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How do Summer Undergraduate Research Experiences Compare to Other Models?

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Abstract

Undergraduate research experiences (UREs) have been shown to be effective in recruiting, retaining and graduating students, especially underrepresented minorities, in science, technology, engineering and mathematics (STEM) majors. A variety of URE program models exist across American colleges and universities. Despite the wide range of URE models, current URE research and evaluation rarely considers differences in models when examining student experiences and outcomes in research programs. The goal of the current paper is to compare the impact of URE structure on student outcomes. The study uses a nonequivalent pre-post control group design to compare program outcomes among four models of URE participation: summer term, single academic semester, two academic semesters, and full academic year. The analyses revealed no significant group differences in program outcomes between summer and single semester participants. However, compared to the summer group, students that participated for two academic semesters reported higher gains in awareness of available research career opportunities and writing research papers for publications. Similarly, participants in yearlong experiences reported higher gains than the summer participants in research skills, understanding of research procedures, and awareness of available research career opportunities and awareness of specialized research career options. The limitations of the study and implications for undergraduate STEM education are discussed.

How do Summer Undergraduate Research Experiences Compare to Other Models?

Introduction and Statement of the Problem

Across American colleges, undergraduate research experiences (UREs) have emerged as effective programs for recruiting, retaining and graduating students, especially underrepresented minorities, in science, technology, engineering and mathematics (STEM) majors. UREs have also gained popularity for their role in enhancing student research skills, research self-efficacy, and aspiration for graduate education in STEM disciplines (Lopatto, 2003; 2007)

The variety of existing URE models differ not only in aims, goals and expected student and institutional outcomes but also in program components and dynamics. For example, Landrum and Nelsen (2002) identified four types of URE mentorship models, namely: (1) Mentor-colleague model where students develop a close one–on-one relationship with the faculty as a mentor or career role model; (2) hierarchical model where students work with graduate students or other non-faculty researchers (e.g., post docs) who are supervised by the faculty; (3) apprentice model where students as novices in the profession study under the tutelage of faculty (as experts) through guided participation and extensive collaboration, long-term observation and practice; (4) contractual model in which tasks, deadlines and expectations are specified and clearly delineated in advance. Each of these models exhibits differences in structures and processes, expectations, requirements and in the period and duration of offering/implementation. Given the variety of URE programs, it is necessary to examine the impact of program type on differences in accrued benefits.

Despite the wide range of URE models, current URE research and evaluation rarely considers differences in models when examining student experiences and outcomes in research programs. For example, although summer experiences are the most common, there is scant research to document the efficacy of this model compared to others. Indeed, we are not aware of any empirical study comparing student outcomes between summer programs and other variants (e.g., year-long research experiences). Although a few studies (e.g., Russell et al., 2007) have reported correlations between participation in longer term UREs (i.e., 12 months or more) and aspirations for doctoral degree, these studies are limited in that the focus was only on student aspiration for doctoral degree with little or no attention paid to other outcomes of UREs, and the analyses did not include direct comparisons of outcomes among year-long, summer and other models.

The goal of the current paper is to compare the impact of URE structure (summer, academic year, and yearlong) on student outcomes. Our guiding hypothesis is that there would be differential outcomes between summer UREs and the other program structures.

Design and procedures

The study uses a nonequivalent pre-post control group design to compare program outcomes among four groups of URE participants: (1) Summer participants, (2) academic term participants—those who participated in either a fall or spring semester, (3) two term participants, i.e., those who participated in a fall *and* a spring semester, and (4) full year (i.e., 12 months) participants. There was no random assignment of students into groups (i.e., students self-select into the groups).

The participants are 122 students who took part in either of two URE programs administered by a Research Center in a Mid-western university. The two programs are very similar in structure and have very similar qualifying requirements for participation (e.g., GPA of 3.0 or more). In addition to the research experience, both programs include a seminar class in the academic semesters and peer or faculty led discussions in the summer. The primary difference between the programs is that students (n=20) apply for a full twelve-month internship in one program while students (n= 101) in the other apply for a single academic semester or summer session internship with the potential to extend the experience for up to twelve months. Another difference is that while one program focuses on interdisciplinary STEM research in general, the other focus on interdisciplinary cancer research in particular. Table 1 provides further descriptions of the participants.

Table 1: Characteristics of Participants

Descriptions		n	%
Gender	*Male*	58	47.50
	Female	64	52.50
Academic standing	*Sophomore*	20	16.40
	Junior	39	31.90
	Senior	63	51.60
Academic major	*Engineering and Technology*	45	36.90
	Science (including Health Sciences & Agriculture)	65	53.30
	Liberal Arts & Social Sciences	12	9.80

The evaluation protocols for the programs include a pre-post participation survey that solicits information about interns' abilities/confidence in research, awareness of research careers, research skills, and their aspirations for graduate education and research careers. Survey items were modified from Kardash et al., (2000), Russell (2005) and Bieschke, Bishop & Garcia, (1996). The specific outcome variables of interest are described as follows:

Research self-efficacy: Research self-efficacy refers to student perceived confidence in their ability to "perform research related behavior" (Bieschke et al., 1993, p.4). Research-self efficacy is a composite variable derived from five Likert type items (e.g., "I have the ability to have a successful career as a researcher," "I am confident that I can understand research procedures"). The reliability of the scale (measured by Cronbach's alpha) was .81 and .85 in the pre- and post- tests, respectively.

Understanding of research processes: This variable measures student "understanding of the nature of scientific knowledge" (Hunter et al, 2006), and consisted of six items regarding student understanding of: "how to formulate a research question," "how to plan a research project," "how scientific knowledge is built," etc. Cronbach's alpha for the scale was .88 in the pre- and .90 in the post- tests.

*Research skills: The pre-post surv*ey also asked students to rate their abilities on 13 different items of research skills (e.g., "documenting a research procedure," "statistically analyzing data using computer software," etc.) Each item or skill is treated as a single variable to allow for the understanding of the exact research skill(s) that differ among the groups.

Other variables of interest are participants' interests in graduate education and research careers, and awareness of research career options and what graduate school may be like.

Analysis and Findings

Data analyses were conducted in SPSS statistical package. For each outcome variable, we calculated accrued gains by subtracting pre- from post-participation scores. We also replaced missing points using the method of linear trend point, a single regression method available in SPSS. Table 2 presents mean pre-post changes in outcomes of interest (by group).

We compared the four groups by conducting regression analyses where group memberships were conceptualized as dummy variables. Although Analysis of Variance (ANOVA) and Dummy Variable Regression (DVR) are both appropriate and produce identical results for group comparisons, we chose the DVR method over ANOVA for two reasons: DVR is better suited to non-randomized and unequal group designs, and allows for a direct statistical comparison of groups to a reference group (in this case, the summer group). We chose the summer group as our reference group because summer UREs appear to be the most common across colleges and universities.

Table 2: Mean Pre-Post Changes in Outcomes of Interest (By Group)

Variables	Summer (n= 20)	1 Sem. (n=46)	2 Sems. (n=36)	Year-long (n=20)
Research self-efficacy	-1.28	-1.13	-0.28	-1.65
Understanding of research processes	2.15	2.80	3.60	5.90
Desire to pursue graduate education	-0.21	-0.26	-0.09	-0.30
Intention to choose research oriented career	-0.05	-0.10	0.15	0.15
Awareness of what grad school may be like	0.47	0.26	0.76	0.70
Awareness of research career opportunities available	0.16	0.14	0.88	1.20
Awareness of research career option/specializations	0.16	0.24	0.65	1.40
Organizing research ideas in writing	-0.15	0.09	0.08	0.65
Working independently on research projects	0.35	0.13	0.31	1.05
Conducting a search of literature for research …	-0.35	-0.04	0.00	0.75
Writing a literature review	-0.05	0.22	-0.14	1.60
Understanding a research paper/journal article	0.15	0.22	-0.06	0.05
Documenting a research procedure	0.25	0.33	0.08	0.85
Statistically analyzing data using software	0.20	-0.26	0.39	0.65
Following experimental or research procedures	-0.32	-0.17	0.06	0.20
Writing the results of your experiment or research	0.05	0.11	-0.06	0.55
Orally communicating the results of research projects	0.25	0.00	0.50	0.80
Writing a research paper for publication	-0.25	0.33	0.56	1.05
Preparing a research poster for presentation	0.70	0.22	0.91	1.25
Overall confidence in research skills	0.11	0.05	0.39	1.10

To conduct the DVR, we created 4 dummy variables to represent each group such that membership in one group =1 and non-membership = 0. We then conducted a series of regression analyses with the learning gains as the dependent variables and the dummy variables representing group membership as the independent variables (interested readers should see Agresti & Finlay (2009) and Slinker & Glantz (1990) for more on ANOVA versus DVR). Table 3 presents the results of the DVR analyses. The un-standardized coefficients reported in Table 3 represent the mean difference between each group and the summer (i.e., reference) group. The standardized coefficients are *italicized* in parentheses. Negative coefficients imply that the group mean is less than that of the reference group and positive coefficients imply that the group mean is greater than that of the reference group. For example, for the variable “understanding of research processes,” the un-standardized regression coefficient for the full year group is 3.75—

the difference between the mean score for the full year group (5.90, see Table 2) and that of the summer group (2.15, see Table 2).

Table 3: Un-standardized Regression Coefficients of DVR: Comparing Summer URE to Other Groups

Variables	Regression Coefficients		
	1 Semester	2 Semesters	Full Year
Research self-efficacy	0.15 *(.02)*	1.00 *(.15)*	-0.37 *(-.05)*
Understanding of research processes	0.64 *(.06)*	1.45 *(.12)*	3.75* *(.26)*
Desire to pursue graduate education	-0.05 *(-.02)*	0.12 *(.01)*	-0.09 *(-.03)*
Intention to choose research oriented career	*-0.04 (-.02)*	0.20 *(.08)*	0.20 *(.08)*
Awareness of what grad school may be like	-0.21 *(-.06)*	0.29 *(.10)*	0.23 *(.09)*
Awareness of research career opportunities available	-0.15 *(-.02)*	0.72* *(.25)*	1.04* *(.29)*
Awareness of research career options you could specialize in	0.08 *(.03)*	0.49 *(.17))*	1.24* *(.36)*
Research Skills			
Organizing research ideas in writing	0.24 *(.11)*	0.23 *(.09)*	0.80* *(.26)*
Working independently on research projects	-0.22 *(-.09)*	-0.04 *(-.02)*	0.70* *(22)*
Conducting a search of literature for research purposes	0.31 *(.13)*	0.35 *(.14)*	1.10* *(0.36)*
Writing a literature review	0.27 *(.10)*	-0.09 *(-.03)*	1.65* *(.45)*
Understanding a research paper/journal article	0.07 *(.03)*	-0.21 *(-.09)*	-0.10 *(-.04)*
Documenting a research procedure	0.08 *(.03)*	-0.17 *(-.06)*	0.60 *(.18)*
Statistically analyzing data using computer software	-0.46 *(-.16)*	0.19 *(.06)*	0.45 *(.12)*
Following experimental or research procedures	0.14 *(.06)*	0.37 *(.16)*	0.52 *(.18)*
Writing the results of your experiment or research	0.06 *(.02)*	-0.11 *(-.04)*	0.50 *(.15)*
Orally communicating the results of research projects	-0.25 *(-.10)*	0.25 *(.10)*	0.55 *(.17)*
Writing a research paper for publication	0.58 *(.21)*	0.81* *(.28)*	1.30* *(.37)*
Preparing a research poster for presentation	-0.48 *(-.17)*	0.21 *(.07)*	0.55 *(.15)*
Overall confidence in research skills	-0.06 *(-.03)*	0.29 *(.14)*	1.00 *(.40)*

Note: * = p < .05; Standardized regression coefficients are italicized in parentheses.

The analyses revealed no significant differences in program outcomes between participants in the summer group and their counterparts in the single semester group. However, compared to the summer group, students that participated for two academic semesters reported higher gains in two items: awareness of available research career opportunities and writing research papers for publications. Similarly, participants in year-long experiences reported higher gains than the summer participants in understanding of research procedures, awareness of available research career opportunities and awareness of research careers options they could specialize in. The year-long group also reported higher gains in five research skills: Organizing research ideas in writing, working independently on research projects, conducting literature searchers, writing literature reviews, writing research papers for publications and overall research skills.

Discussion

As earlier mentioned, the goal of this study was to examine the impact of different models of URE participation (summer, one semester, two semester, and year-long) on student outcomes. In general, the analyses revealed two key findings: (1) there were no significant differences between participants in the summer and single academic semester groups, (2) compared to the summer group, participants in the longer term groups, i.e., two academic semesters and year-long experiences, reported higher learning gains in two and eight items, respectively (see Table 3).

This study contributes to the understanding of URE programs by comparing outcomes between summer experiences and three other groups. The results, taken together, seem to suggest that longer-term experiences may be more beneficial to student learning. The findings support Carter and colleagues' (2009) assertions that long-term URE programs "give students a more in-depth view of research" and "the continuous research experience may also lead to the development of culture, relationships" and other program outcomes (p.442). Russell and colleagues (2007) also reported significant correlations between duration of URE and positive outcomes. However, contrary to Russell et al (2007), we did not observe group differences in aspirations for graduate education and research careers.

This exploratory study is intended to serve as groundwork for larger studies investigating the effects of program duration on the outcomes of undergraduate research experiences. The study is not without limitations. For example, the study suffers from the problem of self-selection bias, a problem that is common to almost all URE research and evaluation studies. Also, we are unable to control for other programmatic and individual factors (e.g., accessibility and availability of faculty mentors, individual motivation, etc.) that may be related to the observed differences. Although an experimental/quasi-experimental design would have been the most ideal, we recognize the administrative and logistic constraints associated with randomly assigning students to URE programs.

Despite the limitations, this study should be of interest to science educators and URE program educators and researchers who may be interested in examining differential outcomes across program structures with the overall goal of identifying best practices and effective URE models. The statistical methodology (regression analysis with dummy variables) employed for the analysis should also be of interest to researchers as an alternative method for group comparisons in non-randomized studies, especially when datasets violate the assumptions of ANOVA.

Implications for undergraduate STEM education

Research and evaluation studies support the notion that undergraduate research experiences enhance student persistence and retention in college (e.g., Nagda et al), aspiration for graduate education and research careers, and promote the development of skills (e.g., research, communication and critical thinking skills) that contribute to successful undergraduate and graduate education in STEM disciplines. The current study suggests that these outcomes may be greater (or higher) for students who participate in yearlong research experiences, rather than single summer experiences. Although these findings are exploratory and should be interpreted with caution, the results emphasize the need for undergraduate STEM programs to devise strategies for incorporating opportunities for longer term authentic research experiences, preferably those that span the summer and academic semesters, into their student academic experiences. As suggested by Nagda et. al. (1998), undergraduate research programs that enroll students during regular academic year are important for making research an "integral" part of students' academic experiences and helping students to see that research is not necessarily something they do in isolation from their other academic pursuits or in the summer when they are "not in school". Longer term URE also offer opportunities for continued contact and interactions with research mentors, (i.e., faculty, post-doctoral researches and graduate students) as academic and career role models. When maintained over the course of a student's career, these mentorship relationships have the potential to increase student engagement, success and retention in STEM courses; provide opportunities and create conducive environment for professional networking and STEM professional identity; and enhance their overall academic/university experience.

It follows, then, that undergraduate STEM departments should ideally introduce their students to research experiences earlier in their programs. Early introduction to research experiences should help students to learn the methods and research processes for their majors, offer opportunities to apply course knowledge to real research and assist students in developing long-term relationships with faculty, graduate and peer mentors.

Finally, the study identifies potential areas for future research. Further studies are needed to clarify the effects of program intensity and duration on the outcomes of UREs. For example, is there a benefit to intensive immersion followed by less intense experience in the academic semesters (rather than a co-op model of intense immersion followed by little or no involvement)? Future studies are also needed to clarify what these results may mean for cross-institutional undergraduate research programs. Over the years, these programs have emerged and are becoming very popular for linking students in small liberal arts colleges with researchers and students in research universities. Given that academic year involvement is not practical or possible for students who are interested in cross-institutional research programs, what are potential best practices for optimizing student outcomes? For example, some of these UREs may need to include academic component (writing/publishing, perhaps) to assist students in maintaining and nurturing these cross-institutional connections. It is possible that, successful URE programs are already creating and nurturing these long-term relationships, but in light of the findings of this study, explicit research centered on these relationships may be particularly fruitful.

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