not show and statistically significant difference in ratio of attempted and earned credits during Fall 2000 between control and REU groups. The two-tailed P value equals 0.1163; t = 1.6076 df = 122 standard error of difference = 0.062. Data show that before REU, based on this indicator, the groups were similar and had equal chances for academic progress (Table 5).

Table 5: Ratio of attempted and earned academic hours before REU.

	Control	RUE
Mean	0.902	1.000
SD	0.205	0
SEM	0.020	0
N	109	15

Table 6 compares the groups' Spring 2001 performance, after REU experience. During that period, the difference in attempted/earned hours ratio between the groups became statistically significant (the two-tailed P = 0.0252; t = 2.2683 df = 118 standard error of difference = 0.080).

Table 6: The ratio of earned and attempted academic hours for REU and control groups in Spring 2001.

	Control	REU
Mean	0.820	1
SD	0.264	0
SEM	0.026	0
N	105	15

Finally, the ratios of earned and attempted hours for combined semesters, Fall-2000 and Spring 2001 were compared. They were found different for two groups, and the difference was statistically significant. The two-tailed P value equals 0.0297; $t = 2.1987$, df = 133, and standard error of difference = 0.066. The difference in the ratio of earned and attempted academic hours for REU and control groups in Fall-2000 and Spring 2001 between groups is not statistically significant, however we might assume it to be big enough to be attributed to treatment rather than sampling (Table 7).

Table 7: The ratio of earned and attempted academic hours for REU and control groups in Fall-2000 and Spring 2001.

	Control	REU
Mean	0.854	1.000
SD	0.2193	0
SEM	0.0200	0
N	120	15

Thus, the analysis showed that undergraduate students with I-TOWER sponsored research experience have performed better academically than the control group by completing all courses they have taken while students from control group failed some courses and did not get academic credits.

2. 2001-2002 group.

2002 REU and control groups' grades for program specific courses, cumulative GPA and ratio of earned and attempted academic hours

The analyses of average grades for program-specific courses, cumulative GPA and ratio of earned and attempted academic hours were also conducted for the group that participated in REU in 2001-2002. First, grades and cumulative GPA's of REU and control groups were compared (Tables 8-12) and then the ratio of earned and attempted credit hours (Tables 13-16).
Table 8 compares Spring 2001 average program-specific grades. Data show that the difference between groups before REU is not statistically significant (two-tailed P value = 0.0800, $t = 1.7648$, df = 127 and standard error of difference = 0.211). That means that both groups had equal chances for academic achievement provided they take similar courses.

Table 8: Average grades for program-specific courses for REU and control groups in Fall-2000

	Control	REU
Mean	2.91764	3.29045
SD	0.88628	0.75870
SEM	0.08489	0.16965
N[1]	109	20

Table 9 compares students' academic performance on program-specific courses in the first semester of their research experience for undergraduates. The *t*-test showed statistically significant difference in academic performance between two groups (the two-tailed P = 0.0036; t = 2.9693, df = 123 and standard error of difference = 0.243). Data show that REU students had better academic performance on program-specific courses than control group during their first research experience semester.

Table 9: Average grades for program-specific courses for REU and control groups for the Spring-2001 Semester.

	Control	REU
Mean	2.63877	3.36010
SD	1.06167	0.49854
SEM	0.10361	0.11148
N	105	20

The next analysis dealt with cumulative GPA for the Spring-2001. Data show statistically significant difference in academic performance of the two groups (the two-tailed p = 0.0082; t = 2.6808, df = 138 and standard error of difference = 0.207). There was a statistically significant difference in overall academic performance between two groups, the REU performing better than the control one (Table 10).

Table 10: Cumulative GPA for REU and control groups for Fall 2000 and Spring 2001.

	Control	REU
Mean	2.7726	3.3265
SD	0.8958	0.5382
SEM	0.0818	0.1203
N	120	20

Next, the groups' academic performance was assessed in the Fall of 2001, and then cumulatively for the period of two semesters. Student *t*-test showed statistically significant difference between groups (the two-tailed P = 0.0012, t = 3.3060; df = 130, and standard error of difference = 0.217). Data indicate significant difference in REU and control group students' performance in Fall 2001, which might be attributed to students' participation in research project. When

[1] N for each group is different because students took different number of courses (some students did not take any courses during the semester).

comparing cumulative GPA for REU and control groups for Fall 2000 and Spring and Fall 2001Student *t*-test showed statistically significant difference between the groups (the two-tailed $p = 0.0020$; $t = 3.1363$, $df = 170$ and standard error of difference = 0.196). Thus, it can be assumed that improvement for REU students can be attributed to treatment /research experience. The results are shown in Tables 11 and 12.

Table 11: Average grades for program-specific courses for REU and control groups for the Fall 2001

	Control	REU
Mean	2.78352	3.50104
SD	1.01776	0.44905
SEM	0.09748	0.09363
N	109	23

Table 12: Cumulative GPA for REU and control groups for Fall 2000 and Spring and Fall 2001

	Control	REU
Mean	2.7646	3.3800
SD	0.9203	0.4796
SEM	0.0754	0.1000
N	149	23

As an additional measure of academic performance, ratios of earned and attempted hours were analyzed. The analysis showed that since their research experience, REU students have been more persistent than control group. Their ratio of earned and attempted academic hours was higher, and the difference was statistically significant.

The groups' ratios of earned/attempted credit hours were compared before the experimental group began its REU. The analysis has not revealed any statistically significant difference between the groups (the two-tailed $p = 0.5575$; $t = 0.5882$; $df = 127$ and standard error of difference = 0.048). That means both groups could be assumed to have a similar level of achievement (Table 13).

Table 13: The ratio of earned and attempted academic hours for REU and control groups of students before REU.

	Control	REU
Mean	0.902	0.930
SD	0.205	0.142
SEM	0.020	0.032
N	109	20

Tables 14 & 15 compare the groups' Spring 2001 performance, after REU experience and cumulative Fall-2000 – Spring-2001 performance. During Spring-2001 the difference in earned/attempted hours ratio between the groups became statistically significant (the two-tailed P = 0.0167; t = 2.4274, df = 123 and standard error of difference = 0.060).

Table 14: The ratio of earned and attempted academic hours for REU and control groups in Spring 2001.

	Control	REU
Mean	0.820	0.965
SD	0.264	0.088
SEM	0.026	0.020
N	105	20

Cumulative ratio for Fall-2000 – Spring-2001 for the experimental group is higher and the difference is close to be statistically significant (the two-tailed p- value equals 0.0571 t = 1.9184 df = 138 standard error of difference = 0.050)

Table 15: The ratio of cumulative earned and attempted academic hours for REU and control groups in Fall-2000 – Spring-2001.

	2001S Comp	2001S URE
Mean	0.8543	0.9500
SD	0.2193	0.0922
SEM	0.0200	0.0206
N	120	20

Tables 16 and 17 compare earned and attempted hours for both groups in Fall 2001 and cumulatively for Spring and Fall of 2001. There is statistically significant difference between REU and control groups for Spring 2001 (the two-tailed P = 0.0375; t = 2.1019, df = 130 and standard error of difference = 0.050) and cumulatively for Fall 2000 and Spring and Fall 2001 The analysis showed statistically significant difference between REU and control groups on the ratio of earned and attempted academic hours for REU and control groups in Fall 2000 and Spring and Fall 2001 (the two-tailed P = 0.0289; t = 2.2041, df = 170 and standard error of difference = 0.046).

Table 16. The ratio of earned and attempted academic hours for REU and control groups in Fall 2001.

	Control	REU
Mean	0.868	0.974
SD	0.240	0.062
SEM	0.023	0.013
N	109	23

Table 17. The ratio of earned and attempted academic hours for REU and control groups in Fall 2000 and Spring and Fall 2001

	Control	REU
Mean	0.8510	0.9530
SD	0.2199	0.0682
SEM	0.0180	0.0142
N	109	23

Survey Results
Students and their supervisors were surveyed after the presentation of research projects. Both faculty and students answered 21 questions using Likert scale and one open-ended question (See Appendix). The surveys for both categories had some insignificant differences. All questions were grouped into five factors based on a factor analysis procedure that clustered correlated questions. The results are shown in charts I-X.

Chart I: Factor Initiative (faculty)

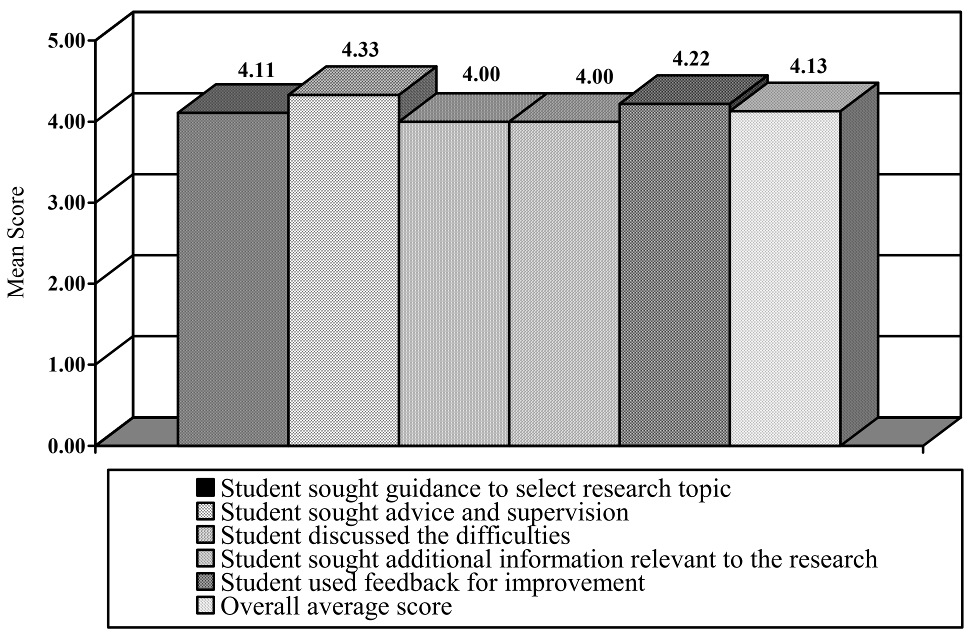

Chart II: Factor Supervision (students)

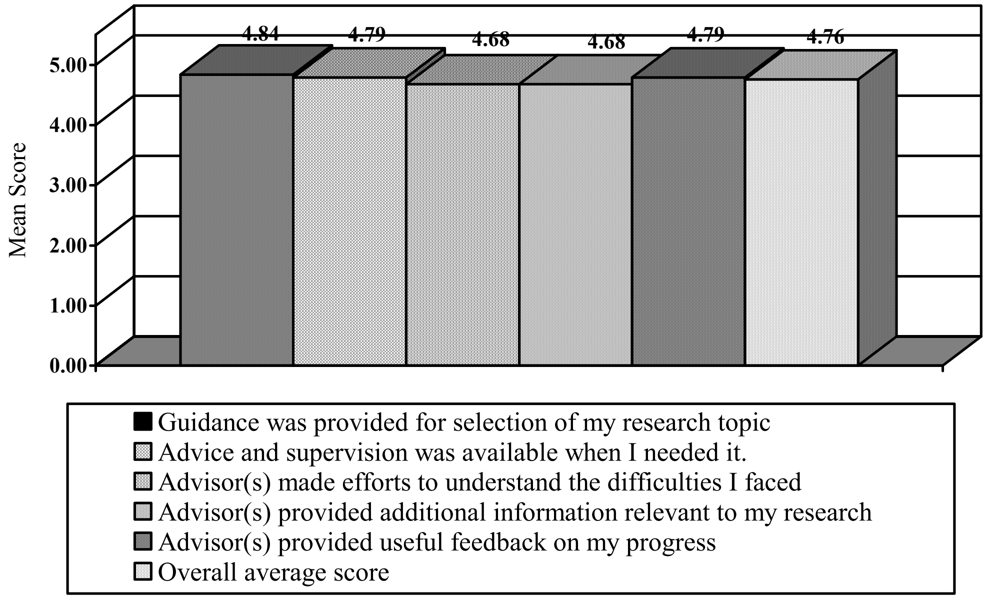

Chart III: Factor Personal Development (Faculty)

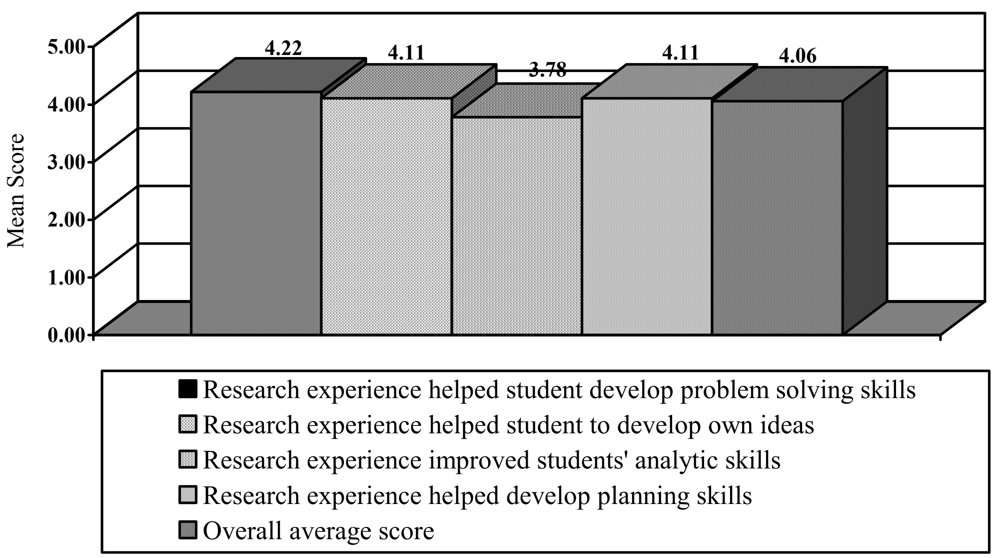

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Chart IV: Factor Personal Development (Students)

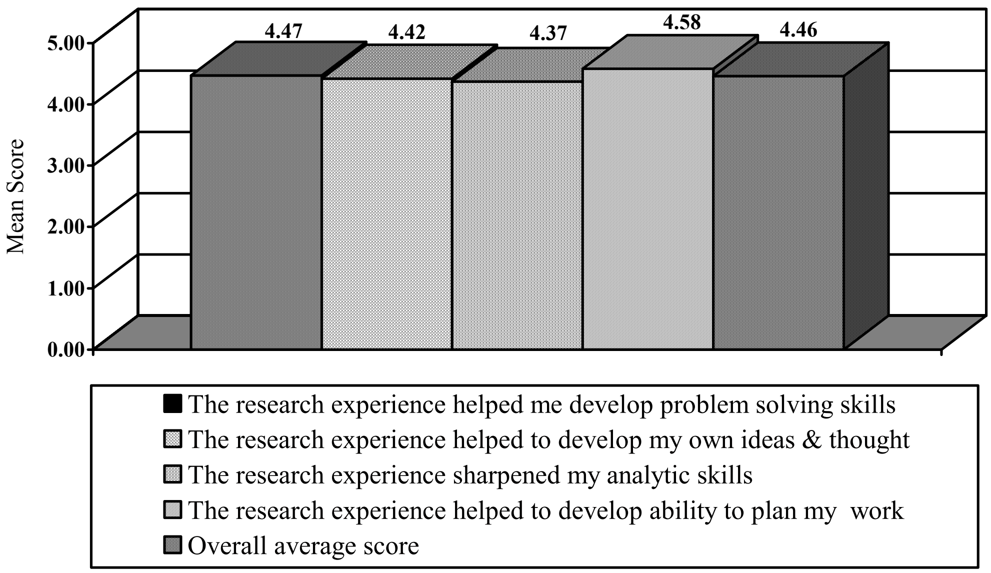


Chart V: Factor Research Opportunities & Research Culture (Faculty)

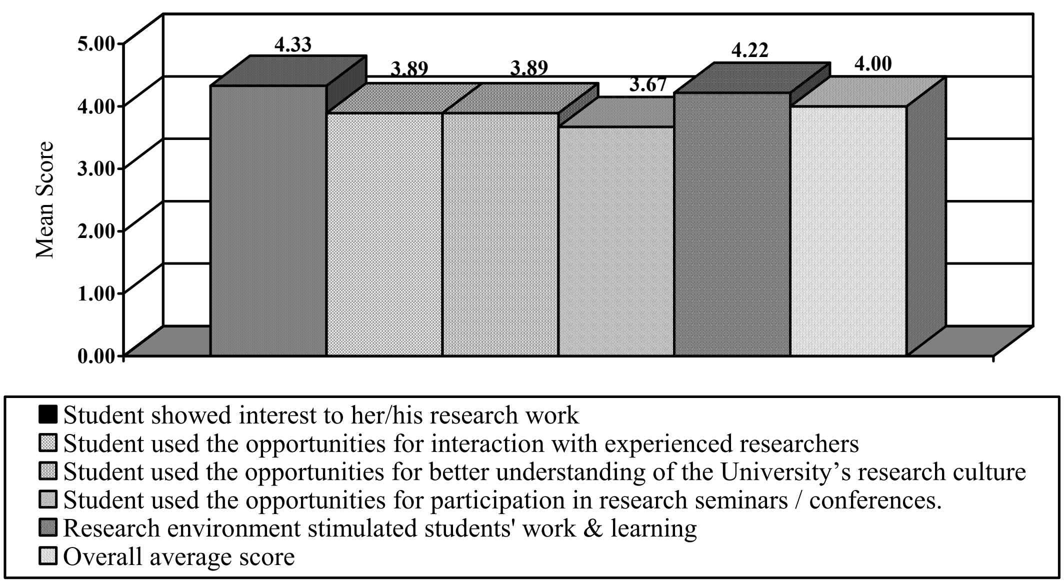
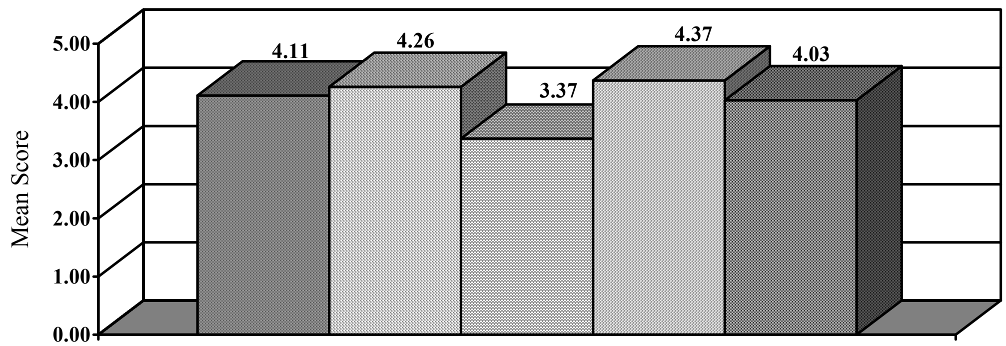
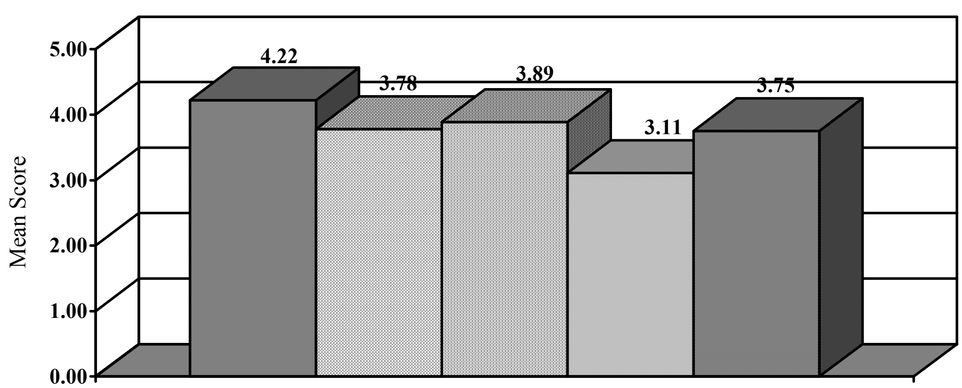


Chart VI: Factor Research Opportunities & Research Culture (Students)



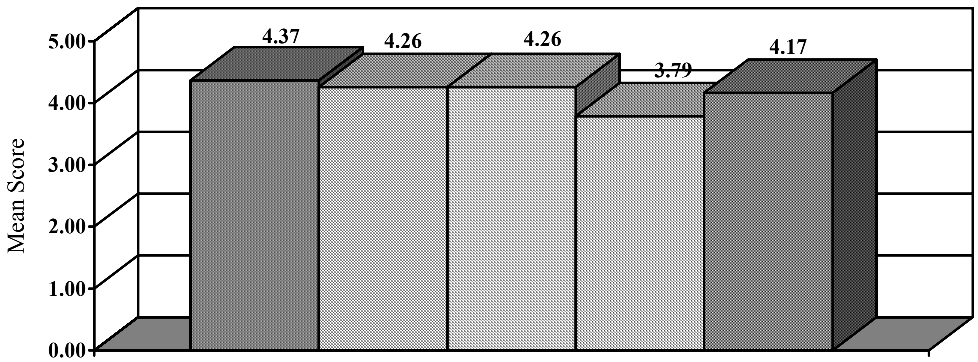
■ The research experience, provided opportunities for interaction with experienced researchers
■ The research experience provided opportunities for better understanding of the research culture
■ The research experience provided opportunities for participation in research seminars / conferences.
■ The research environment stimulated my work & learning
■ Overall average score

Chart VII: Factor Research Support (Faculty)



■ Student had easy access to work place
■ Student had access to technical support
■ Student had access to lab & equipment
■ Appropriate financial support was available
■ Overall average score

Chart VIII: Factor Research Support (Students)



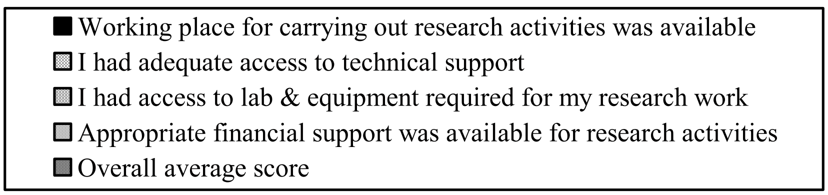
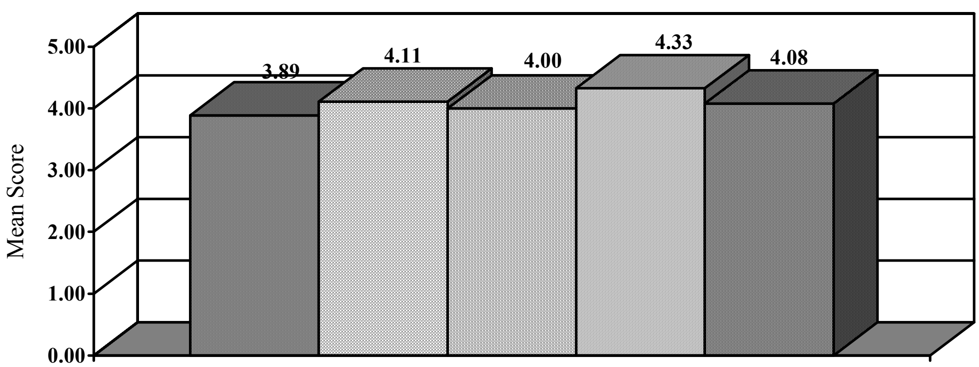


Chart IX: Factor Career Goals and Satisfaction (Faculty)



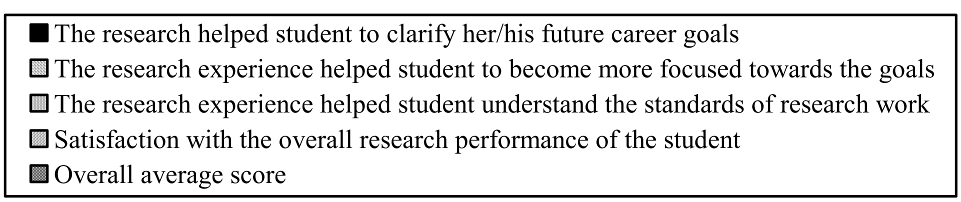
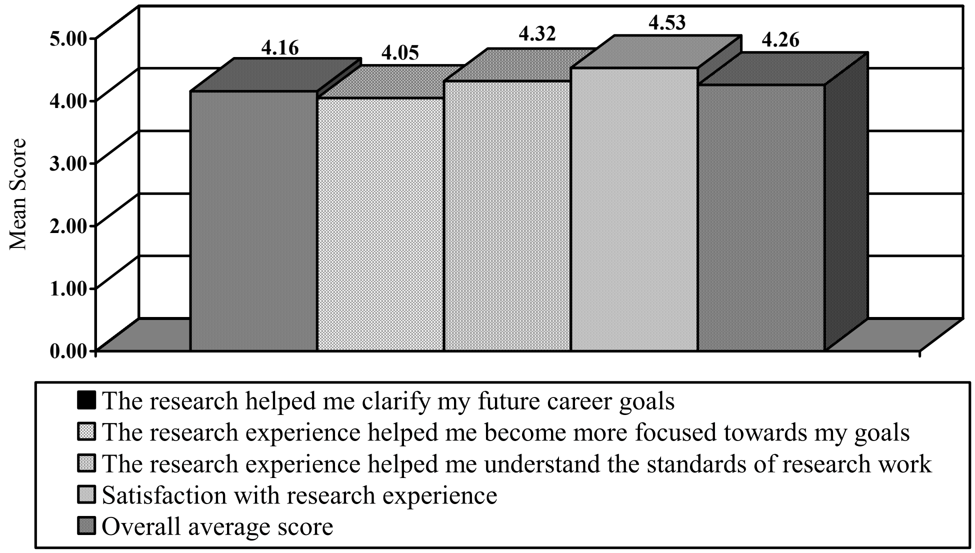


Chart X: Factor Career Goals and Satisfaction (Students)



Factor Analysis

Factor I: Initiative-Supervision

According to the survey analysis, students prefer being supervised rather than being proactive in their research projects. The difference in mean scores on a five-point scale is .63, and this difference is statistically significant at .001 level.

Factor II: Personal Development

The second factor, which included questions about planning, analytic, problem solving and other developmental skills, showed some reservation on behalf of the faculty compared to students' enthusiasm. The difference however was not statistically significant.

Factor III: Research Opportunities and Research Culture

The overall score for this factor is practically the same for faculty and students; however, individual variables scores differ, in one instance (opportunity for participation in research seminars and conferences) reaching the whole point.

Factor IV: Research Support

Faculty believed that support was good; students thought it was excellent. The largest margin of difference was on variable "Financial Support".

Factor V: Career Goals and Satisfaction

The overall score showed that students were slightly more optimistic about the impact of REU on their career and level of satisfaction than faculty.

Retention and graduation
Most of the students in both experimental and control groups are in their junior or senior year and could not have graduated; however, those few in experimental group who were planning to, graduated and were employed. For at least one of the students, the REU experience was specifically instrumental in his attaining a position with a company that designs and manufactures pharmaceutical control systems.

Conclusion
Even with a relatively small sample, there is evidence that involving students in Research Experience for Undergraduates helps them improve academic achievement, produces better retention and increases motivation to persist in their studies. Those students who graduated were able to find good jobs within a month after graduation; one of the students accepted an offer from a major pharmaceutical company to work on industrial version of the device he designed and based on his undergraduate research project.

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APPENDIX: Research Experience For Undergraduates Survey

Project name; Advisor; Student's Major; Gender
Class Standing: Freshman Sophomore Junior Senior

A) Supervision

1. Guidance was provided for selection of my research topic
2. Advice and supervision were available when I needed it.
3. Advisor(s) made efforts to understand the difficulties I faced
4. Advisor(s) provided additional information relevant to my research
5. Advisor(s) provided useful feedback on my progress

B) Personal Development

1. The research experience helped me develop problem solving skills
2. The research experience helped to develop my own ideas & thought
3. The research experience sharpened my analytic skills
4. The research experience helped to develop ability to plan my work

C) Learning Environment

1. The research experience, provided opportunities for interaction with experienced researchers
2. The research experience provided opportunities for better understanding of the University's research culture
3. The research experience provided opportunities for participation in research seminars / conferences.
4. The research environment stimulated my work & learning

D) Facilities

1. Working place for carrying out research activities was available
2. I had adequate access to technical support
3. I had access to lab & equipment required for my research work
4. Appropriate financial support was available for research activities

E) Goals & Satisfaction

1. The research helped me clarify my future career goals
2. The research experience helped me become more focused towards my goals
3. The research experience helped me understand the standards of research work
4. I am satisfied with my research experience

Comments / Suggestions

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