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Academic Research Enhancement Award (AREA) Program Evaluation

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1. Introduction

1.1 Description of Academic Research Enhancement Award (AREA) Program

This report comprises the results of the first full-scale evaluation of the National Institutes of Health's (NIH's) Congressionally-mandated Academic Research Enhancement Award (AREA) program. The AREA program has three objectives:

1. To support meritorious research,
2. Expose students to research, and
3. Strengthen the research environment of the grantee institution.

The AREA program funds research projects through the R15 mechanism.[1] The R15 mechanism provides funding for Principal Investigators (PI) at institutions of higher education that receive relatively small amounts of NIH funding. Currently principal investigators may receive up to $300,000 of funding over three years through competitive review processes at the National Institutes of Health's Institute or Center (ICs) most relevant to the research projects' area of inquiry.

Currently, 21 Institutes and Centers (ICs) participate in the AREA program.[2] The following is a list of ICs that participate in the AREA program:

- National Cancer Institute (NCI);
- National Eye Institute (NEI);
- National Heart, Lung, and Blood Institute (NHLBI);
- National Human Genome Research Institute (NHGRI);
- National Institute on Aging (NIA);
- National Institute on Alcohol Abuse and Alcoholism (NIAAA);
- National Institute of Allergy and Infectious Diseases (NIAID);
- National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS);
- National Institute of Biomedical Imaging and Bioengineering (NIBIB);

[1] In this evaluation, "AREA grant" and "R15" are used interchangeably, although the AREA program is the parent of the R15 mechanism.

[2] In 1985, 7 R15s were funded by the National Institute of Arthritis, Diabetes, Digestive, and Kidney Diseases (AM). After 1985, AM was disbanded as an Institute, and research topics formerly funded by it became part of the portfolios of the National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS) or the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK). Until 2011, the National Center for Research Resources (NCRR) funded R15s, after which it was dissolved.

- Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD);
- National Institute on Deafness and Other Communication Disorders (NIDCD);
- National Institute of Dental and Craniofacial Research (NIDCR);
- National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK);
- National Institute on Drug Abuse (NIDA);
- National Institute of Environmental Health Sciences (NIEHS);
- National Institute of General Medical Sciences (NIGMS);
- National Institute of Mental Health (NIMH);
- National Institute of Neurological Disorders and Stroke (NINDS);
- National Institute of Nursing Research (NINR);
- National Library of Medicine (NLM); and
- National Center for Complementary and Alternative Medicine (NCCAM).

While NIH funding for R15 awards (including new, competing continuations, non-competing continuations, and non-competing and competing supplements) was at a record high of 89 million dollars in 2014, this level is less than 0.6 percent of the total dollar amount NIH invested in extramural research projects the same year. Over the past four years, NIH has committed an average of 81 million dollars to the AREA program per year. Table 1-1 below describes the trend from 2005 to 2014 in the number of awards and funding of R15s relative to all extramural research projects funded by NIH in the same years. The table shows that since 2005, the number of awards remained around an average of 204, with the exception of the most recent year for which we have data, and that the proportion of dollars spent on R15 research increased around 2011 from 0.3 percent to .5 percent.

1.2 History of AREA Program

Congress established the AREA program in 1985 to "develop research in other institutions which offer undergraduate or graduate degrees in the sciences related to health but which historically have not been major participants in NIH programs."[3] While the language of the Appropriations Bill founding the AREA program included institutions that offer undergraduate and graduate degrees, the intent of the Bill was to enhance research programs at undergraduate-serving institutions of higher education. The Bill noted that many of the institutions of higher education responsible for providing undergraduate education to future biomedical scientists, especially institutions that serve minority students, tended to be "small, less prominent" institutions that did not receive many NIH resources. The intention of the Bill was to strengthen the research conducted within these institutions.

[3] U.S. Congress House of Representatives, Committee on Appropriations. Departments of Labor, Health and Human Services, and Education, and Related Agencies Appropriation Bill, 1985, 98th Congress, 2nd session, Report 98-911, July 26, 1984.

Table 1-1. Number of awards and award funding levels as a proportion of all NIH research projects

FY	Number of awards[4]			Funding		
	Number of R15 awards (excludes number of awards for noncompeting supplements)	Number of total research awards (excludes number of awards for noncompeting supplements)	% R15 projects/All research projects	R15 Funding (includes award amounts for noncompeting supplements)	Total research project Funding (includes award amounts for noncompeting supplements)	% $R15/$All research projects
2005	200	37,270	0.54	$40,590,833	$15,029,551,290	0.27
2006	189	36,814	0.51	$39,081,682	$14,852,789,984	0.26
2007	219	37,285	0.59	$45,855,258	$15,049,537,241	0.30
2008	214	36,656	0.58	$44,820,070	$15,013,228,571	0.30
2009	179	35,599	0.50	$37,844,375	$15,396,650,254	0.25
2010	186	35,422	0.53	$52,875,691	$15,858,157,470	0.33
2011	217	35,173	0.62	$78,575,122	$15,815,319,592	0.50
2012	209	35,029	0.60	$79,832,313	$15,923,746,065	0.50
2013	197	33,796	0.58	$76,871,384	$14,917,675,859	0.52
2014	233	33,069	0.70	$89,233,915	$15,635,912,476	0.57

[4] Includes Type 1 (new), Type 2 (competing continuations), noncompeting continuations, and competing supplements.

When the program began making awards in 1985, there was a direct cost cap of $50,000 for two years of support. Four years later, in 1989, Principal Investigators (PIs) were able to apply for 3 years of support with a cap of $75,000. PIs were eligible for a grant through the AREA program, as long as their institution did not receive more than two million dollars in grant money from NIH in every single year four years before their application. PIs were not permitted to hold more than one AREA grant simultaneously, and could not be the principal investigator of another major NIH grant at the time of award. Grants were administered through the Office of the Director (OD).

Documents from 1990 to 1996 from workshops and a NIGMS advisory council discussed the challenges faced by AREA awardees and proposed recommendations. At that time, the R15 award was expected to serve as a stepping-stone to an R01 or R29[5] grant. However, by 1996, the National Institute of General Medical Sciences (NIGMS)—the IC funding more R15s than any other—reported that less than five percent of PIs who had received R15s through NIGMS had been successful in obtaining R01s subsequently.[6] This expectation was re-evaluated as unrealistic for faculty members at R15-eligible institutions, who generally have heavier teaching responsibilities than faculty at prominent, research intensive schools. A second, related concern was that PIs who had received one R15 grant were unable to sustain their research since they were unable to renew the R15 grant or to scale-up their project for an R01. The NIGMS Advisory Council of 1996 noted that ten percent of their R15 recipients had received a second award only by changing their projects enough to qualify as a separate line of research.

1.2.1 1996-1997 Survey and Recommendations

In order to assess the extent to which AREA recipients experienced aspects of the AREA program as needing to be changed, a survey of 49 PIs was conducted in 1996. PIs who were surveyed reported that the grants had a positive effect on students' careers, and that they were able to provide research experiences for an average of 6 students per project. On average, PIs published 1.5 papers per project. They unanimously agreed that allowing competitive continuations of R15s would help them maintain a "productive research program" doing "small-scale, but important, work."[7]

1.2.2 1998 Changes to AREA Program

Based on the 1997 recommendations of the AREA Committee, a number of changes were made to the program. The most important was conceptual—the program was no longer to be used as a "stepping-stone" to larger NIH grants. Instead, by allowing competitive renewals, the R15 mechanism would become a mechanism for sustaining small-scale research programs over a number of years. The second important redefinition to the objectives of the program was that it was to serve to provide quality research experiences for undergraduates in the behavioral and biomedical sciences in order to interest students in pursuing further education and employment in the sciences, thus facilitating a strong scientific workforce pipeline in the United States. An informal poll of NIGMS council members in 1996

[5] The R29 mechanism was a small grant intended for early-career investigators to build a line of inquiry that would then be continued with an R01. It was discontinued in the late 1990s after research showed that R29 recipients were not more likely than those who had not received an R29 to receive a subsequent R01.

[6] May 1996 NIGMS Advisory Council minutes. NIGMS was, and continues, to be the single IC funding the most R15s. From 1985 to 2014, 28 percent of all R15 awards had been made through NIGMS.

[7] Cuca, J., et. al. (1997). Report of the Committee on the Academic Research Enhancement Award (AREA) Program.

found that 50 percent had received their undergraduate degrees at AREA-eligible institutions.[8] More recently, systematic research has revealed that small, private, primarily undergraduate institutions continue to provide the foundational education experience for a disproportionate percentage of the nation's future Ph.D.s in science, math, and engineering.[9]

At the same time that the above objectives were articulated, the committee formed to report on AREA explicitly added a previously unstated goal of the program—to fund meritorious research. Since 1998, the three goals of the program have remained constant: to fund meritorious research, strengthen the research environment of the institution where the grant is held, and expose students to research. Other changes were also instituted in1998: increasing the submission dates to 3 times per year, and raising the direct costs cap from $75,000 to $100,000.

The extent to which any R15 application can demonstrate that it can achieve these objectives has gradually been incorporated into application review criteria. In addition, since the original revamping of the program in 1998, the direct costs cap and institution eligibility caps have increased. Table 1-2 describes these changes.

Table 1-2. Changes to AREA Program

First Application Receipt Date	First Council Round Date	Program Announcement	Direct Cost Cap	Institution Eligibility Cap	Review of AREA-specific criteria
06/26/96	May 1997	PA-96-020	$75,000	$2M	Need evidence that school's B.A.s have received science Ph.D.s
06/25/97	May 1998	PA-97-052	$75,000	$2M	"
05/25/99	October 1999	PA-99-062	$100,000	$2M	Criteria entered as Admin Note
02/25/03	October 2003	PA-03-053	$150,000	$3M	Criteria reviewed in second level
02/25/10	October 2010	PA-10-070	$300,000	$6M	Criteria not mentioned in review
02/25/12	October 2012	PA-12-006	$300,000	$6M	PIs expected to address three goals in proposal

1.3 Logic Model for AREA Evaluation

The AREA program distributes NIH funding to institutions of higher education that have a lesser share of NIH resources. NIH extramural funding tends to accrue to research universities with a very high intensity of research activity, regardless of the number of students who attend those institutions. In the absence of any effort to redress this situation, students at small or regional universities and colleges without

[8] May 1996 NIGMS Advisory Council minutes.

[9] Burrelli, J., et. al. (2008). Baccalaureate Origins of S&E Doctoral Recipients. NSF 08-311. http://www.nsf.gov/statistics/infbrief/nsf08311/#fn1.

substantial, well-funded research programs are likely to be at a disadvantage when seeking to participate in high-quality research projects. This has consequences for the likelihood that these students will choose to become scientists, and in how prepared they will be for further scientific education should they decide to continue.

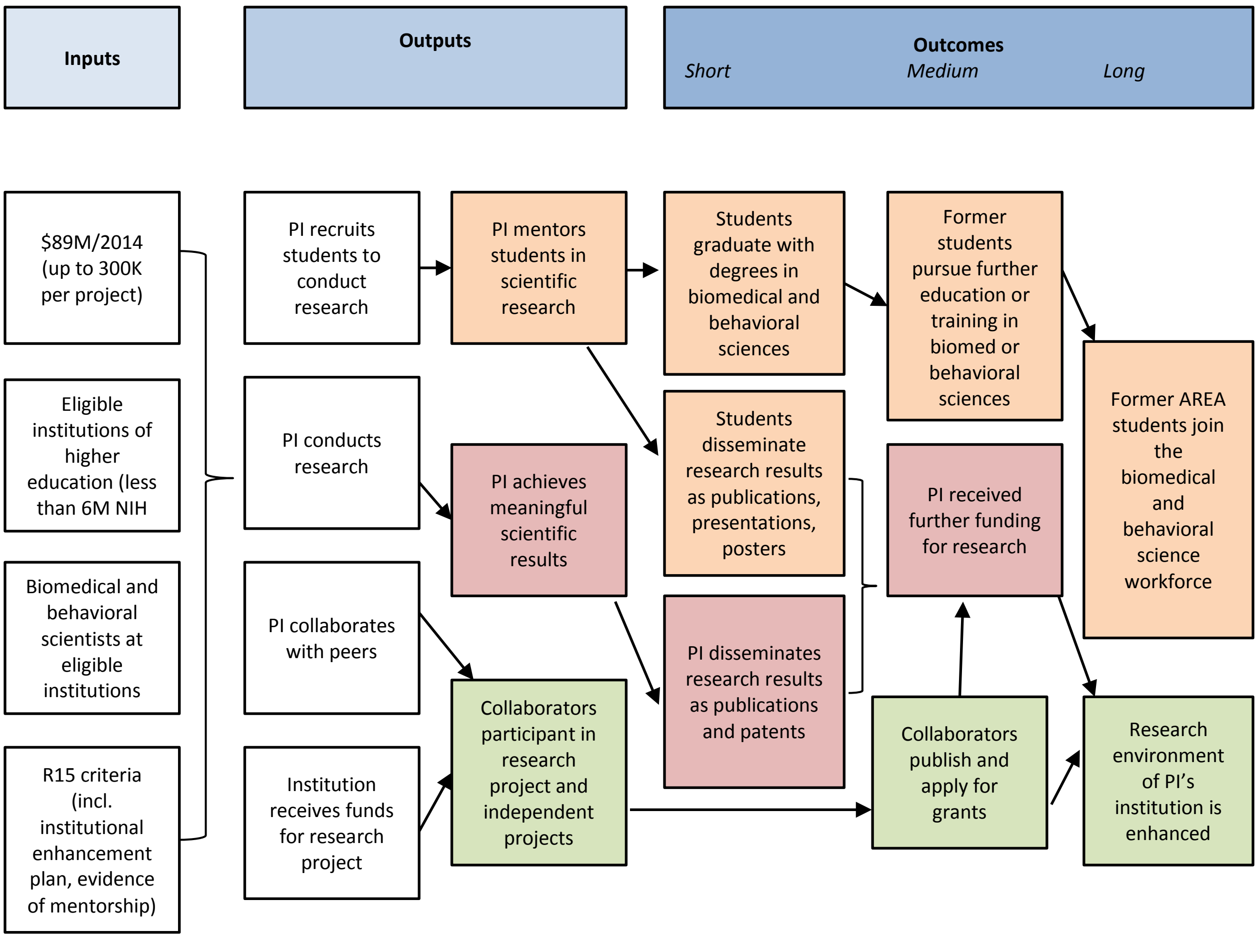
The AREA program is meant to address a lack of high-quality research opportunities for students at institutions of higher education that are not high intensity research institutions. The program should contribute to the advancement of biomedical and behavioral sciences, albeit on a small scale. The theory of the AREA program holds that providing NIH research funding for small-scale, high-quality research projects at small, regional, and less-well-funded institutions of higher education will increase opportunities for undergraduate and graduate student research experiences. Gaining real-world research experience will increase students' commitment to and enthusiasm and preparedness for further graduate education in the behavioral or biomedical sciences. Eventually, these students will strengthen the biomedical and behavioral sciences workforce. At the same time, the institutions of higher education that receive these monies will be able to purchase up-to-date scientific supplies, involve additional faculty or staff in research collaboration with the PI, and foster healthy competition that will raise standards of research excellence.

See Figure 1-1 for a pictorial description of the logic model. The theory of the AREA program holds that high caliber applicants working on competitively-funded projects at AREA-eligible institutions (inputs) will produce important scientific findings and disseminate research results to the scientific community (output and short-term outcome). AREA PIs will sustain their research programs with subsequent external and internal funding (medium outcome). They will recruit students to carry out their AREA project, and provide mentorship to students (outputs). Students will participate in meaningful research tasks, including co-authorship (short-term outcome). Motivated by their developing interest in scientific research, students will pursue further education and training in the biomedical and behavioral sciences and eventually join the biomedical and behavioral science workforce (medium- and long-term outcomes). The research environment of the institution receiving the AREA grant will improve as peers collaborate on scientific projects with the AREA PI (output), make use of improved institutional infrastructure and scientific supplies to conduct their own research, apply for, and receive their own competitive external funding (medium and long-term outcomes).

1.4 Evaluation Questions and Study Design

Westat was tasked by NET Esolutions to carry out an evaluation of whether the three goals of the AREA program had been met throughout its existence, with an emphasis on the years 1988 to the present. The purpose was to identify challenges and gaps in implementation, and to facilitate recommendations. Westat proposed a quasi-experimental evaluation design involving a post-test comparison of R15 award recipients to a never-successful comparison group of R15 applicants. A comparison of AREA projects to projects funded by the "gold standard" of NIH research awards, the R01, was also made. Three major sources of data were used to this evaluation: (1) administrative data on grants and applications available in NIH's Query View and Report (QVR) database and publicly available on NIH RePORTER, (2) bibliometric data on publications and papers retrieved from Thomson Reuters *Science Wire*, and (3) self-report data from surveys of AREA PIs, a comparison group of unsuccessful AREA applicants, and students who were involved in AREA PIs' projects.

Figure 1-1. AREA program logic model*



*AREA program objectives are represented with red, orange, and green. Red shading indicates that the outcome meets the first objective: to fund meritorious research. Orange shading indicates that the outcome meets the second objective: to expose students to research. Green shading indicates that the outcome meets the third objective: to strengthen the research environment.

1.4.1 Evaluation Question 1: Is Meritorious Research Funded?

We operationalize "meritorious research" in three ways for the purpose of this evaluation. Since the scientific fields funded by the AREA program are enormous and complex, it is impossible for any scientist, or even teams of scientists, to make assessments of merit over the entire scope of AREA-funded lines of inquiry. Therefore, we employ quantitative measures of research productivity and research utility to serve as proxies for merit.

Success rates. A competitive program that is prestigious, well-known and relevant should garner many applications. A competitive application process and a valid review process ought to allow for the selection of high quality projects. Evaluating the extent to which the current peer review system for R15 awards is effective in choosing the most innovative and important lines of research is beyond the scope of this evaluation. Therefore, we have examined the competitiveness of the AREA program over recent years through success rates.

Bibliometric analysis. Next, we examined the quality and quantity of peer-reviewed publications, looking at the number of peer-reviewed publications per period of interest, the amount of time it takes for an R15 grant to publish its first paper, citation counts received by R15-funded papers, and the cost per peer-reviewed paper, and the cost per citation. The Thomson-Reuters team, led by Holly Wolcott, Ph.D. and Joshua Schnell, Ph.D., extracted and compiled all bibliometric data for Westat by mechanism type (R15 and R01) from *Web of Science.*

Since the AREA projects and AREA-funded PIs did not have a readily-available control group, we selected two comparison groups to evaluate the relative merit of AREA productivity and quality. First we selected a sample of R01s to match a random sample of R15s for comparison (see "Methods" for description of sampling procedures). The rationale for this comparison is that the R01 is the "gold standard" of research productivity and impact within the NIH extramural research projects program; that is, the R01 award funds the best and most competitive extramural research projects conducted at institutions of higher education. Activity codes more similar to the R15 in size, such as the R03 and R21, are intended to lead to an R01 application.

The second comparison group is a sample of never-successful AREA applicants. These are PIs[10] who applied to the program at least once but had never received an AREA award. This group facilitated a comparison of a "treatment" group to a "no treatment" group. Even so, some never-successful AREA PIs had received other NIH awards, and other never-successful AREA PIs have received grants from other institutions.

Subsequent funding. The third way we defined meritorious research in order to quantify measures for evaluation was to postulate that meritorious research that was funded by the AREA program would be sustainable—it would likely be funded by other government, private, foundational, and internal grants. Therefore, we surveyed AREA PIs and a comparison group of never-successful AREA applicants about funding received subsequent to the AREA grant that sustains the line of research begun for their proposed AREA project.

1.4.2 Evaluation Question 2: Are Students Exposed to Research?

NIH has had no specific requirement to report information on students who were involved in research funded by AREA grants. However, one aim of the grant is to contribute to the development of the biomedical and behavioral sciences workforce pipeline by getting students interested in, and prepared for, further scientific training. Therefore, in addition to examining the magnitude of student involvement in AREA-funded research, we also wanted to know the following:

- How are students involved? What tasks do they undertake on projects? Do they co-author papers and give presentations on findings?
- What are the outcomes of students' involvement? Are they prepared for, and interested in, further education in science? Does the R15 grant contribute to the development of the scientific workforce?

[10]Throughout this report, "PI" refers to an individual—usually a faculty member at an institution of higher education—who leads, or proposes to lead, a scientific investigation. Therefore, we use "PI" to refer to recipients of AREA grants, recipients of R01 grants, and never-successful applicants to the AREA program.

We examined student involvement in AREA-funded research through reports of student work described in AREA Final Progress Reports and Research Supplements to Promote Diversity in Health-Related Research, through a survey of former students who worked on AREA research projects, and through survey and qualitative data collected from AREA PIs about student involvement. See Table 1-3 for the sources of information used to address the research questions.

Table 1-3. Student involvement in AREA-funded projects

Subject		Awardee interview	Awardee survey	Applicant survey (comparison group)	Student survey	Admin-istrative records[11]
Magnitude of student involvement in research	Number of students involved in R15 research		✓	✓		✓
	Number of students who disseminated findings		✓	✓		✓
Student research roles on project	Contributions of students to research process	✓	✓	✓	✓	
	Years/months/ hours per week in lab				✓	
	Lab tasks performed				✓	
	Satisfaction with experience				✓	
Student outputs	Numbers of publications, presentations, posters					✓
Student outcomes	Post-AREA training, education and employment	✓	✓	✓	✓	
	Research since leaving AREA lab				✓	

1.4.3 Evaluation Question 3: Is the Research Environment Strengthened?

Evaluating whether or not the research environment of the institution receiving the award has been strengthened by having the AREA project is probably the most difficult of the three goals of the evaluation since an incrementally "stronger research environment" is difficult to quantify. If researchers

[11] Including AREA Progress Reports and diversity supplements.

at the institution are more productive in terms of publishing more high quality peer-reviewed publications, if there are more students being trained in conducting real world research, if researchers at the institution are collaborating more frequently, and if more of the institutions' researchers are applying for, and receiving, competitive research monies, we might conclude that the research environment has been strengthened. Even so, a whole host of factors (not just the presence of an AREA award) may contribute to any of these outcomes, making the effect of the AREA award on an institution extremely difficult to identify.

To evaluate whether or not the research environment was strengthened by an AREA award, we asked PIs to explain how the award effected their institution in in-depth interviews. We also surveyed PIs about the extent of their collaboration before and after the award with peers within, and outside of, their institution.

2. Methods

We employed four sources of data to evaluate the success of the AREA program. First, we examined the competitiveness of the AREA program using administrative data on applications and awards extracted from NIH RePORTER and NIH Query, View, and Reporting (QVR) database. We also used bibliometric analysis to assess the quantity and quality of the dissemination products of AREA projects and comparison groups. Third, we surveyed former AREA PIs, their former students, and a comparison group of AREA non-awardees about relevant program outcomes. We also interviewed former AREA PIs to understand what challenges and successes they encountered implementing their AREA projects in the context of their institutions, what they believed were the long-term outcomes of receiving the grant, and any recommendations they might have for the program.

We do not discuss methods pertaining to the collection of administrative data from NIH RePORTER and QVR since those data were provided publicly, or by NIH, respectively. Analysis of these data begins in the next chapter.

2.1 Bibliometrics

Bibliometric analysis is frequently used to evaluate academic programs. In brief, bibliometric analysis uses data derived from the citation rates of publications. Since citing previous published work is an integral part of conducting research, citations counts of articles are one measure of the value that other researchers place on any given article. Thomson-Reuters Research Analytics finds that citation rates correlate with other measures of research quality, such as peer review. For this evaluation, the Thomson-Reuters team provided bibliometric data on AREA projects, AREA awardees, AREA non-awardees, and a sample of R01 projects matched to the universe of R15 projects.

2.1.1 R15 and R01 Performance Comparison

Preparation of R15 award universe. We extracted all R15 awards made between the beginning of the program in 1985 until the end of fiscal year 2010 from the NIH QVR database. The new database of R15 awards was cleaned and prepared. Any awards that had received funding through a competing continuation (type 2)[1] were integrated so that the most recent fiscal year entered into the database represented the award, and so that there were no duplicate grant numbers. 2010 was chosen as the final year for bibliometric analysis, since any project that began after fiscal year 2010 was likely to have finished only months before extraction of bibliometric data in December 2014. Projects that began in 2011 or later were expected to be too recent to have accumulated many—if any—publications. We found that 3,903 R15 awards were made 1985-2010.

For the purpose of matching a sample of R01s to the universe of R15s, we grouped the R15s into cells by Institute and Center (IC) and by the 6-year period in which grants began.[2] See Table 2-1. R01s were matched by cell to comprise a stratified random sample of R01s funded by the same IC in the same 6-year period. Therefore, since National Institute of Diabetes and Digestive and Kidney Disorders (DK)

[1] A "type 1" R15 is a new R15 award. A "type 2" R15 is a competing continuation of the project begun during the type 1 R15. Type 2s maintain the same NIH reference number as the previous type 1, but applications for type 2s recompete with all new and continuing grant applications.

[2] The first period, 1985-1991, contains 7 years since there were few R15s awarded in fiscal year 1985.

made 49 new awards from 1998 to 2003, 49 R01s were selected via random stratified sample from among those made by DK 1998-2003. Please see Table C-1 in Appendix C for a key to the two-letter IC codes. For ICs that had awarded 250 or more R15s 1985-2010, we determined that for statistical power, only 250 matches were necessary. For example, we selected only 250 R01s via stratified random sample to match the 438 R15s awarded by the National Institute of Allergy and Infectious Diseases (AI). For the purposes of making the comparison, ICs that had awarded fewer than 20 R15s 1985 to 2010 were dropped from analysis. The total number of R01s matched for comparison was 2,728. See Table 2-2.

Table 2-1. All R15 Awards 1985-2010 by Institute or Center (IC)*

FY	AA	AG	AI	AM[3]	AR	AT	CA	DA	DC	DE	DK	EB	ES	EY	GM	HD	HG	HL	LM	MH	NR	NS	RR	Total
1985-1991	0	27	106	7	30	0	49	0	17	24	55	0	32	19	270	80	0	79	0	0	37	66	0	898
1992-1997	2	16	102	0	28	0	78	5	14	21	51	0	31	16	215	77	3	64	1	7	100	55	1	887
1998-2003	6	48	107	0	13	2	87	21	17	10	49	2	40	25	245	51	3	56	0	34	104	55	0	975
2004-2009	9	39	106	0	25	9	102	22	21	9	35	19	34	18	235	46	1	93	0	35	59	67	2	986
2010	3	2	17	0	5	2	21	3	1	3	15	3	8	3	32	8	1	8	0	6	3	13	0	157
TOTAL	20	132	438	7	101	13	337	51	70	67	205	24	145	81	997	262	8	300	1	82	303	256	3	3,903

*See Table C-1 in Appendix C for the full name of the Institutes represented by organizational two-letter codes.

Table 2-2. Stratified sample of R01 Awards 1985-2010 by IC*

FY	AA	AG	AI	AR	CA	DA	DC	DE	DK	EB	ES	EY	GM	HD	HL	MH	NR	NS	Total
1985-1991	0	27	60	30	36	0	17	24	55	0	32	19	68	76	66	0	31	64	605
1992-1997	2	16	58	28	58	5	14	21	51	0	31	16	54	73	53	7	83	54	624
1998-2003	6	48	61	13	65	21	17	10	49	2	40	25	61	49	47	34	85	54	687
2004-2009	9	39	61	25	75	22	21	9	35	19	34	18	59	44	77	35	49	65	696
2010	3	2	10	5	16	3	1	3	15	3	8	3	8	8	7	6	2	13	116
Total Samples	20	132	250	101	250	51	70	67	205	24	145	81	250	250	250	82	250	250	2,728

*See Table C-1 in Appendix C for the full name of the Institutes represented by organizational two-letter codes.

2.1.2 R15 Awardee and Non-Awardee Performance Comparison

In order to conduct a quasi-experimental comparison among projects that had received the R15 award to those that had not, we compared the bibliometric performance of R15 recipients 5 years after receiving their most recent AREA award, to that of AREA non-awardees 5 years after they proposed their most recent AREA project.

We constructed a database of unique AREA recipients ("awardees") and unique AREA non-awardees from the universe of R15 applications and awards as extracted from the NIH QVR system. In all, we found 3,109 unique awardees and 4,610 unique non-awardees whose most recent project or application had been made 2010 or previously. We chose a random sample of 600 AREA awardees and 600 AREA non-awardees for comparison.

Since non-awardees would not have acknowledged an R15 grant on any publications, we manually searched for the PubMed ID or Web of Science identification number of a "seed" publication of each

[3] Shaded ICs are those with less than 20 awards 1985-2010 eliminated from the analysis.

AREA non-awardee as close as possible to the most recent application. After associating at least a single publication with each sampled awardee and non-awardee manually, Thomson-Reuters created a database of all publications authored by the awardee or non-awardee 5 years before the fiscal year of the most recent award or application, and 5 years after the most recent award or application. For each PI (awardees and non-awardees), the Thomson-Reuters team provided the number of peer-reviewed publications, the total citation count of the publications, the average citation count of each paper, the percent of uncited papers, and journal impact factors for the journals in which their articles were published. Note that all AREA awardee publications were included in this analysis—not just those that pertained to their AREA-funded research—because all non-awardee publications were included, as we were not able to distinguish which publications might be related to the line of research proposed in their application and which were not.

2.2 Surveys

2.2.1 Survey Design

We surveyed AREA awardees, AREA non-awardees, and former students who worked on AREA-funded projects 1985-2010. Survey questions were designed to help assess the extent to which the AREA program has met the three objectives to support meritorious research, expose students to research, and strengthen colleges' and universities' research environments. Table 2-3 describes areas of inquiry that were covered in the surveys and the interview of awardees.

Table 2-3. Survey and interview topics

Evaluation topic	Area of inquiry	Awardee interview	Awardee survey	Applicant survey	Student survey
What has NIH done to advance the goals of the AREA program?	Visibility and outreach		✓	✓	
	Reasons for applying	✓	✓	✓	
Is meritorious research funded?	Dissemination of results of grant		✓		✓
Are students exposed to research?	Student involvement in research	✓	✓	✓	✓
	Process of engaging students in research/ mentorship	✓			
	Student outcomes	✓	✓	✓	✓
	Student demographics				✓
Is the research environment strengthened?	Subsequent research activity	✓	✓	✓	
	Subsequent grants held	✓	✓	✓	
	Collaboration with peers	✓	✓	✓	
	Support from home institution	✓		✓	

To the extent possible, questionnaire items were selected or modified from previous Westat surveys that had been shown to be clear and effective. However, a large number of questions were designed specifically to meet the needs of this evaluation. Once our questionnaire was drafted, we conducted cognitive interviews with three AREA awardees, three AREA non-awardees, and three students who had participated in AREA-funded research. Revisions to improve clarity and increase the ease of completing the surveys were made based on the findings of the cognitive interviews. Final drafts of the surveys were programmed for web administration using a commercial-off-the-shelf software program. See Appendix A for Awardee, Applicant, and Student surveys.

2.2.2 Institutional Review Board (IRB) and Office of Management and Budget (OMB) Clearances

AREA evaluation data collection materials and procedures were reviewed and approved by the US Government's Office of Management and Budget (OMB), staff at the National Institutes of Health (NIH), and Westat's Institutional Review Board (IRB). Westat received IRB exemption on January 24th, 2014 and OMB clearance on February 18th, 2015 (clearance number 0925-0710, exp. 02/28/2018).

2.2.3 First Wave of Awardee and Applicant Surveys

Our intention was to survey the same randomly sampled 600 awardees and 600 AREA non-awardees whose bibliometric information had comprised the treatment/no treatment comparison of research performance. Combining data from the bibliometric analysis with data from the surveys would permit analysis of the interaction of multiple variables on AREA program outcomes.

All available contact information for the sample of 600 awardees and 600 non-awardees was extracted from the NIH QVR database. However, an overwhelming number of sampled PIs (awardees and non-awardees) had no contact information available besides the name and location of the institution of higher education from which they had made their application; there was no e-mail address or phone number listed. Among awardees and non-awardees for whom there was contact information, much of it was not current. Therefore, Westat extensively traced the random sample of 600 awardees and 600 non-awardees to identify or update missing e-mail addresses and verify that the identified e-mail addresses were indeed those of the former awardees and non-awardees. A first round of tracing made use of publicly available search engines such as Google, LinkedIn, ResearchGate, Academia.edu, and People Search. A second round of tracing used LexisNexis databases to confirm the identities of, or locate, those members of the sample who had not yet been verified or identified. The results of the tracing of awardees, non-awardees, and students are described in Table 2-4.

Table 2-4. Number of responses for the first wave of survey administration

Sample Type	Total sample	Deceased	Not located	Sent Survey	Completed Surveys	Refusal	No response
Awardee	600	23	21	556	221	0	335
Non-Awardee	600	48	30	522	92	24	406
Student	601	0	185	416	90	3	323
Total	1,801	71	236	1,494	396	27	1,064

2.2.4 Data Collection Procedures

Sampled awardees, non-awardees, and students were sent an introductory e-mail by the AREA Program Director from the general R15 e-mail address to introduce Westat, and inform them that as part of an evaluation of the program, they would be receiving a request to complete an online survey. The Director provided her contact information to potential respondents in case they had questions. One week after the introductory e-mail was sent, an e-mail invitation with the web link for the survey was sent from Westat to invite participation in the study. Up to two survey reminders were sent to each potential respondent unless he or she had already completed the survey or indicated that they did not wish to participate. The first reminder was sent 1 week after the invitation, the second reminder was sent 2 weeks after the invitation.

2.2.5 Second Wave of Awardee and Applicant Surveys

Since response rates for the first wave of survey administration were low enough to compromise the validity of any findings, we sought to run a second wave of Awardee and Applicant Surveys. We extracted all available contact information from the NIH QVR database for each PI (awardees and non-awardees) who had not been part of the sample groups receiving the first wave of survey administration. Any unique R15 awardee or non-awardee who had an e-mail address listed in the QVR system was considered as a potential survey recipient for this wave. Once PIs who had already been sent survey participation requests in the first wave were eliminated, we had a convenience sample of 1,086 awardees and 1,037 non-awardees. Data collection procedures for the second wave of survey recipients were the same as for the first wave. See Table 2-5 for combined results of survey waves 1 and 2.

Table 2-5. Number of responses for First and Second Waves of survey administration

Respondent Type	First Wave			Second Wave			Waves Combined		
	Completes	Invitations	Percent	Completes	Invitations	Percent	Completes	Invitations	Percent
Awardees	221	556	40	422	1,086	39	643	1,642	39
Non-Awardees	92	522	18	173	1,037	17	265	1,559	17
Students	90	416	22	0	0	0	90	416	22
Total	403	1,494	27	594	2,123	28	997	3,617	28

2.2.6 Characteristics of Awardee and Applicant Survey Respondents

Institution type. Awardees and non-awardees who responded to the survey were similar to the universe of awards and unsuccessful applications by institution type (Figure 2-1).[4] The proportion of respondents whose home institutions were classified as Primarily Undergraduate, Professional Schools, or Other, are within 3 percentage points of the relative proportion of the universe of awards and applications. Awards from Research Universities were slightly underrepresented in the survey since only 34 percent of all awardees had been at Research Universities, whereas 39 percent of all awards in the history of the program 1985-2010 went to Research Universities. This difference is statistically significant with a p-value of 0.02. Non-awardees at Masters Colleges and Universities who responded to the survey over-represented the universe of unsuccessful applications from Masters Colleges and Universities by 7 percent. This difference is statistically significant with a p-value of 0.01. See Appendix B for a description of how institutions of higher education were classified for this evaluation. See Appendix C, Table C-2 for

[4] "Institution type" refers to that assigned by the Carnegie Classification for Institutions of Higher Education. See Appendix B.

the percentages of survey respondents by institution type in comparison to the universe of awards and applications by institution type.

Figure 2-1. Awardee and non-awardee survey respondents nearly match the universe of awards and applications

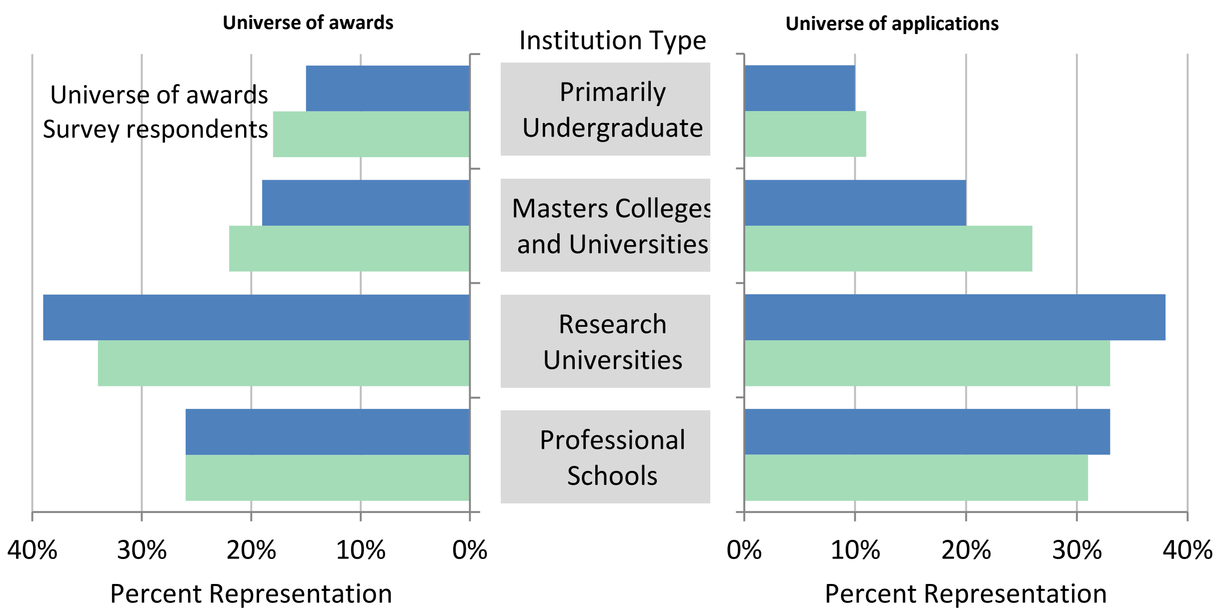


Table C-2 in Appendix C contains more detail on these data.

Fiscal year of most recent award or application. Awardees and non-awardees were more likely to have had a recent award or application to the AREA program (see Figure 2-2). The fiscal year with the highest number of awardee and non-awardee survey respondents was 2010. 94 awardees whose last award was in 2010 responded comprising 15 percent of the total number of awardee respondents. 27 percent of non-awardee responses had made their most recent application in 2010. 68 percent of awardees who responded to the survey received their AREA award in the last decade. In contrast, less than 10 percent of awardee respondents held their last R15 grants in the first 10 years of the AREA program.

Figure 2-2. Percentage of awardee and non-awardee respondents by fiscal year of last award or application

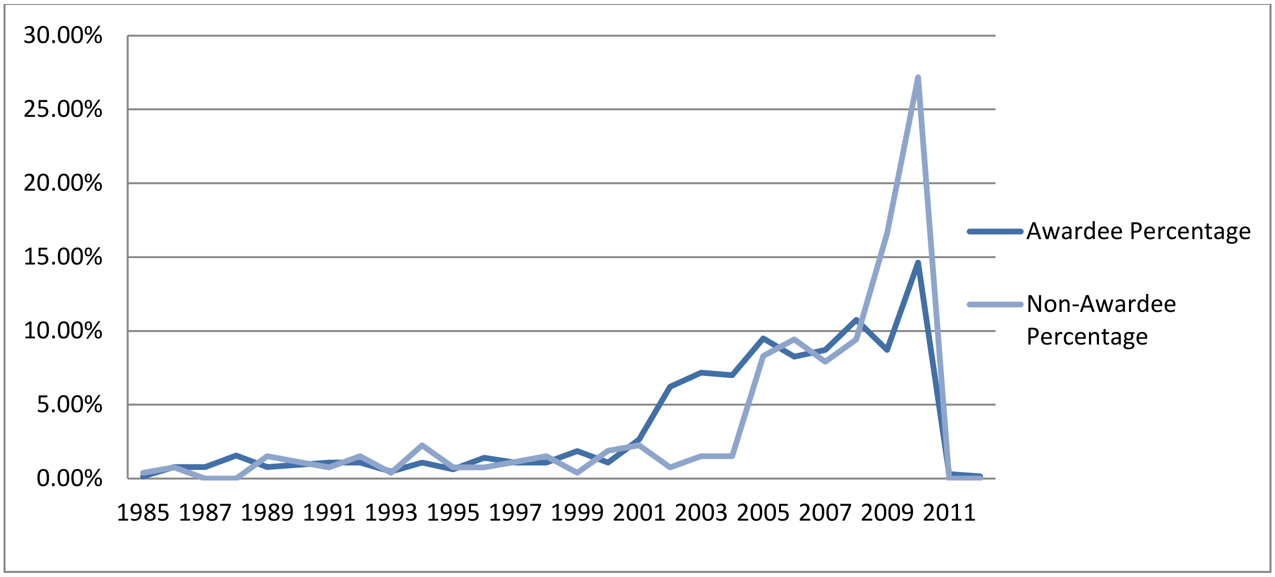


Table C-3 in Appendix C contains more detail on these data.

We think there are two reasons for the fact that most survey respondents were from recent years. First, while our First Wave of survey administration carefully traced contact information for randomly sampled awardees and non-awardees, our Second Wave made use of the e-mail address listed in QVR. PIs who made their most recent application more than 10 years ago and failed to update their contact information in NIH eRA Commons were unlikely to be reached in the Second Wave if their address had changed. Second, we suspect that awardees and non-awardees who are interested in re-applying for an AREA grant in the future were more likely to respond than those who had given up on receiving an AREA grant a number of years ago. Interview responses lend support to the latter conjecture. Some awardees interviewed expressed concern that the AREA program would be discontinued, and said they were personally interested in receiving future grants.

2.2.7 Student Survey Respondents

Sources of information about students. There were two sources of information on students who participated in AREA-funded research: AREA Final Progress Reports and AREA Diversity Supplements. First, AREA Final Progress Reports, when submitted, sometimes listed names of students who had been involved in the PI's research project. The total number of AREA projects awarded from fiscal years 1998 to 2010 was 2,422. Of the 2,422 projects, Westat was able to access scanned or uploaded AREA Final Progress Reports from the QVR system for 651 projects (27 percent) in February 2014.

Of students researchers referred to in the Final Progress Reports, not all were named. Some PIs merely described the number, type and nature of student involvement. For example, one PI wrote:

> Within the last 3 years, 14 [college name] undergraduate students have each worked 3-24 months on this research project. Of the 14 students, 2 are [currently] in PhD programs, 2 are accepted into medical school, and 9 [now]

> work as clinical or laboratory research assistants. Three undergraduate researchers presented their work at national meetings of the [scientific society name], and nearly all the student researchers presented at regional or local conferences.

In contrast, other PIs submitted tables with student names, degree programs, and any outcomes of AREA-funded research and training, such as admission to professional or graduate school, and papers published. Still other PIs provided bibliographic information on publications and presentations and highlighted, or otherwise marked, the names of students who were authors. In total, approximately 65 percent of high school students, 84 percent of undergraduate students, 83 percent of graduate students and 100 percent of postdoctoral students were named in the AREA Final Progress Reports.

Westat read the AREA Final Progress Reports and abstracted information about PIs' students. We constructed an Excel database to capture the following information: numbers of students reported, students' name, degree program, institution, publication authorship, presentations, poster authorship, education or employment after AREA project work, any other pertinent information. Unfortunately, there was no contact information for students contained in any AREA Final Progress Reports.

The second source of student names was minority/diversity or disability administrative supplements given to AREA PIs. In all, we identified 151 students who were the beneficiaries of minority/diversity, or disability supplements 1997-2010. Names of students were extracted from electronic Notices of Grant Award (NOAs) available in QVR. Even less information about students who received support through supplements was available through QVR than for students reported in AREA Final Progress Reports. In most cases, the NoA did not mention the student's degree program (undergraduate, graduate, high school student, etc.) or whether the student was receiving the supplement as a person with disabilities or as an underrepresented minority. Since postdoctoral students or persons re-entering the workforce who held terminal clinical or research degrees were named with their titles on the NOAs, it was possible to eliminate postdoctoral students and those who were re-entering the workforce from the universe of potential survey respondents.

Selection of students for survey. Since facilitating the educational opportunities of minority/diversity students is an important objective of NIH's initiatives, we decided to survey all 151 students who had been the beneficiaries of minority/diversity or disability administrative supplements attached to R15 parent grants. To select 450 students from among those named in the AREA Final Progress Reports, we employed equal probability of sampling (EPS) method. First, we randomly selected 450 AREA PIs from among the 694 who named students in their AREA Final Progress Reports. Once we chose the PIs, we randomly selected one student from each sampled PI's lab for a total of 450 students. This sampling method was employed to guarantee that only one student was selected from each lab. While the representation of PIs and their laboratories was evenly distributed, students of PIs reporting smaller numbers of students had a greater representation in the final sample.

Tracing student sample contact information. Methods to trace the contact information of students were similar to those reported above for awardees and non-awardees. However, students were much more difficult to find. It is likely that some students changed their surnames after graduation, and others were not enrolled in degree programs at the institution of higher education where they carried out AREA-funded research. Tracers reported that students who were currently in academia seemed easier to find, since they often were listed on their colleges' or universities' web pages. We expect that the ease with which those working in the academy were located introduced bias into the final count of those for whom our contact information was current. In all, we were unable to find any contact information for 185 students of the 601 sampled.

Survey administration. 416 students of the 601 sampled were sent introductory, invitation and reminder e-mails to participate in the web survey on the same schedule as the awardees and non-awardee in Wave One. Data collection procedures followed for student respondents were the same as those for awardee and non-awardee respondents.

Characteristics of student respondents. Of the 92 students who responded to the survey, two-thirds (67 percent) were female. 15 percent identified as Asian, 14 percent as African-American, and 10 percent as Hispanic or Latino. 3 students reported their heritage as American Indian or Alaskan Native and 1 student said they were Native Hawaiian or Other Pacific Islander.

The average age of the students who responded was 33 years and the median age was 30 years. See Figure 2-3 for frequencies of students' birth dates.

Figure 2-3. Age distribution of student respondents

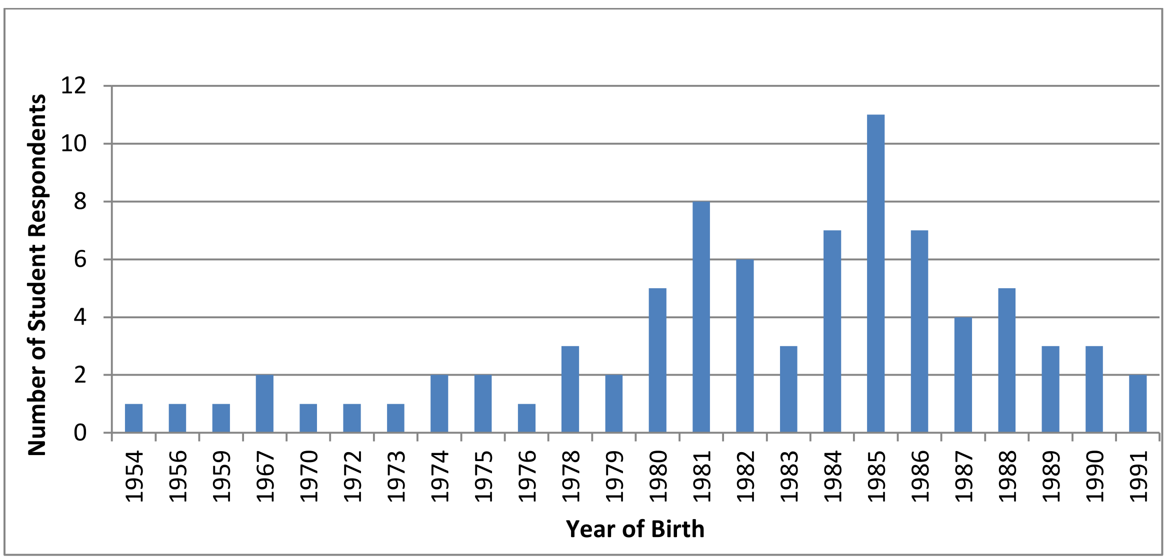


Table C-4 in Appendix C contains more detail on these data.

Two-thirds of students who responded to the survey had been undergraduates at the time they worked in an AREA-funded laboratory. Masters and Ph.D. students represented 18 and 17 percent, respectively, of those who responded. See Figure 2-4. Note that some students were involved in AREA research during more than one degree program. For example, a student may have begun working on AREA research as an undergraduate and continued research through a Masters' degree.

Figure 2-4. AREA students' degree programs

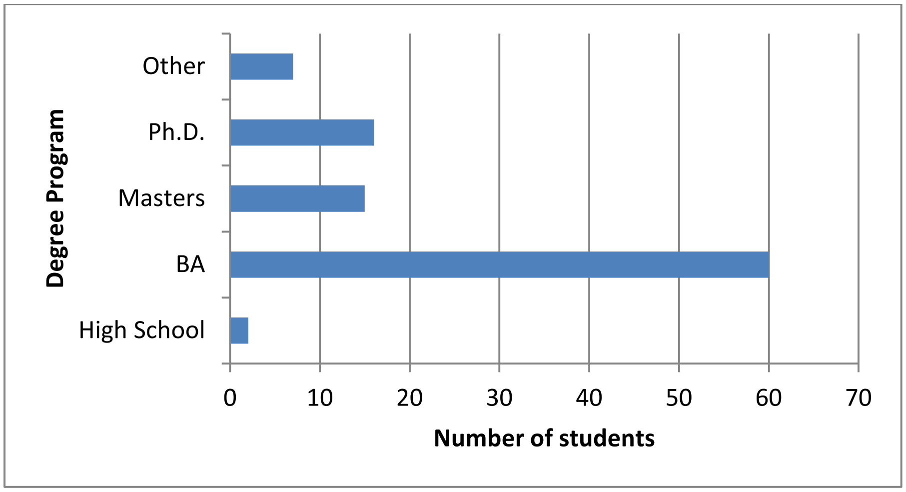


Table C-5 in Appendix C contains more detail on these data.

2.3 Interviews

Sampling. AREA PIs who had completed the Awardee Survey were contacted by e-mail to request an in-depth interview. The first wave of requests for interviews consisted of 50 AREA PIs who had been chosen to represent a diversity of years the grants were held and type of institution of higher education (primarily undergraduate, masters' colleges and universities, research universities or health professional schools), region of the country, and gender (the latter was inferred by the subject's first name). This was a convenience sample; however selections were made without viewing respondents' survey data. Replies to Westat's request for an interview were overwhelming and we politely declined some interviewees' offers. A total of 20 semi-structured interviews were conducted. See Table 2-6 for the distribution of interviewees by the first year of their final AREA grant and type of institution of higher education.

Interviews. Interviews with awardees who had already completed the web survey provided an in-depth exploration of how the interviewees' mentoring, institution-capacity building, and research were impacted by AREA funding. Please see Appendix A for a copy of the semi-structured interview instrument. Since we had sent a survey request to everyone for whom we had a working e-mail address, we assumed that persons who did not respond to the survey either were refusing to participate, or that we did not have an accurate e-mail address for them on record. The interviews averaged thirty minutes in length and received IRB and OMB approval under the same submission as the rest of the data collection instruments (see section 2.2.2 for clearance and approval dates).

The interview guide included several areas such as: student involvement and mentorship of students, student outcomes, the PI's research and career, research environment, sustainability (i.e., positive changes that were sustained after the grant period) and suggestions for improving the AREA program. PIs who received awards before 2004 were asked about the change in environment from when they received the award until now regarding: student participation in faculty research, the importance of research funding and productivity versus the importance of teaching and service obligations and the availability of resources for conducting research.

Table 2-6. Interviewee's most recent active grant and type of school

FY first year of final grant	Type of Institution				
	Primarily Undergraduate	Masters Colleges and Universities	Research Universities	Health Professional Schools	TOTAL
1988		1	1		2
1990	1				1
1999	1				1
2001	2				2
2002		1			1
2005		2	1		3
2006			1		1
2007			1		1
2008			2	1	3
2009				1	1
2010	1	1	1		3
2014[5]	2				2
TOTAL	7	5	7	2	20

[5] At the time of the interviews two recipients of earlier AREA grants had just learned that they had been awarded an R15 for 2014.

3. Evaluation Results Part I: Is Meritorious Research Funded?

This chapter presents evidence for the merit of R15 research. We discuss:

- The competitiveness of the AREA program,
- The productivity of R15 grants, and
- The sustainability of lines of research begun with the R15.

For the purpose of this evaluation, we sought to determine the worthiness of the research supported by AREA grants from 1985 to 2010. We used three different approaches to understand the merit of the research conducted. First, we examined the competitiveness of the grant program. Since eligibility for the program excludes institutions of higher education with high levels of research activity, AREA applications compete only among other applications from principal investigators in similarly resource-limited circumstances. Since the pool of eligible non-awardees for R15s is a small subset of the pool of all who apply for NIH extramural grants, we found that other ways of evaluating merit were warranted. Hence, another approach was to describe the productivity—in terms of original, peer-reviewed research paper output—of awarded projects in order to assess the extent to which they advance scientific work. Third, we explored sustainability of the lines of research funded by the Program by examining the extent to which AREA PIs received subsequent funding.

To address the question of whether or not AREA PIs research performance is high quality, we made use of four sources of data: administrative, bibliometric, survey, and interview data. The competitiveness of the AREA grant program was examined using publicly-available administrative data from NIH RePORTER. Bibliometric data were prepared and analyzed in order to assess AREA PIs' research productivity and compare it with the research productivity of PIs who had received a NIH R01 award, and who had applied for and never received an R15. Finally, we examined research performance by assessing the extent to which the lines of research begun by AREA PIs during their grant period received subsequent funding. The sustainability of PIs' lines of research was evaluated using self-report survey data and interview data.

Findings:

- AREA grants are very competitive. The numbers of applications to the AREA program has continued to increase since the program began, and at present, an applicant to the R15 mechanism is less likely to receive a new award (Type 1), or a competitive renewal of an award (Type 2) than is an applicant to the R01 grant mechanism.
- AREA grants produce high-quality research papers. Since 1998, per dollar of funding, they may be judged equivalent to the research performance of R01 grants. While AREA PIs produce fewer papers per grant than PIs funded by R01s, the cost to NIH of each R15-funded paper in the AREA program is 57 percent of the cost of each R01-funded paper. When we calculate the cost per citation for papers acknowledged to be funded by either grant program beginning 1998 through 2010, we find that costs are roughly similar. That is, per dollar of funding, papers acknowledged to have been funded by R15s or R01s are cited at similar rates that are not significantly different.

- AREA PIs report they are able to sustain the research begun with the R15 mechanism. PIs reported success with R15 competitive continuations (Type 2s), other external grants from federal or government sources, private foundations, or sources internal to their institutions of higher education.

3.1 Are AREA Grants Competitive?

3.1.1 AREA Program Size and Scope (NIH RePORTER, QVR)

To examine the competitiveness of AREA grants, first we discuss the size of the AREA program and the percentages of awards offered across 23 NIH Institutes and Centers (IC) in order to establish the magnitude of the program and its development over time. We found that the number of R15 awards made by NIH have remained roughly constant since the early 2000s, with an uptick in 2014, the most recent year examined for this evaluation.

From the time the AREA program was established in 1985 until the end of 2014—the last year for which full data were available at the time of data analysis—4,850 R15s had been awarded, with 4,433 new awards (Type 1) and 417 competitive renewals (Type 2). Over time, the number of grants awarded by the program rose, peaking in the late 1990s-early 2000s, and after which it averaged around 200 grants awarded per year (Figure 3-1). Across the entire span of the program, from 1985 to 2014,[1] an average of 169 AREA grants were awarded every year across 23 Institutes and Centers (ICs), with three Institutes—the National Institute of General Medical Sciences (1,344 awards), the National Institute of Allergy and Infectious Diseases (528 awards), and the National Cancer Institute (461 awards) combined accounting for nearly 48 percent of the total. The number of AREA awards was the highest in the most recent fiscal year examined for this evaluation, 2014, during which 232 grants were awarded.

Figure 3-1. Number of AREA grants by fiscal year

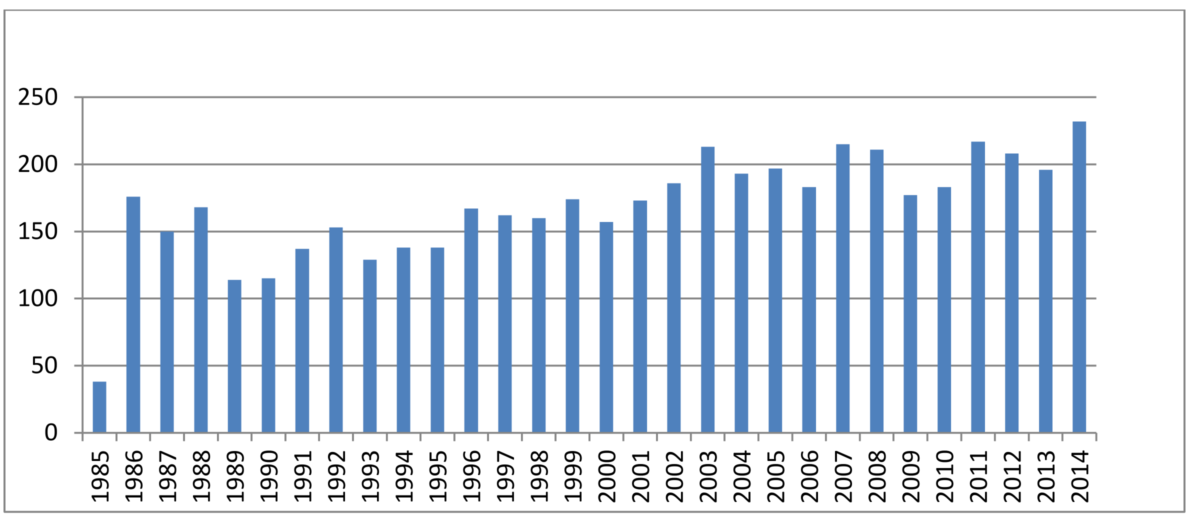


Table C-6 in Appendix C contains more detail on these data.

[1] These calculations and tables do not include any R15 awards made through the American Recovery and Reinvestment Act of 2009.

Figure 3-2 shows that the number of Type 2 AREA awards also increased since the establishment of the Type 2 R15 in 1998 until about 2005. In the first several years in which R15 renewal grants were offered—from 1998 to 2001—there were few applications and awards granted to previous recipients looking to continue research, perhaps because the availability of Type 2 R15s was not yet widely known among the community of eligible researchers. Subsequently, the number of Type 2 awards increased, peaking in 2005 with a total of 39 grants. Over the two decades since this type of grant has been offered, an average of 25 type 2 R15 grants have been awarded each year. Over the past 5 years, from 2010 to 2014, an average of 28 Type 2 grants were awarded each year.

Figure 3-2. Number of Type 2 AREA grants by fiscal year

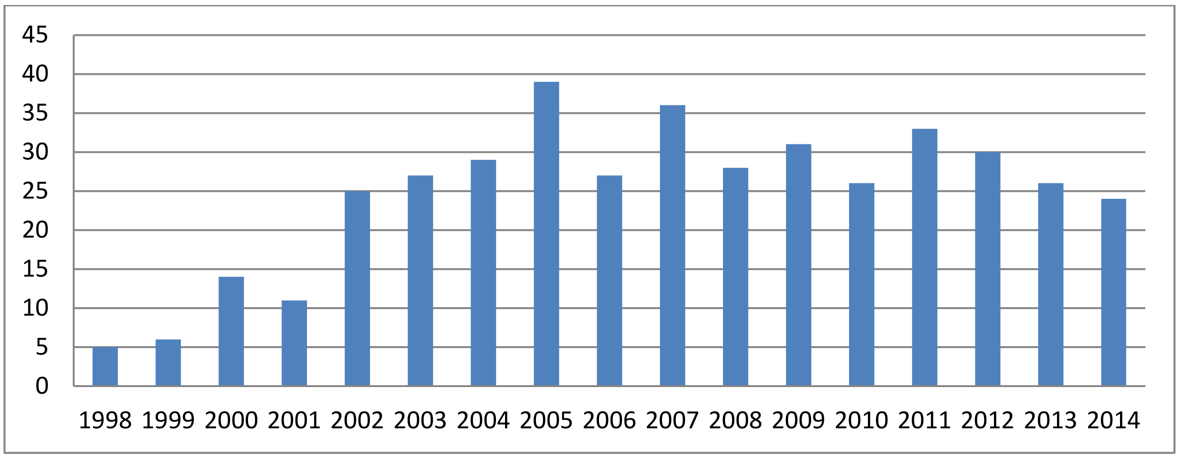


Table C-7 in Appendix C contains more detail on these data.

3.1.2 Success Rates[2] (NIH RePorter, QVR)

Having established the size of the program, we discuss its competitiveness. While the numbers of R15 awards have not increased markedly over the history of the program, the number of applications to the program has, causing success rates to plummet. Although the numbers of R15 awards given yearly has remained steady since the late 1990s to early 2000s, applications to the program have increased dramatically. From 2005 to 2014, the number of applications for AREA awards has increased nearly 2.5 times, from 662 reviewed applications in 2005 to a record high of 1,633 reviewed applications in 2014. With the larger pool of applications, the R15 has become much more competitive.

We compared the competitiveness of the R15 (via success rates) to the R01 mechanism in Figure 3-3. In the last decade, the AREA award's success rate, defined as the percentage of reviewed grant applications that receive funding,[3] has decreased by more than 50 percent, from 30 percent in 2005 to 14 percent in 2014. Since 2005, the success rate for R15s has declined faster than the success rate of the R01. R01 success rate decreased from 24 percent in 2005 to 18 percent in 2014, a decrease of 25 percent. Since 2010, R15 applications have become less likely to be funded than R01 application. The AREA program is as competitive as the R01 program, if not more competitive. However, this finding

[2] Data for the discussion of success rates come from http://report.nih.gov/success_rates/index.aspx accessed November 2015.

[3] A description of how success rate is calculated by NIH may be found here: http://report.nih.gov/UploadDocs/NIH%20Success%20Rate%20Definition%202012.pdf.

must be interpreted in light of the fact that the AREA program is restricted to researchers at institutions of higher education that are not at the highest level of research intensity. In contrast, the pool researchers eligible for R01s includes those at institutions with any level of research intensity.

Figure 3-3. AREA grant success rate, 2005-2014

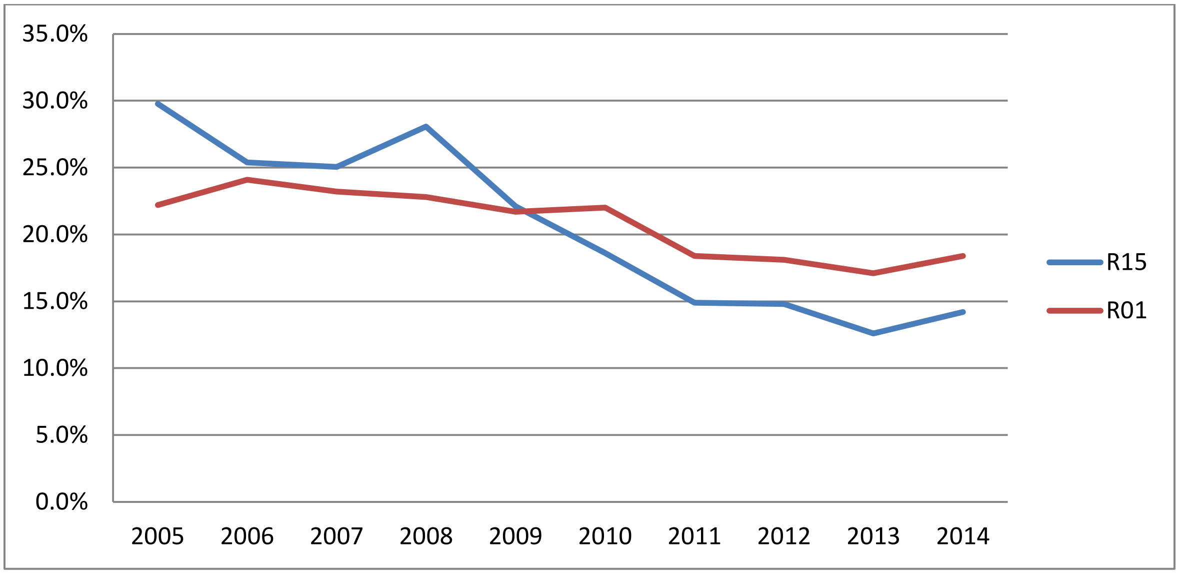


Table C-8 in Appendix C contains more detail on these data.

Figure 3-4 shows that the success rate of competitive renewal (Type 2) applications has ranged from 61 percent to 13 percent. From 2002 to 2005, Type 2 success rates stayed between 52 and 62 percent (not shown). Rates of success have since declined to below 30 percent in more recent years, making the Type 2 AREA award more comparable to the Type 2 R01 grant success rate. Type 2 R01s' success rate has been in the range of 30-40 percent since 2005. In recent years, R15 PIs' chances of being able to sustain their line of research using NIH funds is roughly comparable—if not slightly slimmer—than that of PIs funded by R01s.

3.2 How Productive are R15 Projects?

3.2.1 R15 Scholarly Outputs (Bibliometrics)

The first step in examining the research performance of the AREA program is to describe bibliometric features of the peer-reviewed research papers that acknowledge funding through the R15 grant mechanism. For the purpose of evaluation we examine the productivity of projects up to, and including, 2010. Since we gathered bibliometric data in December 2014, projects which began in 2011 and later had 1 year or less post-completion to publish findings. Therefore, we chose to limit our analysis to projects up to and including a start date of 2010.

Figure 3-4. Type 2 AREA grant success rate, 2002-2014

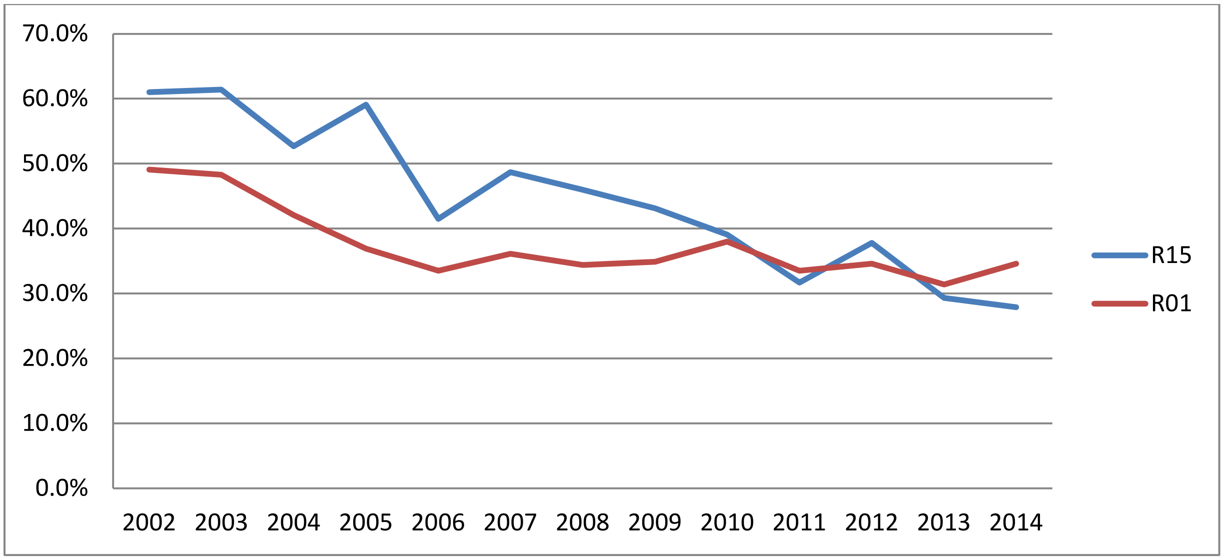


Table C-9 in Appendix C contains more detail on these data.

Papers per project. Of the 3903 unique[4] projects funded 1985-2010, 7,380 original, peer-reviewed papers located in the *Web of Science* database acknowledged NIH R15 funding, for a mean of 1.9 papers per funded project. The median number of papers per project is 1 paper. Forty-two (42) percent of projects produced no papers, with another 42 percent of projects produced 1-3 papers. Figure 3-5 shows the number of R15 projects that yielded 0-13+ papers.

Figure 3-5. Number of R15 projects, 1985-2010, that produced 0-13+ papers

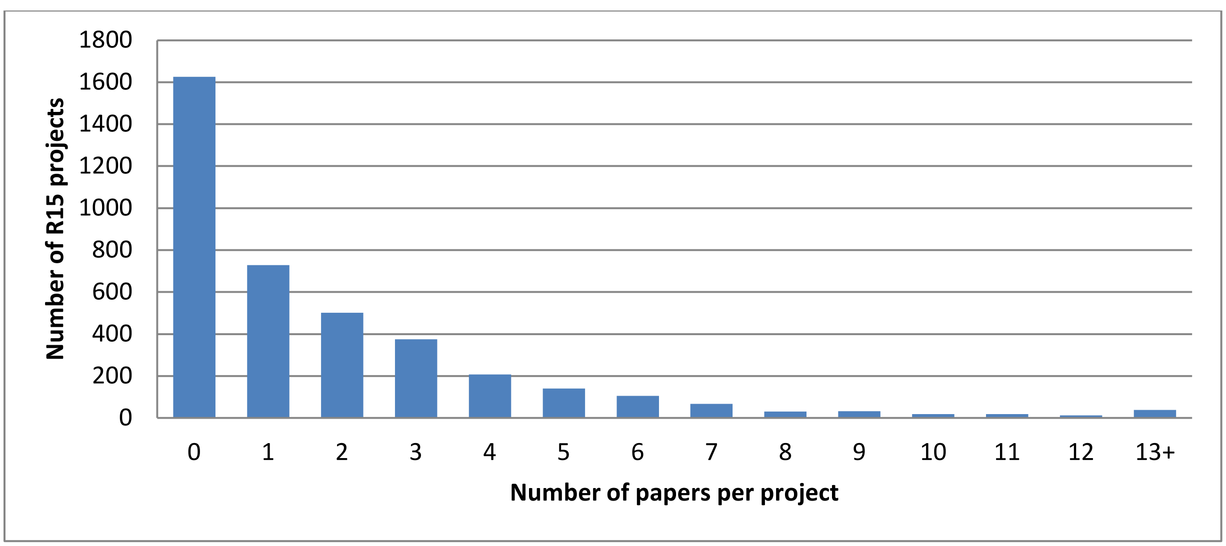


Table C-10 in Appendix C contains more detail on these data.

[4] For gathering bibliometric data, competitive renewals (Type 2 grants) could not be distinguished from the original (Type 1) grant.

Cost per paper. From the beginning of the AREA program in 1985 through 2010, NIH spent slightly more than $344 million in funding the total costs of R15s. When the total costs of R15 projects 1985-2010 are divided by the number of R15-acknowledged papers produced within the same time frame, the average cost of each R15 paper published is $88,205.

Citations per paper. The range of numbers of citations through the end of 2013 was 0 to 782, with a median citation count of 10 and an average citation count of 19.5. This means that, on average, each R15-acknowledged paper was cited nearly 20 times as of the final day of 2013.

Journal Impact Factors (JIFs) of journals with AREA papers. Journal Impact Factor is a measure of the relative importance of the journal in which articles are published. It is based on the average citations for each paper in the journal's preceding 2 years.[5] For example, a Journal Impact Factor in 2013 would be based on the average number of citations of articles published in that journal in 2011 and 2012.

The range of Journal Impact Factors of the journals in which R15-acknowledged papers are published is 0.1 to 45.6. The median impact factor of the journals publishing R15-acknowledged papers is 2.9 and the average impact factor is 3.4. These impact factors are based on the exact or closest year available to that of the paper's publication year as measured by Thomson-Reuters.

Change in productivity over time. In general, the average productivity of R15 projects has been rising since the program began. Figure 3-6 shows that the average papers per project has risen 1 paper per project over the period from 1985 to 2008. Beginning in 2009, projects appear to produce fewer papers, but this is the result of truncation: as of late 2014, PIs had not yet disseminated all their results. Projects 1985-1997 produced a mean of 1.3 papers, whereas projects 1998-2010 produced a mean of 2.3 papers. This difference is statistically significant with a p-value less than 0.00005.

Figure 3-6. Mean papers per project

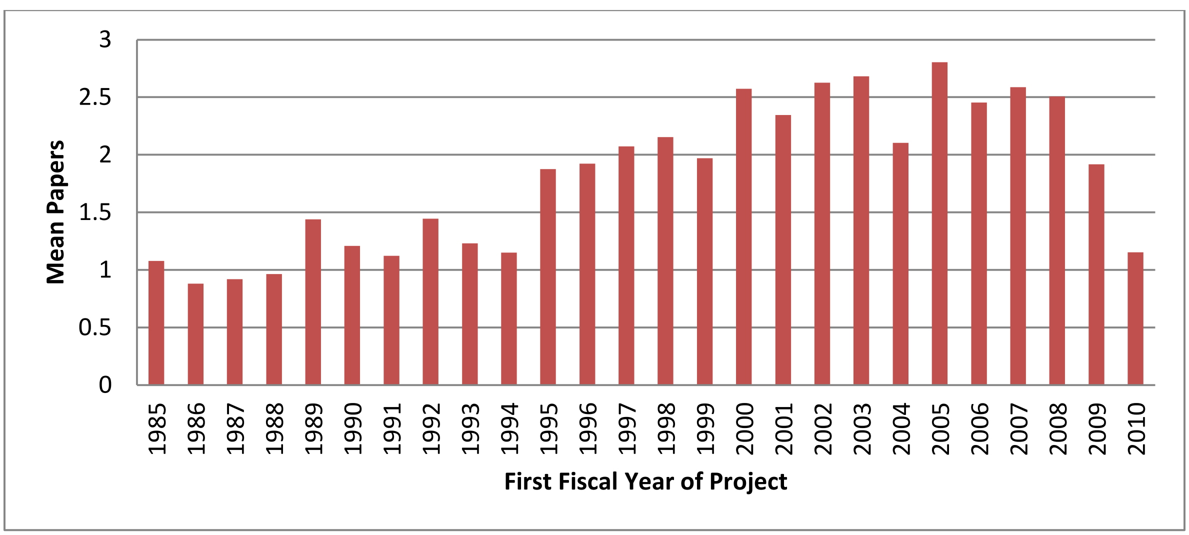


Table C-11 in Appendix C contains more detail on these data.

[5] A full description of how Journal Impact Factor is calculated is available on the Thomson-Reuters website at http://thomsonreuters.com/products_services/science/free/essays/impact_factor/.

3.2.2 R15 Scholarly Outputs Compared to Outputs of the "Gold Standard" of NIH Mechanisms—the R01 (Bibliometrics)

Rationale for comparison. The NIH R01 grant mechanism is "the original and historically oldest grant mechanism used by NIH."[6] Colloquially, biomedical and behavioral scientists are considered to have "made it" as full-fledged independent researchers only after they receive their first R01. Since the R01 has this reputation as promoting and rewarding the highest caliber research, we sought to assess the research performance of AREA awards in comparison to them.

3.2.2.1 Are the R15s comparable to the R01 sample?

Before comparing the grants on research productivity operationalized as numbers of peer-reviewed publications and numbers of citations, we examined how comparable the sample of R01s was to the universe of R15s by subject matter and funding levels. We assessed how comparable the R01 sample was to the R15s using two steps that focused on—subject matter comparability and funding trends across time for both programs—respectively. The extent to which subject matter is similar among the R15s and R01s, the more likely that the differences and similarities in research productivity across the two mechanisms is real, and not an artifact of differences in the disciplines of the R15 and R01 projects. Likewise, the extent to which funding levels adjusted for inflation are constant across R15s and R01s, the more likely findings about research productivity are real and not due to fluctuating funding levels.

Subject matter comparability. The first step in comparing the research productivity of R15s to R01s was to test whether our sample of R01s was comparable to the universe of R15s. Since biomedical and behavioral science sub-disciplines vary in rates of research paper production, time to publication, and the costs associated with projects, we sought to ensure that the sub-disciplines represented by the sample of R01s was comparable to those of the R15s. We relied upon the Journal Subject Codes[7] applied to the peer-reviewed publications of the sampled R01s and universe of R15 to identify the subject matter of each article. Every publication listed in *Web of Science* has one or more Journal Subject Codes identifying the area and content type of the publication. In comparing our R15 universe of publications against the publications from our sample of R01 projects, we found 175 unique Journal Subject Codes, many of which appear in similar proportions across the two research programs. Figure 3-7 shows the percentage of journal articles acknowledging R15 and R01 funds by Journal Subject Code.

Note that the number of Journal Subject Codes reported for R01 publications is higher than for R15 publications. This is because there were many more R01 publications in our sample of R01 projects than in the R15 comparison universe.

The twelve most common Journal Subject Codes of R15 projects account for 51 percent of all R15 publications' Journal Subject Codes, and those same codes account for 47 percent of R01 publications' Journal Subject Codes. In addition, R15 and R01 publications have the same top two Journal Subject Codes: "Biochemistry & Molecular Biology" and "Neurosciences." The only Journal Subject Code that is common among R15 publications but uncommon among R01 publications is Organic Chemistry. While the proportions of individual Journal Subject Codes distributed among R15 and R01 publications are somewhat different, we believe that the sub-disciplines are similar enough for comparing research outputs.

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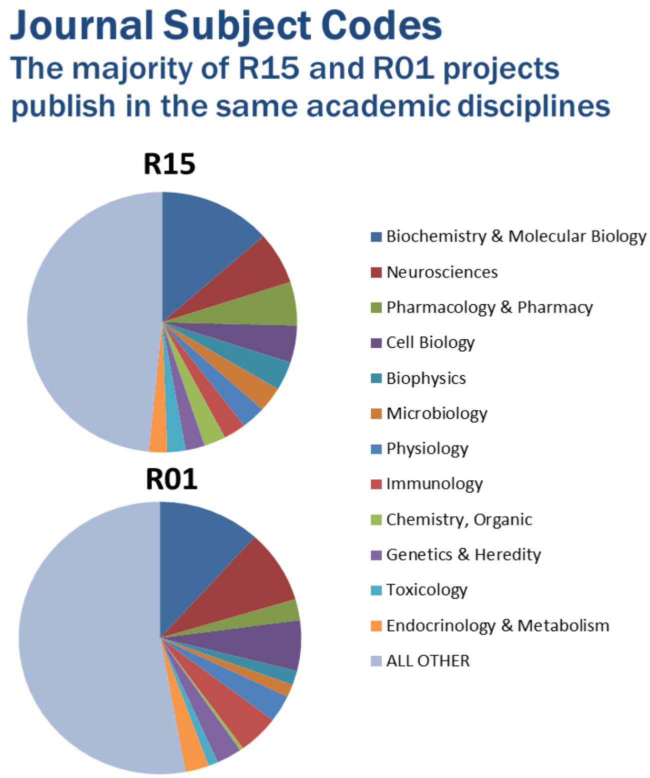
[6] http://grants.nih.gov/grants/funding/r01.htm, accessed 12/28/2015

[7] Journal Subject Codes were identified through *Web of Science.*

Figure 3-7. Frequency and percentage of the twelve most frequent R15 Journal Subject Codes

JOURNAL SUBJECT CODE	R15	R01
Biochemistry & Molecular Biology	1714 (14%)	5588 (12%)
Neurosciences	822 (7%)	4169 (9%)
Pharmacology & Pharmacy	681 (5%)	1209 (3%)
Cell Biology	584 (5%)	2863 (6%)
Biophysics	452 (4%)	797 (2%)
Microbiology	394 (3%)	737 (2%)
Physiology	367 (3%)	1517 (3%)
Immunology	343 (3%)	2243 (5%)
Chemistry, Organic	326 (3%)	215 (0.4%)
Genetics & Heredity	291 (2%)	1392 (3%)
Toxicology	285 (2%)	542 (1%)
Endocrinology & Metabolism	276 (2%)	1299 (3%)



Funding trends comparison. As a second step to assess the comparability of the research performance of R15 and R01 grants, we examined the trends in funding of the R15 and R01 programs after adjusting for inflation using the Biomedical Research and Development Price Index (BRDPI). The R01 activity code supports moderate and large scale projects. Many R01s are million-dollar awards over the cost of the entire project period. In contrast, the direct costs cap on R15s has ranged from $50,000 in 1985 to $300,000 in 2010. R15 projects are smaller in scope.

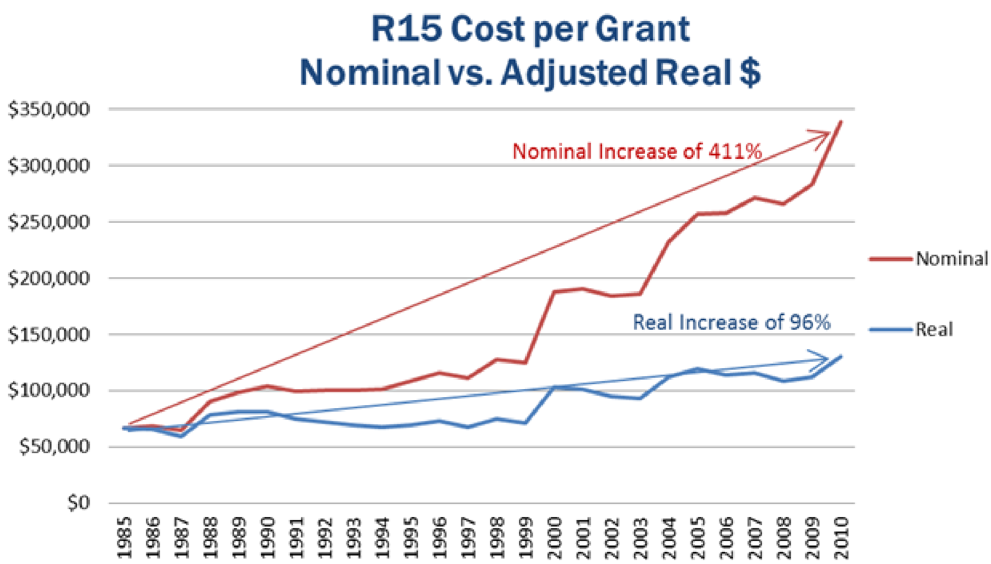
During the period of 1985-2010, the Direct Costs and Eligibility Caps of AREA R15 grants have increased several times. Each increase has resulted in a direct increase in total project costs per grant in terms of real dollars. Across the entire span of 1985-2010, the average real total project cost of an R15 nearly doubled. During the same period, the average total project cost for a grant in the R01 sample fell by nearly 35 percent. Changes in funding per grant[8] from 1985-2010 is shown in Figure 3-8. The arrows in Figure 3-8 indicate the change in R15 costs over the 25 years of the program: nominal costs increased 411 percent and real costs increased 96 percent over the period. The increased productivity of R15 projects after 1998 may be related to the increase in real funding for R15s.

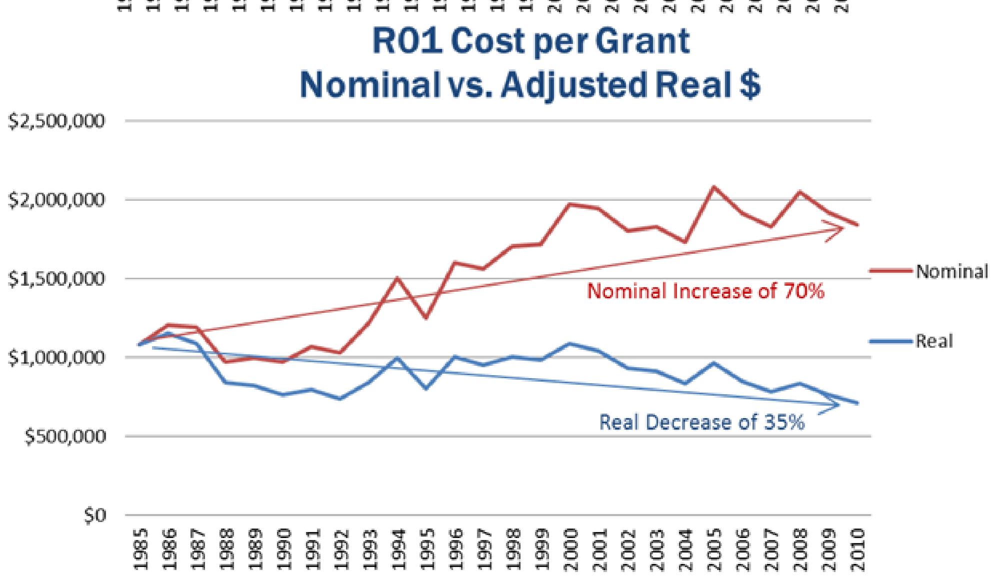
After assessing the extent to which the sample of R01s are comparable to all R15s 1985-2010, we find that they are similar enough to serve as reasonable comparisons. The R01 sample matches the R15s in sub-disciplines and scientific topics. We do find an increase in real dollars of funding among R15s across the 25 years investigated for this study; however, since we do not find a clear funding trend among our

[8] Note that each R01 and R15 grant is represented only one time. All years of funding for a single grant were aggregated and counted towards the total for the first fiscal year the project was active.

sample of R01s, we do not expect to see an effect of funding levels on R01 research productivity over time. That is, the fluctuation of funding levels for R01s is likely related to the true costs necessary to carry out the projects, rather than the result of an artificially-imposed funding cap.

Figure 3-8 Average total project costs per grant adjusted with BRDPI (Biomedical Research and Development Price Index) for inflation





3.2.2.2 How likely are R15 and R01 projects to produce peer-reviewed publications?

A critical goal of research is to publish findings. Not all projects manage to reach publication, and it is important to know with what likelihood a project will successfully publish. A comparison of the likelihood of an R15 or R01 project publishing at least one paper is shown in Table 3-1 below.

Table 3-1. Percentage of projects with at least one paper

Research Grant Type	1985-2010	1985-1997	1998-2010	1998-2003	2004-2009	2010
R15	**58%**	**51%**	**65%**	68%	66%	34%
R01	**88%*** **	**88%*** **	**88%*** **	91%***	88%***	62%***

Pearson's chi-squared test: ***p<.001

R01 projects are considerably more likely to publish than R15 projects; 88 percent of R01 projects acknowledged at least one peer-reviewed paper, whereas 58 percent of R15 projects acknowledged at least one peer-reviewed paper in the period 1985-2010.

Table 3-2. Percentage of projects with at least two papers

Research Grant Type	1985-2010	1985-1997	1998-2010	1998-2003	2004-2009	2010
R15	40%	31%	47%	48%	50%	29%
R01	81%***	80%***	82%***	85%***	84%***	53%***

Pearson's chi-squared test: ***p<.001

In addition to reaching initial publication more frequently, R01 projects also publish more than one paper at considerably higher rates than R15 projects. The percentage of R15 grants with at least two papers is 40, whereas the percentage of R01 grants that produced at least two papers is 81 percent for projects that began in the 1985-2010 period.

3.2.2.3 What is the time to publication?

We examined the relative time it takes for AREA projects and R01-funded projects to publish their first peer-reviewed finding. R15 projects take an average of 34 months (2.8 years) before they publish one finding, whereas, R01 projects take 25 months (2.1 years). This 9-month difference has lessened over time. From 2004 to 2009, R15 project produced their first paper after 23 months, whereas R01 projects took 18 months, a difference of 5 months.

Table 3-3. R15 and R01 average time to first publication (in years)

Research Grant Type	1985-2010	1985-1997	1998-2010	1998-2003	2004-2009	2010
R15	2.8	3.4	2.4	3.0	1.9	0.8
(percent projects)[9]	(58%)	(51%)	(65%)	(68%)	(66%)	(34%)
R01	2.1****	2.4****	1.9****	2.4****	1.5****	0.5***
(percent projects)[8]	(88%)	(88%)	(88%)	(91%)	(88%)	(62%)
Difference	0.68	0.99	0.53	0.58	0.44	0.23
	(8 mos.)	(12 mos.)	(6 mos.)	(7 mos.)	(5 mos.)	(3 mos.)

Unpaired t-test: ***p<.001 ****p<.0001

[9] The percent of projects for which there were papers.

3.2.2.4 How do R15s and R01s compare on numbers of peer-reviewed papers and citations per project?

Papers per project. For comparing the research performance of R15 projects relative to R01 projects, our primary outcome measures are number of papers published in academic journals, and the citation counts of those papers. In Table 3-3 below, note that the average and median number of papers are significantly different in the R15 to R01 comparison.

Table 3-4. Mean (median in parenthesis) papers per project

Research Grant Type	1985-2010	1985-1997	1998-2010	1998-2003	2004-2009	2010
R15	1.9 (1)	1.3 (1)	2.3 (1)	2.4 (1)	2.4 (2)	1.2 (0)
R01	10.2**** (6)	11.1**** (6)	9.5**** (6)	10.6**** (7)	9.4**** (7)	3.9**** (2)

Unpaired t-test: ****p<.0001

From 1985 to 2010, R01 projects produce roughly 5 times the number of peer-reviewed papers as R15 projects, on average. For both classes of research project, the mean number of papers produced is considerably larger than the median, because of a large upper-tail of the distribution. That is, most R01 projects only produce 6 papers, but a smaller number of very productive projects have many papers. The number of papers per project nearly doubled for R15 projects between the pre-1997 and post-1997 periods (from 1.3 to 2.3 papers) and this difference is significant with a p-value less than 0.00005.

Citations per project. Table 3-4 shows the average numbers of peer-reviewed papers per period of time for R15s and R01s. R15-acknowledged papers produced an average of 41 citations per project[10] from 1985 through 2010. In contrast, R01-funded projects produced nearly 500 citations per project within the same time period. The average R01-funded peer-reviewed paper was cited twice as often as the average R15-funded peer-reviewed paper. Since R01 projects have an average of 5 times more papers than R15 projects, when aggregated, R01 projects are cited roughly 12 times more often than R15 projects.

Note that citations accrue over many years, and more recent papers are less likely to have large citation counts. Therefore the decline of R01 citations in more recent years is not surprising as it is likely just a result of truncation. R15 projects do not demonstrate such a sharp decline in citations per project in more recent periods due to their increased paper production rates.

Table 3-5. Mean citation counts per project

Research Grant Type	1985-2010	1985-1997	1998-2010	1998-2003	2004-2009	2010
R15	41	41	40	53	33	11
R01	499****	687****	345****	476****	259****	82****

Unpaired t-test: ****p<.0001

[10] Note that this analysis is based on citations per R15 or R01 project, rather than citations per paper. The average number of citations per R15-funded paper is 19.5. Citations per project are used here in order to facilitate the comparison to the sample of R01s.

3.2.2.5 How do R15s and R01s compare on costs per project, per paper, and per citation?

While R01 projects are more frequently cited, produce more papers and are more likely to publish at all than R15 projects, they are considerably more expensive. Comparison of the cost effectiveness of these two project types by research performance suggests that R15 project are a good value relative to R01s.

Cost per project. Table 3-5 shows that the average cost of an R15 project is only 10 percent of the average cost of an R01 project, over the entire period of 1985-2010.[10] The cost gaps have lessened as the AREA program increased their funding caps. Costs have not been adjusted for this analysis.

Table 3-6. Mean (unadjusted) costs[11] per project

Research project type	1985-2010	1985-1997	1998-2010	1998-2003	2004-2009	2010
R15	$164,909	$95,761	$223,580	$166,504	$260,777	$338,500
R01	$1,581,613 ****	$1,228,036 ****	$1,880,694 ****	$1,837,247 ****	$1,912,896 ****	$1,826,040 ****
R15/R01	10%	8%	12%	9%	14%	19%

Unpaired t-test: ****p<.0001

Cost per paper. The average cost of a paper produced by an R15 project is only 57 percent of the average cost of a paper produced by an R01 project. While R01 projects produce more papers than R15 projects on average, the total project cost is proportionally larger than the increased number of papers. Table 3-6 shows the average cost per R15 and R01 paper.

See Appendix D for breakdowns of costs per paper for per Institute or Center and per year for R15s and for R01s. Charts in Appendix D were calculated by dividing total project costs for all projects awarded in the IC during the year (or span of years) by the total number of papers acknowledging project funding as of December 2014.

Table 3-7. Mean (unadjusted) costs per paper

Research project type	1985-2010	1985-1997	1998-2010	1998-2003	2004-2009	2010
R15	$88,205	$70,986	$96,682	$69,525	$108,373	$293,616
R01	$154,398 ****	$110,447 ****	$196,103 ****	$173,999 ****	$202,676 ****	$463,503 **
R15/R01	57%	64%	49%	40%	53%	63%

Wald test, linearized standard error: **p<.01 ****p<.0001

Costs per citation. We employed the measure of "cost per citation" in order to compare how costly it is for a R15-funded project to reach scholarly significance relative to how costly it is for a R01-funded

[11] These cost data are based on Thomson-Reuters' proprietary sources derived from NIH databases. Cost includes direct, indirect, and supplemental costs made by NIH on behalf of the R15 and R01 projects.

project to reach scholarly significance. Here, we operationalize “scholarly significance” by examining the extent to which other researchers cited papers funded by the project. For this measure, costs per citation were calculated by projects granted by a single IC within a single fiscal year, so that the costs of all projects with 0 publications were included in the numerator.

We found that, for projects that began in the period 1985-2010, a R15 project citation cost 27 percent more than that of a R01-funded project. If cost per citation is the primary outcome measure in comparing the bibliometric productivity of research projects, then R01 projects historically have been roughly 27 percent more cost-effective than R15 projects over the period 1985-2010. Table 3-7 shows the average costs in 5 time periods that represent programmatic changes.

After changes were made to the AREA program in 1998, R15 projects have become more productive and have been cited more frequently. In fact, there were periods of time where R15 cost per citation was superior to R01 cost per citation, such as 1998-2003. Across the entire 1998-2010 period, which is the focus of this evaluation, cost per citation of both types of research project were within two percent of each other, and were not statistically significantly different (See Table 3-7). Note the differences among the costs per citation ratio (R15/R01) across time periods. 1985-1997 R15 citations cost 129 percent of R01 citations, but from 1998-2003, the cost for a R15 citation is only 81 percent of the cost of a R01 citation. This is a considerable reduction in cost, most likely do to the increase in papers per R15 project after 1998. After the 1998-2003 period, the cost of R15 citations once again exceeds R01s. It is likely that the longer amount of time necessary to bring about a first R15 publication in comparison to a first R01 publication is responsible for this uptick in R15 citation costs.

See Appendix D for breakdowns of costs per citation for per Institute or Center and per year for R15s and for R01s. Charts in Appendix D were calculated by dividing total project costs for all projects awarded in the IC during the year (or span of years) by the total number of citations of papers that acknowledged project funding as of December 2014.

Table 3-8. Mean (unadjusted) costs per citation

Research project type	1985-2010	1985-1997	1998-2010	1998-2003	2004-2009	2010
R15	$4,035	$2,309	$5,532	$3,144	$8,001	$30,844
R01	$3,172****	$1,788****	$5,428	$3,862**	$7,400	$22,255*
R15/R01	127%	129%	102%	81%	108%	139%

Wald test, linearized standard error: *p<.05 **p<.005 ****p<.0001

Summary of research performance comparison. While R01-funded research projects are significantly different in terms of higher citation rates and numbers of peer-reviewed papers published in comparison to R15-funded research projects, their cost is also significantly greater than that of R15-funded research projects. When the comparison of R15 to R01 projects is adjusted for cost, the difference between the programs’ performance is smaller. Since 1998, the difference is insignificant.

From 1985 through 2010 AREA-funded research projects have been a tenth of the average cost of R01 research projects. Dollar-for-dollar, an R15 project produces nearly twice as many papers as an R01 project, but an R01 project was cited 27 percent more times. R15 projects are significantly more likely to produce no papers at all, and take significantly longer to publish their first paper than R01 projects.

In more recent years, the R15 program increased its funding caps several times, and R15 projects have become both more expensive and more productive. Two metrics have improved greatly: increased likelihood of reaching publication, and lower time to first publication.

In the period after the programmatic changes (1998-2010) R15-funded projects are comparable—and sometimes superior—to R01-funded research when considering efficiency outcomes such as cost per paper and cost per citation.

3.2.3 AREA PIs' Scholarly Outputs Compared to Non-Awardees' Scholarly Outputs (Bibliometrics)

Given the limitations of a posttest only assessment, the strongest design for the AREA evaluation includes a comparison of a sample of individuals who received the R15 award to a sample who did not receive the R15. This design allows us to gauge the impact of the R15 on PI research performance. The samples used for this comparison of scholarly outputs are simple random samples of all awardees and all non-awardees. Using the awardees and non-awardees names as identifiers, we extracted data regarding research performance 5 years before the FY of the awardees' most recent AREA grant, and 5 years after the FY. Likewise, Thomson-Reuters extracted bibliometric information on research performance 5 years before the FY of the most recent unsuccessful application, and 5 years after the FY. See Chapter 2 on methods for a more detailed discussion of sampling and data extraction.

In order to evaluate the outcome of the treatment, the performance of awardees and nonawardees was compared to see if awardees were more successful with publishing peer-reviewed papers than nonawardees in the 5 years following their grant or proposed project. The hypothesis was that AREA PIs would be more productive in the 5 years following the grant than non-awardees, and that AREA PIs would be more productive 5 years after receiving the grant than in the 5 years preceding the grant.

Productivity after proposed project start date 1985-2010. Table 3-8 describes the median and mean number of papers for the samples of awardees and non-awardees 1985-2010. We found that sampled PIs who received an AREA grant in the period under review, 1985-2010, published a median of two papers[12] 5 years after the first year of the grant, versus non-awardees, who published a median of only one paper 5 years after their proposed budget start date. This difference is significant with a p-value of 0.0001.

[12] Note that the means and medians of AREA PI's peer-reviewed papers are higher than the means and medians of peer-reviewed papers attributed to AREA projects. AREA PIs publish on more than just their AREA project.

Table 3-9. Comparison of number of papers of 1985-2010 awardees and non-awardees 5 years after proposed beginning of project

PIs with start date 1985-2010	Median number papers (range)	Mean number papers (std. dev.)
Awardees (n=600)	**2** (0-48)	3.8 (5.5)
Non-Awardees (n=600)	**1** (0-45)*	3.5 (6.0)
ALL (n=1200)	2 (0-48)	3.7 (5.8)

*Median difference between awardees and non-awardees significant with p-value=0.0001.

Productivity after proposed project start date 1998-2010. Table 3-9 compares average and median numbers of papers just for awardees and non-awardees whose project start date was 1998 or later. However, the median differences among numbers of peer-reviewed papers for awardees and non-awardees in the more recent time period 1998-2010, while still higher for AREA PIs than non-awardees, is no longer significant (p-value=0.38). That is, AREA-eligible applicants and grantees seemed to have published at nearly the same rates beginning in 1998. In fact, the mean number of papers for non-awardee PIs is higher than for AREA PIs, although not significantly.

Table 3-10. Comparison of number of papers of 1998-2010 awardees and non-awardees 5 years after proposed beginning of project

Type of PI	Number	Median number papers (range)	Mean number papers (std. dev.)
Awardees	342	**3** (0-48)	4.5 (5.9)
Non-awardees	291	**2** (0-45)*	5.1 (7.6)
ALL	633	3 (0-48)	4.8 (6.8)

*Median difference between awardees and non-awardees with a p-value=0.38.

While perhaps surprising that in the more recent era of the AREA program, receipt of the grant does not seem to have a significant effect on productivity, this finding is consistent with a study of the productivity of PIs who received, and did not receive, R01 grants. This study, conducted with NIH data on R01 applications from 1980-2000, found that, at most, the receipt of an R01 leads to a 7 percent increase in productivity 5 years after submission, or 1.2 additional papers over an average of 14 papers for non-awardees. The authors of the research speculated that PIs who did not receive R01s were able to fund their research through other means—other NIH mechanisms, other federal funding sources, commercial or private sources.[13]

Indeed, as discussed in "Sustainability of AREA PIs' line of research with other sources of funding" below, it seems to be the case that for the non-awardees who responded to our survey, 94 percent of non-awardees still managed to carry out their line of research and pull together modest amounts of funding to do so (slightly more than an average of $40,000 per 5-year period) suggesting that it is quite likely that most AREA PIs in the bibliometric sample were able to do the same.

[13] Jacob, Brian, and Lars Lefgren. (2011). The impact of research grant funding on scientific productivity. *Journal of Public Economics,* 95:1168-1177.

Productivity before and after receiving grant. When we compare the productivity of the sampled AREA PIs before and after receiving their most recent R15, we find that, while the mean number of papers increases from 3.5 papers 5 years before receiving a R15 to 3.8 papers 5 years after receiving a R15, the median number of papers stays stable at 2, and all differences are not significant. When we examine the mean and median numbers of papers for AREA PIs whose most recent grant began in the period 1998-2010, we find that the median increases from 2 papers before the grant, to 3 papers after the grant, but this difference is also not significant (p-value=0.31). Table 3-10 shows differences in the average and median numbers of papers produced by AREA PIs before and after receiving the grant.

Table 3-11. Awardees' productivity 5 years before and 5 years after receipt of grant

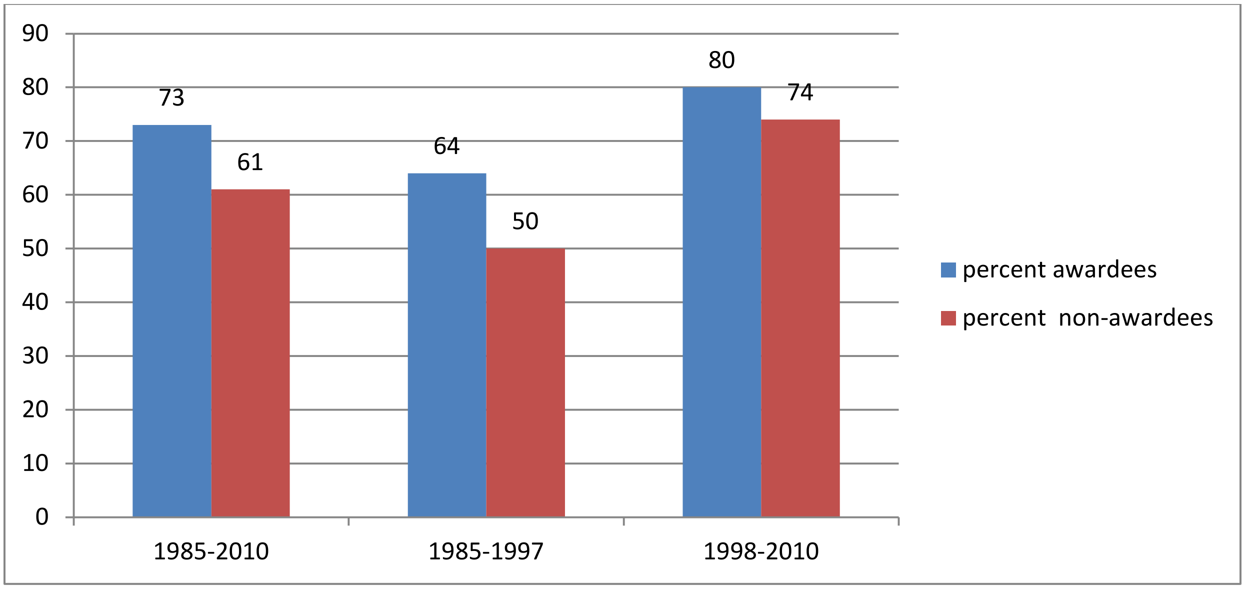
	1985-2010 (n=600)		1998-2010 (n=342)	
Sampled AREA PIs	Mean number of papers (std. dev.)	Median number of papers (range)	Mean number of papers (std. dev.)	Median number of papers (range)
5 years before grant	3.5 (5.2)	2 (0-49)	4.3 (6.0)	2 (0-48)
5 years after grant's first year	3.8 (5.5)	2 (0-48)	4.5 (5.9)	3 (0-48)

Likelihood of publication after proposed start date. Since bibliometric research on the entire population of R15 grants 1985-2010 revealed that approximately 42 percent of grants never have a peer-reviewed paper attributed to them, we sought to investigate whether the AREA grant has a positive effect on whether eligible PIs published peer-reviewed work at all. Therefore, we compared the sample of awardees to that of non-awardees to ascertain whether more awardees had at least one paper published than non-awardees in the five-year period after the proposed start of the project.

For all time periods investigated in this comparison, a significantly greater proportion of AREA awardees than non-awardees had published at least one paper 5 years after the first year of their proposed AREA projects. Out of 600 awardees who began their most recent project 1985-2010, 439 had published within the 5-year period, whereas only 367 of 600 non-awardees had published within the 5-year period after their most recent proposed start date. The p-value for the difference is less than 0.0001. Figure 3-9 show the proportions of awardees and non-awardees who published at least one paper 5 years after the proposed start date. The differences remain significant when the samples are split into two time periods—one representing PIs who applied for R15s before the aims of the program changed in 1998, and one including only PIs who applied after the program shifted its mission. [14]

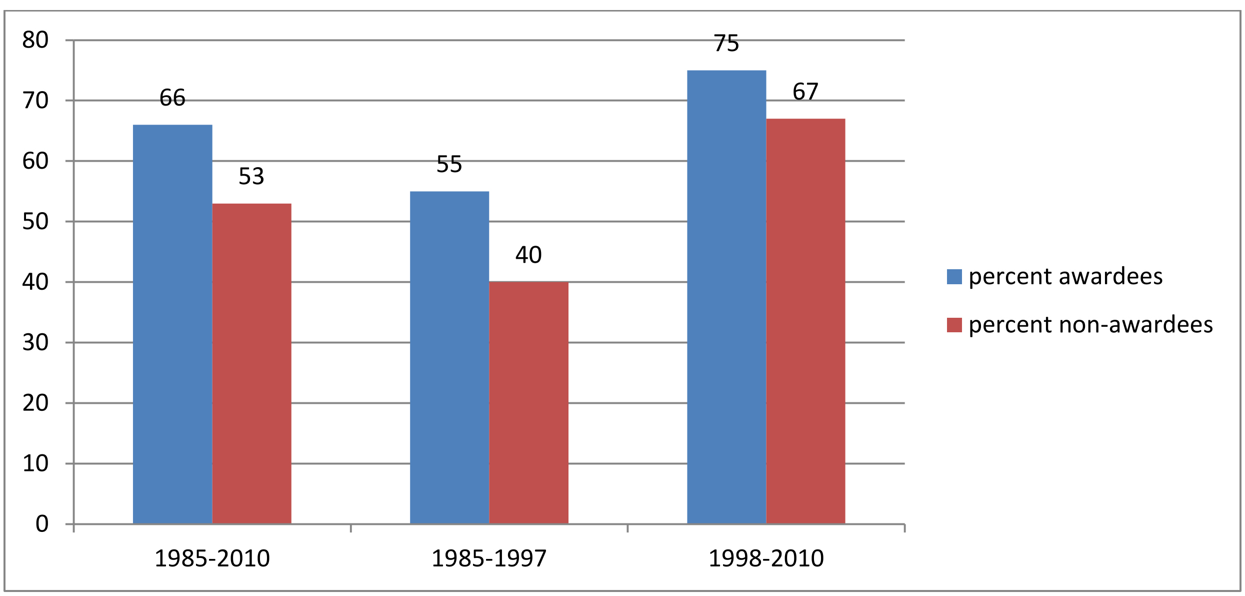
[14] The p-value for the differences among awardees and non-awardees who applied 1985-1997 is 0.0008, and the p-value for the 1998-2010 difference is 0.04.

Figure 3-9. Percent awardees and non-awardees with at least one paper 5 years after proposed start date



However, it is also important to note that awardees were also significantly more likely to publish at least one paper in the 5 years preceding their most recent AREA award than non-awardees were to publish in the 5 years before their most recent AREA application. P-values for the differences across awardees and non-awardees are as robust as those for the post-AREA comparisons made above. See Figure 3-10 below for percent differences between awardees and non-awardees who published before the proposed start date of the AREA project.

Figure 3-10. Percent awardees and non-awardees with at least one paper 5 years before proposed project start date



Therefore, we suggest that the whether or not PIs publish after receiving the AREA grant is not primarily due to the treatment effect of receiving the AREA grant. Instead, the observed difference may be due to the fact that PIs who published in the 5 years preceding their most recent award or application were more likely to receive AREA awards than those who did not publish at all in the preceding 5 years, and PIs who publish are more likely to continue to publish whether or not they receive an AREA grant.

Likelihood of unpublished PIs to publish after proposed project. To determine whether there was any impact of the grant on PIs who had not published at all in the preceding 5 years, we compared the likelihood of publishing at least once after the project start date among all awardees and non-awardees who did not have a single publication in the 5 years preceding their proposed budget start dates. We found that receiving funding seemed to be enough impetus to get PIs who had not published in the previous 5 years to publish at least once in the next 5 years. Among the group of non-awardees and AREA PIs who had not published in the 5 years before grant receipt, 47 percent of AREA PIs published at least once 5 years after receiving the grant, whereas only 37 percent of AREA PIs published once. The p-value corresponding to this difference is 0.03. See Table 3-11.

Table 3-12. Effect of AREA grant receipt on PIs who had not published before proposed AREA start

Type of PI	Number of PIs who did not publish before start date	Number who published after start date	Percent
Awardees	203	95	**47**
Non-Awardees	281	103	**37***
ALL	484	198	41

*Proportional difference between awardees and non-awardees with a p-value=0.03.

We conclude that AREA PIs were more likely to publish than non-awardees in the 5 years following the AREA start date over the 1985-2010 period of the program. However, since AREA PIs were more likely to publish before beginning their AREA grant, we cannot attribute the difference in whether or not they published to an effect of the R15. However, for those PIs who had not published before receiving the grant, the R15 did seem to spur them to publish.

3.3 Sustainability of AREA PIs' Line of Research

3.3.1 Amount and Sources of Subsequent Funding (Survey Results)

Receipt of subsequent internal and external funding. The ability to generate additional external funding to continue lines of research begun with AREA grants is the third measure we investigate to assess whether the R15 grants are funding meritorious work. Both the Awardee and Applicant Surveys inquired about sources for funding to continue lines of research represented in AREA projects. Table 3-12 shows the percentage of funding by source and Project Investigator (PI) type (awardee and non-awardee) over the 5 years since their proposed AREA projects.

Results make clear that awardees and non-awardees differed in their reliance on internal and external funding as sources for continuing research. "Internal funding" refers to money provided by the institution of higher education where the PI works. It may be competitive or not competitive. Only 9 percent of awardees' funding was internal, whereas 26 percent of non-awardees' funding was internal.

Conversely, awardees received approximately 91 percent of their funding from outside their institutions, through competitive federal, state, private, or other governmental sources, while Non-awardees received approximately 74 percent of their funding from these sources. Chi-Square testing of the proportions of awardees and non-awardees who indicated that they received funding from outside their institution revealed that Awardees were significantly more likely to report external funding ($p<0.0001$). These findings indicate that those awarded R15 grants are successful in sustaining high-quality research after their AREA award. Moreover, they are more likely than non-awardees to be pursuing work valued by organizations outside their institutions.

Table 3-13. Percentage of funding over 5 years to continue the line of research by source by PI type

Source of funding	Percentage of funding over 5 years	
	Awardee PI	Non-Awardee PI
Within institution	9%	26%
Outside institution	91%	74%
Count (n)	580	128
Missing*	62	137

*Indicates no answer to either part of the question.

Awardee Survey question 5; Applicant Survey question 21.

Table C-11 in Appendix C contains more detail on these data.

Subsequent funding levels. We also examined the amount of funding received from each source. Both the Awardee and Applicant Surveys asked respondents for the dollar amounts over the same 5-year period to pursue lines of research related to their AREA projects. As shown in Figure 3-11, average dollar amount reported by source differed notably for awardee and non-awardee PIs. The means reported by awardees were higher from both within their institutions ($22,664) and outside their institutions ($239,096). Since the mean is susceptible to extreme outliers, we also explored whether this finding holds for median values[15] (not shown). Examination of the median yielded a similar story: median awardee amounts were higher than non-awardee amounts regardless of source. Thus, though they obtain a greater percentage of their funding from external sources than non-awardee PIs, awardee PIs typically generate larger amounts of funding from both internal and external sources than non-awardee PIs do. This finding further supports the claim that awardee PIs continue to pursue high-quality research after their AREA projects.

[15] The median is the number in the middle of all those reported; thus, it is less susceptible to outliers.

Figure 3-11. Mean funding by source by PI type

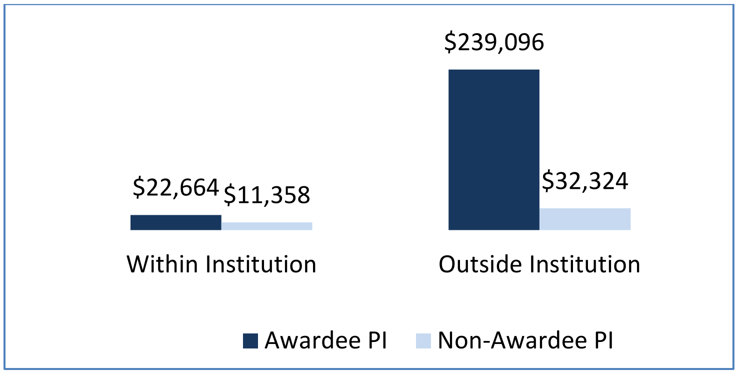
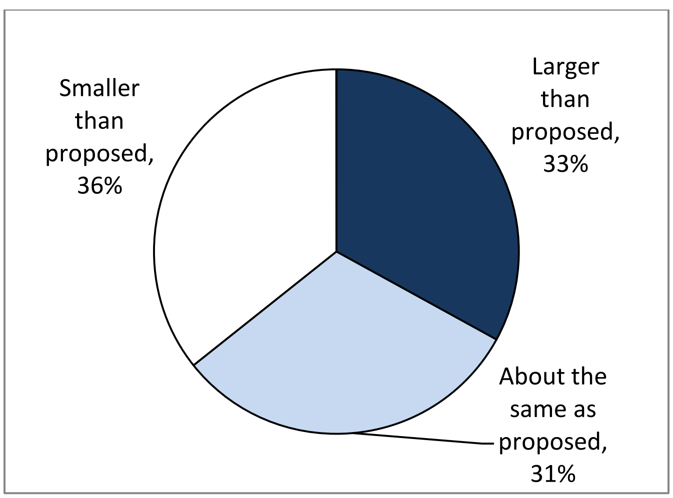


Table C-12 in Appendix C contains more detail on these data.

Subsequent research of non-awardees. Though their funding levels were not as large, nearly all non-awardee PIs (94%) indicated that they had done work related to their proposed AREA application. The Applicant Survey inquired after the scope of subsequent research relative to the proposed AREA project. Respondents could indicate whether the scope was larger, about the same, or smaller than the proposed AREA project. The frequency of responses is pictured in Figure 3-12. About 64 percent (=31% + 33%) of non-awardees indicated that their work was as large as or larger than that they had proposed in their AREA application.

Figure 3-12. Distribution of scope of non-awardee PIs' subsequent research relative to proposed AREA project



Applicant Survey question 20.
Table C-13 in Appendix C contains more detail on these data.

Subsequent funding sources. Table 3-13 lists the top ten sources of external funding which awardees and non-awardees received to pursue related lines of related research over the 5 years following their AREA project applications. The count presented in the final row of the table reflects all responses to the question, not just responses that made the top ten. With a total of 77 non-awardee PI responses, we do not attach much significance to the order of these sources. We note them solely to demonstrate the high-quality of on-going work necessary to win awards from the organizations listed.

The National Science Foundation (NSF) was the most frequently cited external source by both types of PIs. Nearly 22 percent of awardee PIs and about 23 percent of non-awardee PIs indicated that they received external funding from NSF. About 20 percent of awardee PIs and 14 percent of non-awardee PIs indicated NIH as an external source but they did not detail which program within NIH. Of the NIH programs respondents listed, Awardees most frequently listed the following: the R01 (11%), IdEA (5%), R21 (3%), and SCORE (3%). NIH Programs non-awardees most frequently listed included the R01 (9%), RUI (9%), R21 (5%), SCORE (3%), and ESPSCoR (3%). The United States Department of Agriculture (USDA) and the Department of Defense (DOD) made both top ten lists. There were awardees and non-awardees who listed amounts of external funding but did not cite the source.

Table 3-14. Top ten sources of continuing funding for awardee and non-awardee PIs (n = 262)

External Funding Source-Awardee PI	Percent (n)	External Funding Source-Non-Awardee PI	Percent (n)
NSF	22% (50)	NSF	23% (18)
NIH	21 (49)	NIH	14 (11)
NIH R01	11 (26)	NIH R01	9 (7)
USDA	7 (17)	NSF RUI	9 (7)
NIH IdEA	5 (11)	NIH INBRE	9 (7)
NSF RUI	4 (8)	DoD	7 (5)
Other or unknown	4 (8)	NIH R21	5 (4)
NIH SCORE	3 (7)	NIH SCORE	3 (2)
NIH R21	3 (6)	NSF EPSCoR	3 (2)
DoD	2 (5)	USDA	3 (2)

Awardee Survey question 6; Applicant Survey question 22.
Tables C-14 and C-15 in Appendix C contains more detail on these data.

Summary of subsequent research. Results from analysis of the Awardee and Applicant Surveys indicate that awardees are successful at continuing high-quality research after receiving an R15. They reported a greater percentage of external funding and higher amounts, on average, of funding regardless of source. Most non-awardees continue with lines of research proposed but their funding is more limited and relies more heavily on their own institutions. The scope of their work is not necessarily limited, as one-third of non-awardees indicated a larger scope than proposed.

3.3.2 Sustaining the Line of Research (Interviews)

Similar to what was suggested by the survey results, many PIs interviewed by the Westat research team reported that they were able to sustain the line of research pursued when they held the R15 grant. Faculty reported that funding begets more funding. As one professor (Masters 2002) explained:

> More people want to award funds to people who have had funding. I've gotten some other large grants. Not necessarily research grants, but they're education grants providing research support for our use. I think that wouldn't have happened if I did not have the prestige of having the [R15] award.

Another professor (PUI 1990) reported that their AREA award allowed him to "ramp up" his research to a highly productive level and sustain it at that level. A third (PUI 2014) said that he has used the R15 mechanism to sustain a research program over 15 years. A fourth PI (RU 2007) said "The AREA is one of the life-bloods of our department," that along with a few other sources of federal funding, sustains research productivity and the involvement of undergraduate students in research.

A way to collect preliminary data. Even though the mission of the AREA program is no longer to serve as preparation for a successful R01 application, a few PIs (RU 1988, Masters 2005b, Prof 2008, Prof 2009, PUI 2010), still think of it as a way to gather preliminary findings. Faculty members who have received awards over the past 20 years reported that the R15 served as a "stepping stone" to other grants such as R01s, R03s, and RC2s.

The majority of interviewees who referred to the R15 as a way to collect preliminary data received their awards while they were faculty at research universities or professional schools. They considered R15 as less competitive than the R01, and therefore, achievable for a project in the earlier stages of development. One PI (RU 2005) explained, "Especially in these days when it's very competitive—we need to get an R01—an AREA really does help. Especially [for] young investigators and those who've been around for a bit to, to get a body of preliminary data that then can be used for possibly a R01 application." A PI (Prof 2008) who recently received an R01 said, "The [AREA] research allowed me to ask additional questions, so that I could put together another application that was around the same focus but a different area. That basically allowed me to get an R01."

Institution endowment and the AREA grant. Faculty at primarily undergraduate institutions with relatively large endowments reported that the institution may help sustain their research program so that they may continue to involve undergraduates in research. They reported that their institutions may provide support for animal care, routine supplies, and laboratory space, etc. For example, a professor (PUI 2001) reported that after his R15 expired, his institution gave him an endowed chair comparable to what he would have received as an AREA recipient per year. Another faculty member (PUI 2014b) at a PUI with a large endowment said that the fact that she has an AREA award presently means that she "is not placing any burden on the department budget that supports undergraduate research." However, she added that internal research support may be available when she does not have external funding.

In contrast, some PIs who taught at Masters' Colleges and Universities or Research Universities reported that without external funding, they must curtail research. This was the case for the PI (RU 2007) quoted above as saying that the AREA was the "lifeblood" of research at his institution. Likewise, another faculty member (Masters 1999) explained that without any external funding "that was actually death as far as my research career went." This PI reported that he continued to collect results and publish "at a relatively low level" for a number of years after the period of the grant had ended, although he has not been able to gather sufficient preliminary results to pursue external funding since then.

3.4 Do Awardees' Careers Accelerate After Winning an R15? How? (Interview Results)

Unanimously, AREA PIs interviewed felt that the R15 had a considerable impact on their career. For many, the fact of getting an NIH grant enabled them to receive tenure at their institution, or, to be promoted to full professor from associate. Faculty members who were already tenured reported that it helped them maintain research productivity. Frequently, it allowed faculty with heavy teaching loads at teaching-intensive institutions to stay "in the game," in the words of one professor who received an award in 2010 at a Primarily Undergraduate Institution (PUI). Faculty members reported being able to publish more and better papers, and interact with the scientific community meaningfully.

Faculty members at Primarily Undergraduate Institutions frequently reported that they are expected to involve undergraduate students in research, and that the R15 facilitated their promotion by advancing their careers as researchers and as mentors. For example, a recently retired faculty member at a PUI who had received an R15 in 1990 reported, “In all of the sciences at [name of college], you’re expected to engaged students in collaborative research just as part of your job, and if you don’t do that, you won’t get recommended for tenure.” This professor found that receipt of the award allowed him to strike a balance among his responsibilities. At the time he received the R15, he received tenure and was named Department Chair. He said,

> Without the grant, becoming Department Chair right after tenure, my research would have been obliterating because of the chairing responsibilities. But because I had the research grant and the money for summer students, I was able to build a productive research lab in spite of the fact I had additional administrative responsibilities.

Similarly, others reported that without the R15, their research program would have never flourished in the face of other demands. For example, a Health Professional School faculty member said that he spent the first half of his career “just teaching students…taking students on rounds and helping them to develop as decent [clinicians].” He received the R15 in 2008 as a tenured professor which changed him into a “more developed clinical researcher. Before the AREA grant, I was probably just a clinician. But once I got the AREA grant, people started inviting me to give Grand Rounds and research presentations that I wouldn’t have been able to do if I hadn’t received the R15.”

For many this grant was seen as the beginning of further research, increased institutional funds as well as greater collaboration and student involvement. The prestige and recognition of having received the award was also viewed as very helpful in increasing collaboration and future funding. In addition, resources of the grant help institutions bolster their labs with better equipment and attend meetings so the investigators are able to work at a competitive level in the scientific community.

4. Evaluation Results Part II: Are Students Exposed to Research?

Ensuring student participation in high-quality research is a central objective of the AREA program. Since a large number of biomedical and behavioral scientists begin their studies at small, regional, and teaching-intensive institutions of higher education that are not major recipients of NIH support, the AREA program has the potential to contribute to the development of the nation's future biomedical and behavioral scientists by facilitating opportunities at these schools. This chapter presents the evidence for the involvement of undergraduate, graduate, and health professional students in AREA-funded research. We discuss:

- The magnitude of student involvement in AREA-funded research,
- The research tasks assumed by students,
- Student participation in the dissemination of research findings through publications, presentations, and posters,
- Students' satisfaction with their research experiences, and
- The educational and career outcomes of students who participated in AREA research.

We sought to evaluate the extent to which our theory of the AREA program holds, that is, whether the program has its intended effects. The intended outcomes of the AREA program are increased participation of students in meaningful research activities (including performing experiments, analyzing results, and disseminating findings) further education in biomedical or behavioral science, and eventual careers as scientists (see Figure 1-1, Chapter 1).

Primary data sources. To understand the involvement of students in AREA research, we made use of two types of data: (1) surveys of AREA PIs and students, and (2) AREA Final Progress Reports authored by AREA PIs.

(1) Surveys of AREA PIs and their students

- AREA PIs described the magnitude of student involvement, the research activities undertaken by students, the extent to which students disseminated research findings, and career and educational outcomes for them.
- Former students who participated in AREA-funded research reported on their research activities in AREA laboratories, their satisfaction with their research experiences, and their career and educational outcomes.

(2) AREA Final Progress Reports, written by AREA PIs at the time of their grants' completion, provided information about the magnitude of student involvement in AREA-funded research and the extent of participation in disseminating research findings through publications and presentations or posters at scientific conferences.

Comparison group. To understand whether the AREA grant facilitated the exposure of students to research above and beyond the research experiences offered as part of coursework at AREA-eligible institutions, we compared the research exposure of students of PIs who were not recipients of an R15 (non-awardees) to the research exposure of the students of AREA PIs (awardees). We conducted a survey of non-awardees as part of the quasi-experimental design of the evaluation. Similar to AREA PIs, non-awardees reported on the magnitude of student involvement, the research activities undertaken by students, the extent to which students disseminated research findings, and career and educational outcomes for students. Table 1-4 in Chapter 1 presents information on areas of inquiry and data sources in tabular form.

Limitations. Data from surveys had limitations. While First Wave survey recipients were sampled randomly from among the universe of PIs, and their e-mail addresses and contact information were carefully traced, Second Wave survey recipients were a convenience sample of PIs with e-mail addresses listed in QVR. As a consequence, PIs who responded to the Second Wave survey were more likely to be recent NIH applicants with up-to-date contact information.

Response rates for the PI surveys were low. For Wave One of the PI surveys, low response rates were likely due to passive refusals, since PI e-mail addresses and contact information were traced. However, QVR information that is out-of-date compounded low response rates due to passive refusals in the Second Wave. Lack of information to adequately trace students listed in the AREA Progress Reports and Notice of Grant Awards (NOAs) caused difficulties obtaining correct contact information for students and contributed to low response rates to the Student Survey. Finally, since we asked PIs to report on student participation in their research projects many months, years, or even decades after their projects had ended, it is likely that poor recall contributed to inaccuracies about student research participation.

Data extracted from AREA Final Progress Reports have limitations also. Final Progress Reports were unavailable for nearly three-quarters (73 percent) of the AREA projects 1998-2010—the time period for this assessment. It is not clear how the AREA projects for which reports are available may differ from those for which reports were not available, introducing unknown biases into the results. Further, AREA Final Progress Reports were unstructured and differed in form and content. Simply because an AREA Final Progress Report does not describe student participation—for example, in presenting findings at conferences—does not mean that students did not give presentations, since AREA PIs were not asked explicitly to discuss student research experiences in these reports. In addition, because AREA Final Progress Reports are written close to the end of the active period of the grant, they do not capture all information regarding subsequent disseminations of research results.

Because of these limitations, all findings should be interpreted cautiously. The following are conservative conclusions derived from the analyses discussed subsequently.

Findings:

- AREA PIs were able to provide research experiences for students.
- Baccalaureate students were overwhelmingly represented on AREA PIs' research projects in comparison to graduate, health professional, and postdoctoral students.
- AREA-funded PIs were able to involve more students in their research projects than (non-awardee) PIs who did not receive an AREA grant. The difference was statistically significant.
- The most common research experiences of students were: conducting experiments, analyzing and displaying results.

- Students are involved in disseminating research findings through authoring and co-authoring publications and presenting papers and posters at conferences.

- Students who responded to the survey were overwhelmingly satisfied with their research experiences on AREA-funded projects.

- PIs report that the majority of students who worked on their projects completed further training in the sciences beyond the degree program in which they were enrolled at the time of their research participation. This is true for AREA awardees and non-awardee PIs.

- The majority of former students who responded to the Student Survey reported that they pursued further education in science after completing the degree program in which they were enrolled at the time of AREA project participation.

- Among students who reported current employment, more than half indicated that they were employed in a biomedical or behavioral science field.

4.1 How Many Students are Participating in R15-Funded Projects?

4.1.1 Comparison of Numbers of Students Participating in AREA Awardees' and Non-Awardees' Research (Awardee Survey and Applicant Survey)

To examine the effect of an AREA award on the magnitude of the student research experiences made possible by the AREA award, the numbers of high school[1], undergraduate, graduate, and health professional students who worked in the laboratory either during the AREA PI's most recent AREA award or the three-year period following the most recent application of the non-awardee were ascertained through the Awardee Survey or the Applicant Survey respectively (see Appendix A). By comparing the numbers of AREA awardees' students to those of non-awardees' students, we are able to assess what effect receipt of the R15 may have had on the numbers of students involved in research.

Awardee respondents reported a total of 10,229 students worked in their laboratories over the course of their AREA projects, or an average of 17 students (13 median) per awardee PI. The number of students in awardee PI labs ranged from 0 to 155 students.

Non-awardees reported a total of 3,318 students.[2] The number ranged from 0 to 80 students with an average of 14 students (10 median) per PI involved in research projects in the 3 years after their projects' proposed start date. The differences in average lab sizes of awardee and non-awardee PIs were statistically significant (p=0.01).

Figure 4-1 shows the differences in numbers of students reported by awardees and non-awardees by the degree program of the student. With a mean of 12 (10 median), awardees were significantly more likely to provide research experiences to undergraduate students than non-awardees. Non-awardees involved an average of 9 undergraduate students in their research projects over the course of the 3 year period following their AREA application. Statistical analysis demonstrates that the difference in the

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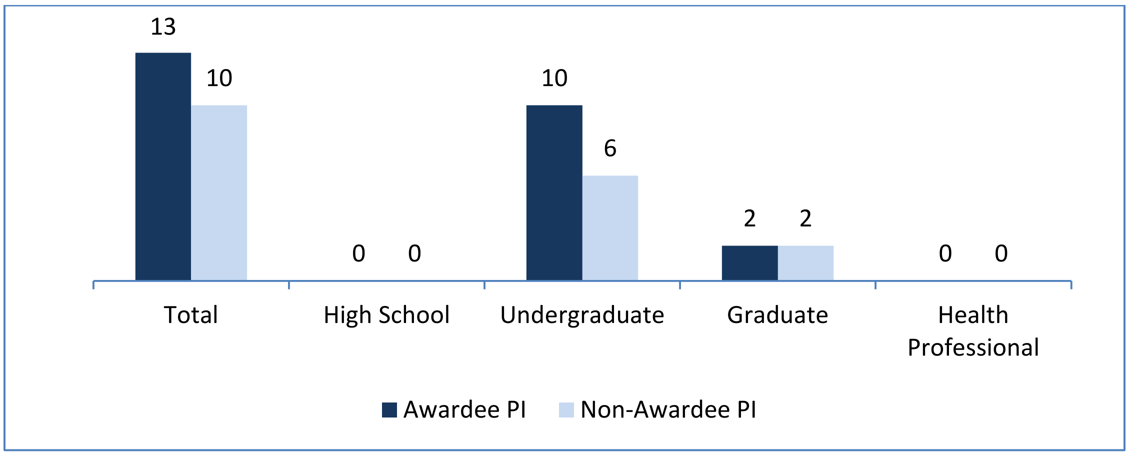
[1] Providing research experiences for high school students is not part of the AREA mandate, but since some AREA PIs did work with high school students, their numbers were included in the analysis.

[2] 642 awardees responded to the Awardee Survey while only 265 non-awardees responded to the Applicant Survey.

magnitude of undergraduate student research involvement of awardee PIs versus non-awardee PIs was significant (p<0.05).

Arguably, one of the best uses of the AREA award at teaching-intensive, regional, or primarily undergraduate institutions is to facilitate undergraduate research experiences. Of the 634 awardees that reported on undergraduate participation, nearly 94 percent reported that undergraduates were involved in their laboratories. On average, 71 percent of the students exposed to AREA research were undergraduates. The high involvement of undergraduate students is encouraging.

Figure 4-1. Median number of students involved in awardee and non-awardee research



Awardee Survey question 11; Non-awardee Survey question 10.
Table C-16 in Appendix C contains more detail on these data.

Numbers of graduate students, health professional students, and high school students are similar across awardee and non-awardee research projects. High school and health professional students were the least likely to work in labs of awardees and non-awardees, with both reporting medians of 0 and averages of about 1. Differences were not statistically significant across awardee and non-awardee reports of high school, graduate, and health professional student research involvement.

4.1.2 Numbers of Students Participating in Research as Reported in AREA Final Progress Reports

Of 2,444 AREA projects awarded from fiscal years 1998 to 2010, the NIH QVR system had Final Progress Reports available for 651 (27 percent) as of February 2014. Of the 651 Final Progress Reports submitted, 626 (96 percent) included information about student involvement in research.

Because data is available for less than a third of projects funded in the period under investigation (1998-2010), and because data were extracted from unstructured reports with few requirements pertaining to form and content, results described below must not be interpreted as representative of the success of undergraduate and graduate student training via the AREA program as a whole. Even so, the results are encouraging as they suggest that AREA PIs are able to use the mechanism to provide research experiences to students—especially undergraduates—and that some of these experiences are of high enough quality that students are able to publish or present their work in recognized venues.

Figure 4-2 illustrates the large range among in the number of students who worked in AREA-funded laboratories, with 31 awardees reporting they worked with only one student on AREA-funded research.

In contrast, one awardee reported working with 69 students (not shown). On average, PIs documented 11 students (median was 9 students) in the AREA Final Progress Reports. The largest number of PIs (54) reported that they worked with five students (mode).

Figure 4-2. Number of students per AREA project

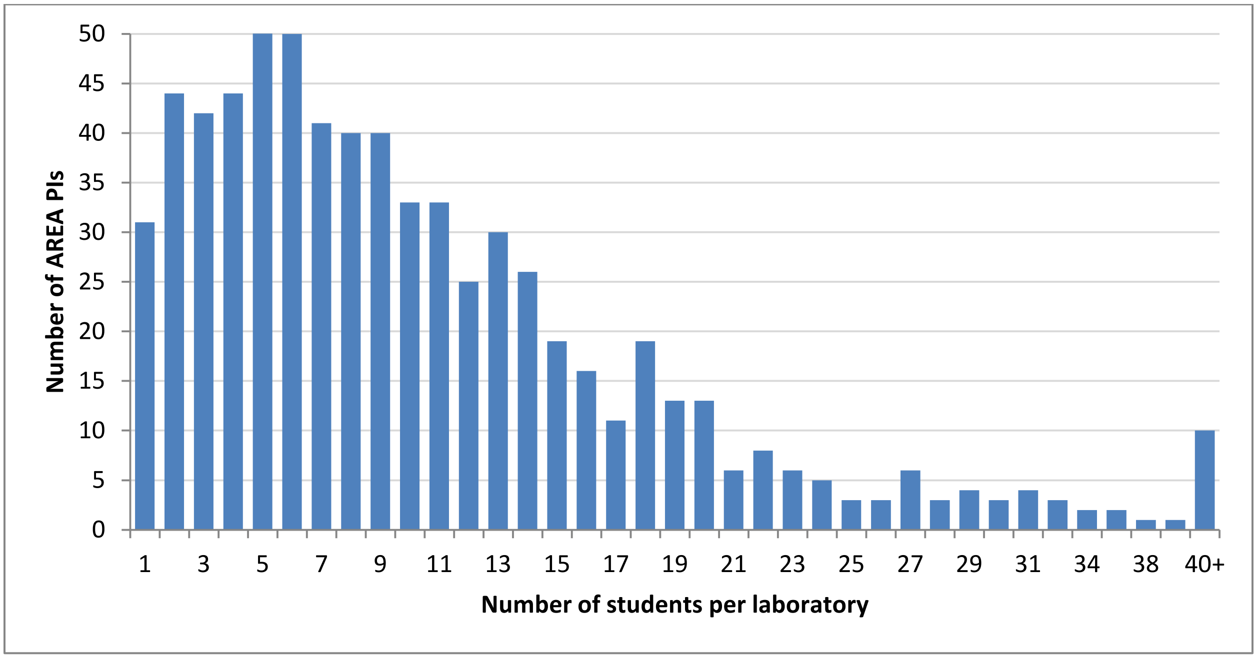


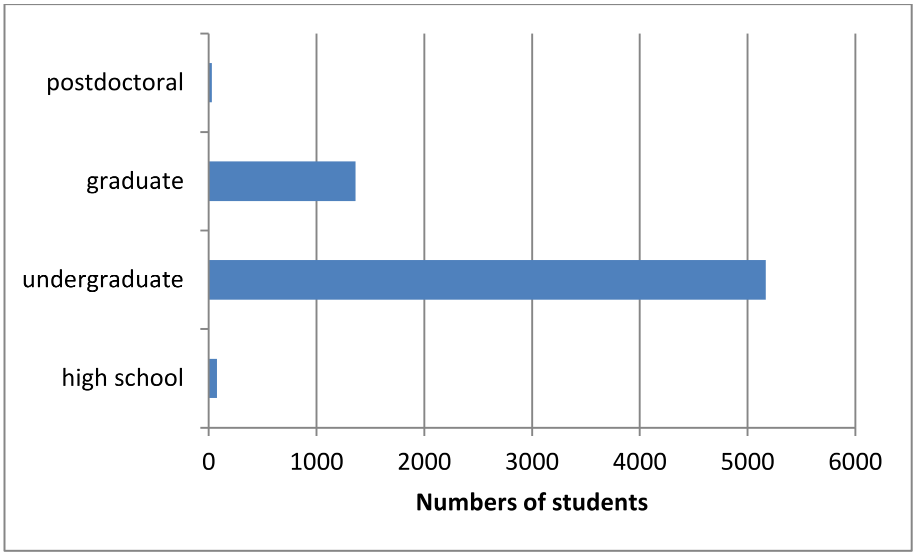
Table C-17 in Appendix C contains more detail on these data.

Student characteristics. The total number of students mentioned by PIs who submitted AREA Final Progress Reports 1998-2010 was 7,404, although the degree programs of only 6,079 (82 percent) were described in the AREA Final Progress Reports. Figure 4-3 below shows students by degree program with the largest percentage of students (almost 85 percent) at the undergraduate level followed by graduate students (22 percent). Note that some students were reported as involved in the PIs' laboratory during more than one degree program, therefore the totals exceed 100 percent. PIs did not describe the education level of students mentioned for almost 10 percent of students they reported. Figure 4-3 illustrates the totals by degree program.

Summary. Surveyed AREA PIs reported involving a median number of 13 students in research per award whereas AREA Final Progress Reports suggested that a median number of 9 students received research experience through each AREA grant. Students who participated in AREA research were overwhelmingly undergraduates. Survey responses demonstrated that 71 percent of all students involved in AREA research were undergraduates whereas the AREA Final Progress Reports suggested that at least 85 percent of students were undergraduates. Taken together, it seems reasonable to conclude that grant recipients are able to use the R15 to involved students, especially undergraduates, in research.

Receipt of the AREA grant appears to have a significant effect on the numbers of students involved in research, especially the numbers of undergraduates participating in research. Surveyed AREA awardees provided significantly more research experiences to students—especially undergraduates—than non-awardees.

Figure 4-3. Numbers of students by degree program



4.2 How Are Students Involved in AREA Projects? Is Their Involvement Relevant to Their Education or Career Goals?

4.2.1 Comparison of the Research Experiences of Students Participating in AREA Awardees' and Non-Awardees' Research (Awardee Survey and Applicant Survey)

Comparing awardee and non-awardee responses regarding the nature of students' involvement in research projects allowed us to assess the effect of the R15. The Awardee and Applicant Surveys asked PIs to report on student involvement in all phases of the research process. Response options included: contributing ideas to the research design or experiments, developing materials or resources for research, performing experiments data collection or analysis, and planning next steps. Since undergraduate and graduate students may have different research roles, we examined responses by student type. Tables 4-1 and 4-2 present the percentages of PIs that report student involvement in the various roles by PI type (awardee versus nonawardee). For undergraduate students, there are no striking differences in the percentages by PI type. Over 97 percent of awardee and non-awardee PIs reported that undergraduates performed experiments, collected data, or analyzed results. The lowest percentages of awardee and non-awardee PIs reported involved undergraduates contributing ideas to the research design or planned future research. Chi-Square testing of differences in the proportions of PIs reporting each type of contribution did not reveal any statistically significant differences.

Results for graduate students were largely similar to those of undergraduate students with exception of involvement in contributing ideas to the research design or to experiments. The largest percentages of PIs reported that their graduate students performed experiments, collected data, or analyzed data. However, there was a 7 percentage point difference in the percentages of awardee and non-awardees PIs who reported that graduate students contributed ideas to the research design or to experiments, with a greater percentage of non-awardee PIs reporting this. Chi-Square testing of differences in the proportions indicating this role for graduate student revealed that the difference is statistically significant at the 0.05 significance level ($p<0.0001$). None of the other differences in proportions were significant.

Table 4-1. Percentage of PI-reported research roles of undergraduate students by PI type

Undergraduate Student Involvement in…	Percentage of PIs Awardee	 Non-Awardee
…contributing ideas to the research design or experiments	57%	57%
…developing materials or resources for research	61	68
…performing experiments, data collection or analysis	98	98
…planning next research steps	63	59
Count (n)	594	232
Missing*	49	33

*Indicates no answer to any part of the question.

Awardee Survey question 14; Applicant Survey question 12. Respondents could choose all that apply.

Table 4-2. Percentage of PI-reported research roles of graduate and health professional students by PI type

Graduate or Health Profession Student Involvement in…	Percentage of PIs Awardee	 Non-Awardee
…contributing ideas to the research design or experiments1	76%	84%
…developing materials or resources for research	74	80
…performing experiments, data collection or analysis	91	91
…planning next research steps	76	77
Count (n)	486	202
Missing	157	63

*Indicates no answer to any part of the question.

Awardee Survey question 17; Applicant Survey question 15. Respondents could choose all that apply.

[1]Results of a Chi-squared test of the difference in proportions of awardees and non-awardee reports were statistically significant.

4.2.2 Student-Reported Research Experiences (Student Survey)

Student satisfaction. Student satisfaction with their research experiences indicates not only that the experience was positive, but that it seemed meaningful in light of their interests, education, and career goals. Table 4-3 presents the percentages of students satisfied with the opportunities offered by their involvement in AREA project research. Satisfaction rates exceeded 80 percent in six of seven domains. Since 97 percent of student reported that they were satisfied, either very or somewhat, with the opportunity offered to work closely with a senior scientist or professor, we can conclude that students felt positively about the mentorship they received. The lowest satisfaction rate was with satisfaction with opportunities to publish, as 65 percent of student indicated that they were satisfied with the opportunity to publish. However, nearly a quarter of students were indifferent to publishing, since only 12 percent reported that they were somewhat or very dissatisfied with publishing opportunities. This indifference may reflect the publishing expectations of undergraduates.

Table 4-3. Percentage of AREA student very or somewhat satisfied with AREA-research experience

Type Opportunity/Experience	Percentage of Students Very or Somewhat Satisfied
Participating in all phases of the research process	93%
Working closely with a senior scientist or professor	97
Mentoring on topic of research	93
Mentoring on academic and career development	86
Level of feedback on work	87
Presenting research findings at a conference	82
Publishing	64
Count (n)	90
Missing	0

Student Survey question 13.

Table C-18 in Appendix C contains more detail on these data.

Summary. The quality of the research experience, as judged by involvement in all phases of the research process (research design, development, data collection, analysis, planning), is not different for students participating in AREA research versus students participating in research funded through other means. PIs reported that almost all undergraduate students (98 percent) collect and analyze data, and more than half of undergraduate students contribute to research design, the development of research materials and resources, and the planning of future research inquiries. Student reports confirmed involvement in experiments and analysis. Further, they confirm that students' participation in AREA research was satisfying and meaningful.

4.3 Are Students Contributing to Projects in Terms of Co-Authorship?

4.3.1 Comparison of Numbers of Student Co-Authors of AREA PIs and Non-Awardees (Awardee Survey and Applicant Survey)

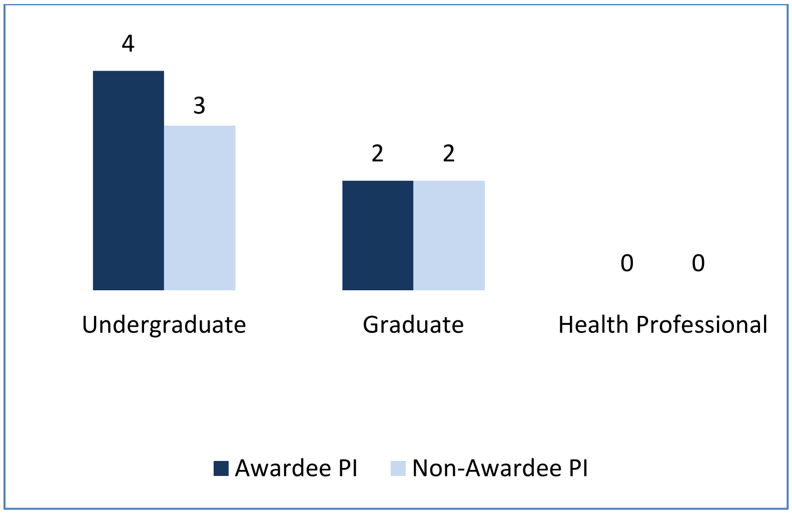
Survey data indicates that students are involved in the dissemination of findings. Awardee PIs reported a total 5,874 students who served as co-authors with an average of 9.5 student co-authors per awardee. Non-awardee PIs reported a total of 2,212 students who served as co-authors with an average of 9.1 students involved with disseminating findings per non-awardee PI. Since extreme values[3] were reported by some PIs, Figure 4-4 depicts the median numbers of students disseminating findings per PI by the degree program of the student. The median number of undergraduates who co-authored dissemination products was one student greater among awardees than non-awardees. The median numbers of graduate students per PI and health professional students per PI were the same across both groups of PIs. Differences among AREA awardee respondents and non-awardee respondents were not significant.

In order to explore whether PIs were equally likely to report students of each type involved in the dissemination of results, we also examined the proportions of PIs reporting student involvement in disseminating findings. Even though the median number of health professional involved in disseminating findings was zero for both types of PIs, the proportion of non-awardee PIs who reported having a health

[3] Some PIs use large lecture courses to carry out their research projects. Other PIs may have students (especially professional students) work in their laboratories during short rotations.

professional involved in dissemination was significantly different than the proportions of awardee PIs (p=0.005), with non-awardee PIs more likely to report this. This may reflect differences in school represented in our sample: nearly 29 percent of non-awardee PIs were affiliated with health professional schools while only 23 percent of awardee PIs were. Differences in the proportions PIs reporting undergraduate or graduate student involvement in disseminating findings were not statistically significant.

Figure 4-4. Median number of students disseminating findings per PI by level of student and PI type



Awardee Survey question 13; Applicant Survey question 11.
Table C-19 in Appendix C contains more detail on these data.

4.3.2 Student Publications, Presentations, and Posters Described in AREA Final Progress Reports

Instances of co-authorship.[4] Not all R15 grant recipients documented their students' involvement with dissemination of the results of AREA-funded research in AREA Final Progress Reports. Even so, at least 3,482 names on AREA-funded publications, conference presentations, conference posters and manuscripts for submission were identified as those from among the 6,079 students[5] named in the 651 AREA Final Progress Reports available to Westat on QVR. That is, for every 2 students identified as participating in AREA research, at least 1 instance of co-authorship were referenced. Figure 4-5 shows a breakdown of the types of dissemination products for which students received authorial credit. Any single product may be counted more than once for the purpose of this analysis if more than one student authored it. Likewise, a unique student may be counted more than once if he or she was responsible for authorship on more than one product.

[4] It is important to remember that AREA Final Progress Reports are written months after completion of the R15 grant. Since our bibliometric analysis revealed that the average time to first publication was more than three years (see "Evaluation Results Part I: Is Meritorious Research Funded?"), it might be expected that if the PIs would have reported on dissemination products several years after their grants' completion, the total counts would be significantly higher.

[5] Altogether, data abstractors estimated that 7,404 students were involved in AREA research detailed in the 651 AREA Final Progress Reports available on QVR.

Figure 4-5. Instances of student authorship on AREA-funded dissemination productions (n=3,482)

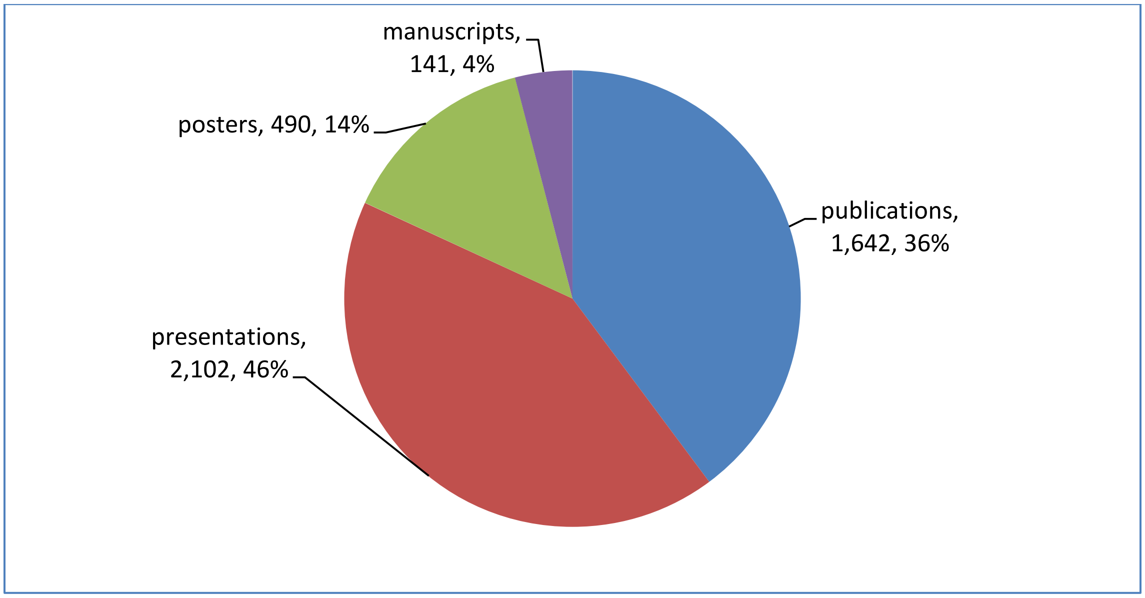


Table C-20 in Appendix C contains more detail on these data.

The student was counted as authoring a "publication" if he or she was named as an author on an article published in a scientific journal. These articles included original research articles, review articles and other publications that were not peer-reviewed. "Presentations" included talks given at regional, national or international scientific conferences. Undergraduates who gave presentations at their college or university were counted as having authored a presentation. Since the purpose of the data abstraction was to determine to what extent students were involved in AREA-funded research in a meaningful way, we included presentations given by undergraduates at their home institutions as having responded to the AREA program mandate to provide meaningful research opportunities for students. However, students who were reported as defending theses were not counted; we assumed the defense was a requirement of graduation and therefore did not represent any additional value added to the student's education. Likewise, M.A. and Ph.D. theses were not counted as publications or manuscripts. "Posters" included posters given at regional, national, or international scientific meetings. "Manuscripts" included only publications that had been submitted for review or for publication shortly before the Progress Report was written. We excluded manuscripts or articles that were described as in preparation. The pie chart above includes dissemination products where the student may have been listed as an author anywhere on the list (first author, second author, third author, etc.)

The following graph (Figure 4-6) displays the quantity of publications, presentations, posters, and manuscripts co-authored by students participating in AREA research by the degree program of the student at the time of authorship.

Figure 4-6. Instances of student authorship on AREA-funded dissemination productions by student degree program (n=3,482)

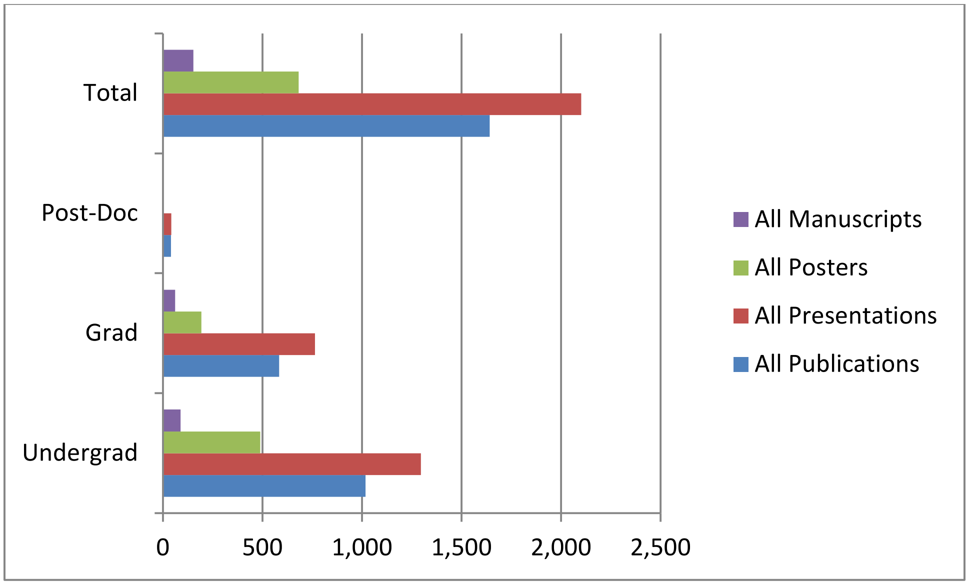


Table C-21 in Appendix C contains more detail on these data.

First-authored publications. The following pie chart, Figure 4-7, shows the numbers of students by degree program who were named as first-authors on an AREA-funded research publication at the time that the AREA Final Progress Report was submitted. The graph shows that there were more undergraduate than graduate or postdoctoral first-authors among students named by AREA PIs. Note that some students were responsible for more than one first-authored publication. 163 unique undergraduate students produced 190 papers representing 4 percent of the (named) undergraduates (n=4,339) who participated in AREA research, whereas 12 percent of unique graduate students (n=141/1,130) and 43 percent of unique postdoctoral students (n=13/30) were noted as having served as first authors on papers. In total 5 percent of all students were identified as first-authoring publications.

Figure 4-7. Number of first-authored publications by students' degree program (n=451)

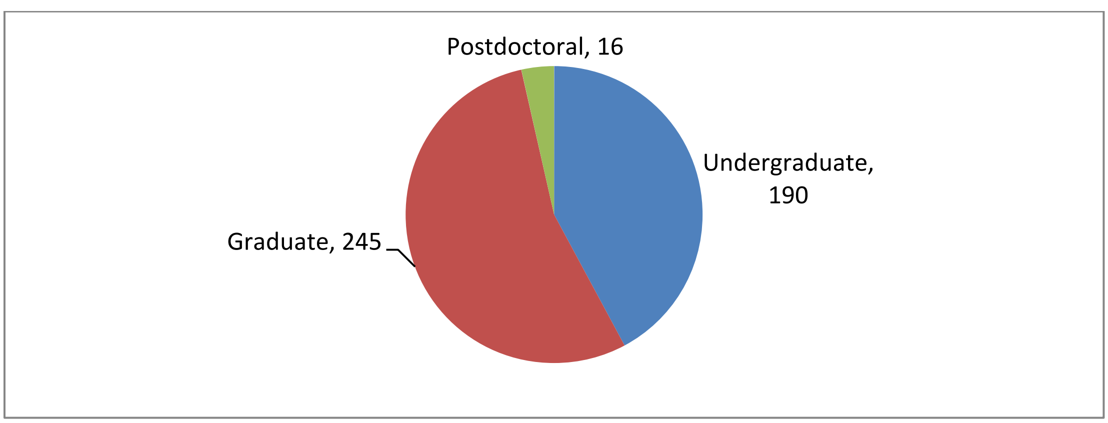


Table C-21 in Appendix C contains more detail on these data.

First-authored presentations. Undergraduate students were much more likely to first-author conference presentations than papers (Figure 4-8). 55 percent of the presentations reported in the AREA Final Progress Reports were given by undergraduates as first authors, 43 percent were graduate students and 1 percent were presented by postdoctoral students.

Figure 4-8. Number of first-authored presentations by students' degree program (n=905)

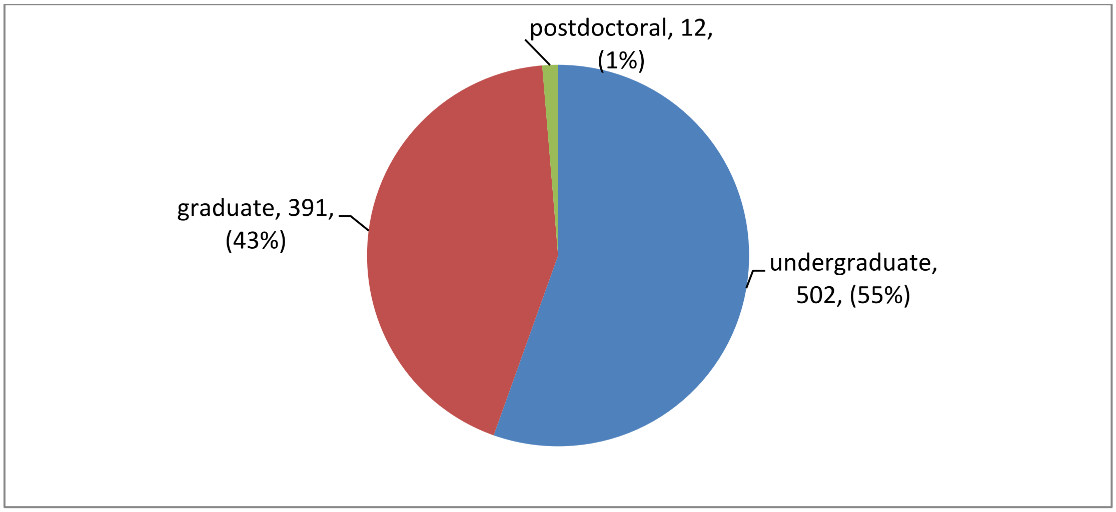


Table C-21 in Appendix C contains more detail on these data.

Summary. Students involved in AREA research do serve as co-authors on publications, presentations, and posters, attesting to the substantial commitment to mentoring shouldered by PIs, and the presumably major effect on students' education in biomedical and behavioral sciences. However, the presence of AREA funding cannot be identified as the sole factor responsible for this high level of student research participation. Since AREA PIs and never-successful AREA non-awardees reported similar rates of student co-authorship as outcomes of student participation in the line of research proposed to the AREA program, factors other than the receipt of an AREA grant, such as institutional commitments to providing meaningful real-world research experiences to students, must be more influential.

4.4 Do Students Undergo Subsequent Graduate Training and Remain in Research?

4.4.1 Comparison of Educational and Career Outcomes of AREA Awardees' and Non-Awardees' Students (Awardee Survey and Applicant Survey)

Our theory of the AREA program holds that participation in AREA research will encourage undergraduate students to pursue further education and eventual employment in scientific fields. The Awardee and Applicant Surveys asked respondents to report on outcomes for their students. Table 4-4 presents findings for undergraduate students by type of PI. The majority of awardee and non-awardee PIs report that their students continued with education in the sciences. Health professional education is particularly popular, with over 80 percent of awardee and non-awardee PIs reporting this outcome. Nearly 85 percent of non-awardee PIs reported that their undergraduate students pursued graduate education in the same field. This is about 10 percentage points greater than the percentage of awardee PIs reporting this outcome. Chi-square testing of the proportions of PIs reporting this outcome revealed that the difference in the two proportions is statistically significant (p=0.007), with non-awardees more likely to report this outcome than awardees. Non-awardee PIs were also more likely to indicate that their undergraduate students sought employment in another scientific field than awardee PIs. (p=0.006). On the other hand, awardee PIs were more likely to indicate that their undergraduate students sought employment in a biomedical or behavioral field (p=0.037).

Table 4-4. PI-reported undergraduate student outcomes by PI type

PI Reported Undergraduates Student…	Awardee PI % (n)	Non-Awardee PI % (n)
…pursued graduate education in same field.*	75% (538)	85% (200)
…pursued education in different field, biomedical or behavioral.	54 (538)	57 (183)
…pursued health professional education.	82 (538)	84 (197)
…sought employment in a biomedical or behavioral field.*	54 (538)	45 (197)
…sought employment in another scientific field.*	24 (538)	38 (149)

Awardee Survey question 16; Applicant Survey question 14.
*Differences are significant.
Table C-22 in Appendix C contains more detail on these data.

Table 4-5 presents similar data for graduate students where the response options asked out outcomes pertaining to research and employment. Over 60 percent of PIs—awardee and non-awardee—reported that their graduate students either pursued research in biomedical or behavioral field, or attained employment in academia or in research. For both outcomes, the percentage of awardee PIs reporting the outcomes was more than 10 percentage points higher than the percentage of non-awardee PIs. Chi-Square testing of the differences in proportions for each outcome reveals they are statistically significant, with awardee PIs more likely to report this outcome in each case. Differences in proportions were not statistically significant for the other two outcomes.

Table 4-5. PI-reported graduate student outcomes by PI Type

PI Reported Graduates Students…	Awardee PI % (n)	Non-Awardee PI % (n)
…pursued research in biomedical or behavioral field.*	73% (414)	62% (164)
…attained employment in academia or in research.*	77 (412)	65 (164)
…attained employment as a clinician.	35 (406)	40 (170)
…attained employment outside behavioral or biomedical sciences.	27 (361)	30 (170)

Awardee Survey question 19; Applicant Survey question 17.
*Differences are statistically significant.
Table C-23 in Appendix C contains more detail on these data.

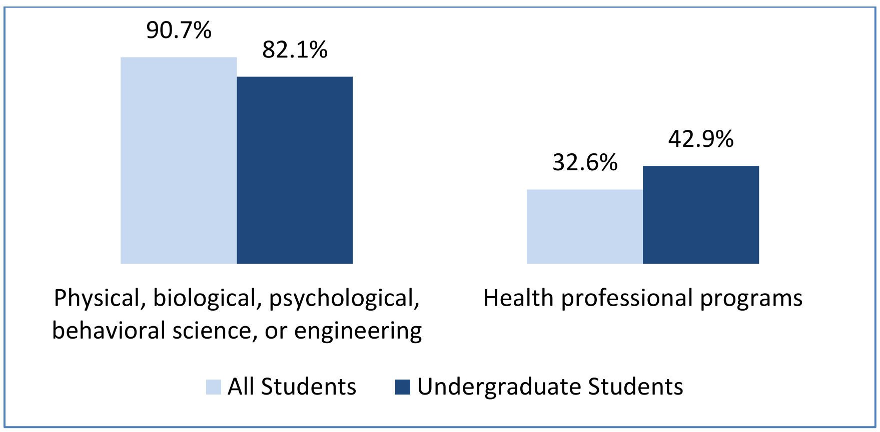
Analysis of Awardee and Applicant Survey responses indicates that both types of PIs see large percentages of their students go on in scientific education, research, and employment. PIs reported that undergraduate students were very likely to pursue education in a health profession. Awardee PIs were more likely that non-awardee PIs to report that their undergraduates pursued employment in the biomedical or behavioral fields. They were, however, less likely than non-awardee PIs to report that their undergraduates pursued graduate studies in their own field. For graduate students, pursuit of research in biomedical or behavioral fields and employment in academic or in research were the most frequently reported outcomes regardless of PI type; nonetheless, awardee PIs were more likely to report these outcomes for their graduate students than non-awardee PIs. Analysis of Student Survey responses explores students' perspectives on outcomes.

4.4.2 Student-Reported Educational and Career Outcomes (Student Survey)

The Student Survey also asked how involvement in the AREA project influenced interest in the sciences. 89 percent (not shown) of students reported that working on AREA projects either increased or confirmed their interest in further education or training in the sciences. Thus, by providing a variety of research experiences with which they are largely satisfied, AREA research projects do encourage students to continue in the sciences.

About half (52 percent) of student respondents reported that they pursued further education in scientific fields after participation in their AREA project. Students who pursued more education were successful, as figure 4-9 shows that more than 90 percent of all students who pursued further education were admitted to a graduate program, a postdoc, an internship or other training, and more than 30 percent were admitted to a health professional program. The graph displays aggregate data for all students and for undergraduate students separately.

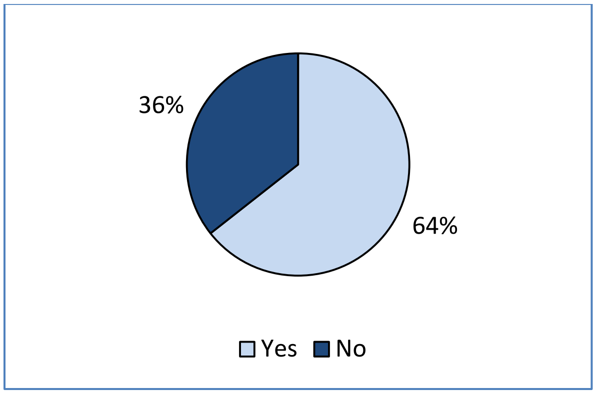
Figure 4-9. Among students pursuing further education, the percentage of students admitted after AREA project participation by field of study



Student Survey question 23.
Table C-24 in Appendix C contains more detail on these data.

Employment in scientific fields is an equally important metric of AREA program. Of those who indicated they were employed either full- or part-time, the Student Survey inquired whether they were employed in a biomedical or behavioral sciences field. As depicted in Figure 4-10, just over two-thirds (64 percent) reported that they were employed in these fields.

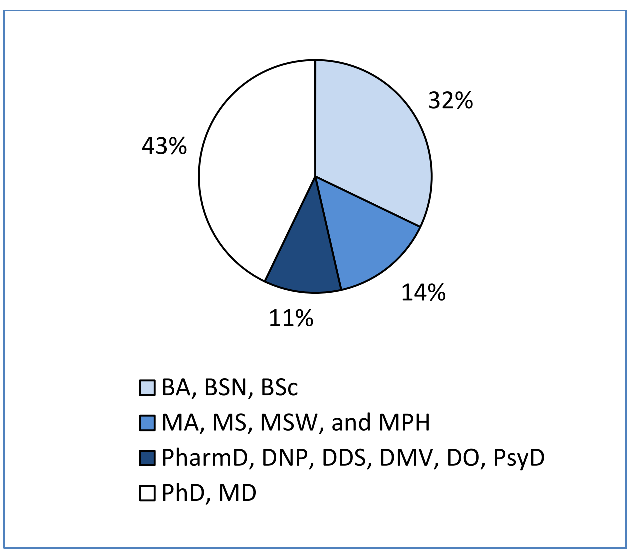
Figure 4-10. Among employed former students (n=73), percent in biomedical or behavioral science fields



Student Survey question 30.
Table C-25 in Appendix C contains more detail on these data.

Another measure by which to gauge the effect of AREA participation on student outcomes is the highest level of education obtained. The Student Survey asked respondents to list degrees they have obtained and the years in which they were obtained. We categorized students according to the highest degree obtained and present the distribution of students within categories in Figure 4-11. Approximately 43 percent of students obtained a Ph.D. or an MD as their highest degree. Nearly one-third (32 percent) received bachelor's degrees including BA, BSN, or BSc as their highest degree. About 14 percent received master's degrees. Just over 10 percent obtained degrees that included PharmD, DNP, DDS, DMV, or DO. The large share of students receiving Ph.D. or MD degrees is striking. Unfortunately, given the lack of a control group, we are unable to explore whether this is atypical for students involved in scientific research at AREA-eligible institutions. Totaling the students with advanced degrees, Student Survey results indicate that 68 percent (=43 + 14 + 11) obtained degrees that included education beyond a bachelor's.

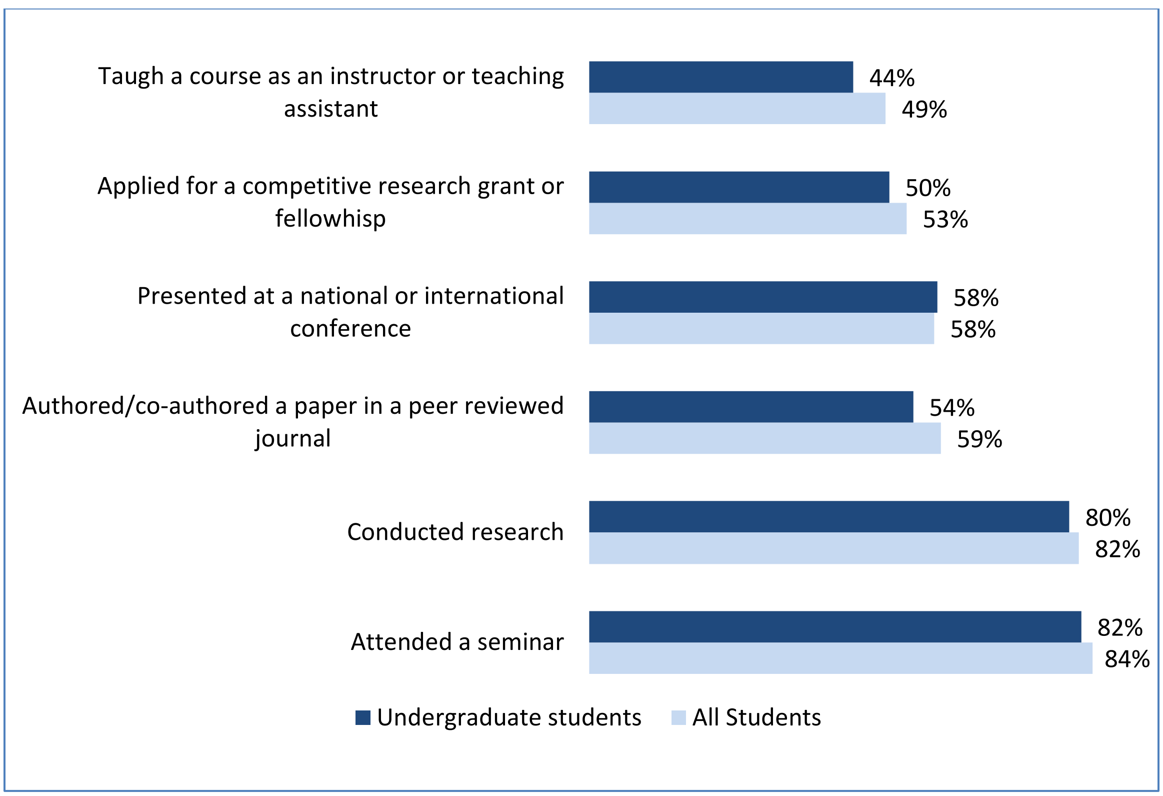
Figure 4-11. The percentage of students by highest degree obtained



Student Survey question 18.
Table C-26 in Appendix C contains more detail on these data.

Analysis of research activities subsequent to AREA participation is the final metric by which we evaluate the effect of AREA participation on students since it demonstrates commitment to participation in the field. The Student Survey asked respondents whether they had engaged in activities pertaining to scientific research in the biomedical or behavioral sciences subsequent to participation in AREA research. Response options included attending a seminar, workshop, or lecture outside of class, conducting research, organizing a seminar, workshop or lecture, presenting at the national conference, authoring or co-authoring a paper in a peer-reviewed journal, authoring or co-authoring a technical article, teaching a course as an instructor or teaching assistant, applying for a competitive grant or fellowship, or receiving competitive funding for research. Figure 4-12 presents the findings by type of research activity and student level, undergrate or graduate. At least 80 percent of students attended a seminar or conducted research subsequent to their AREA project; these were the most frequently reported activities regardless of student level. About 59 percent of undergraduates authored or co-authored a paper in a peer reviewed journal. A similar percentage (58 percent) indicated that they presented at a national or international conference. In addition, over half of undergraduates (53 percent) applied for a competitive research grant or fellowship. These data indicate that the majority of undergraduates pursued research after their participation in AREA projects.

Figure 4-12. The percentage of students participating in research activities subsequent to AREA projects by type of activity and level of student



Student Survey question 19.
Table C-27 in Appendix C contains more detail on these data.

Summary. Overwhelmingly, former students involved in AREA research found that the experience confirmed or increased their interest in the biomedical and behavioral sciences. More than one-third of student respondents had obtained Ph.D.s or MDs, and the majority (52 percent) had continued with education in the sciences. Over half reported authoring a peer-reviewed publication. While the sample of students is likely to overrepresent individuals for whom up-to-date contact information was readily available on public websites (such as graduate students or faculty at colleges or universities), these are nonetheless positive outcomes.

However, the effect of the R15 grant on outcomes for students who work in faculty laboratories is less clear. Analysis of data comparing the outcomes of AREA PIs and non-awardee PIs does not present a clear picture of how the grant effects students who are already committed enough to scientific education to pursue research experiences beyond college coursework. Similar to the findings regarding student co-authorship discussed above, whether or not students pursued further education, training, and employment in the biomedical and behavioral sciences seem heavily effected by factors other than whether or not the PI with whom the student worked was funded by an AREA grant.

5. Evaluation Results Part III: Is the Research Environment Being Strengthened?

We sought to understand how AREA PIs thought receiving the award had improved the research environment of their institutions. We hope that this information will assist in creating recommendations regarding how R15s should be implemented so that they do result in stronger research environments. According to the theory of the AREA program as depicted in the logic model (Figure 1-1), other faculty at the institution receiving the R15 ought to collaborate with the AREA PI in the production of high-quality research, or be encouraged by the AREA PI's success to apply for and receive external funding themselves. These outcomes would bring about the production of high-quality research, thus incrementally improving the research environment.

This chapter describes how AREA PIs believe the research environments of their institutions of higher education had been improved by receiving the AREA grant. We discuss:

- The effect of the R15 on how the recipient institutions of higher education are perceived,
- Institutional changes that occurred at least partly as a result of receipt of the award,
- The extent to which AREA PIs collaborated with others at their institutions, and with those at other institutions, and
- PIs' attitudes toward collaboration within and outside of their institutions.

Primary data sources. To understand the effect of the R15 on the research environment of the recipient institution of higher education, we employed two sources of data: surveys of AREA PIs regarding the extent of their collaborations, and qualitative data from in-depth interviews with AREA PIs. In-depth interviews elicited their thoughts about what may have changed at their institution due to their receipt of the AREA award, and their opinions about collaboration within and outside of their institution.

Findings:

- AREA PIs reported that receipt of the grant created positive peer influence whereby other faculty at their institution applied for their own R15s or other external grants,
- They believed that the prestige of the NIH grant contributed to the reputation of their department and institution of higher education,
- Receipt of the AREA award dovetailed with other transformations at primarily undergraduate institutions and regional colleges and universities to increase standards of research excellence,
- Opinions about collaboration with peers at their institution were mixed, and
- AREA PIs felt positively about collaborating with researchers at institutions with very high intensity research programs.

Peer influence. Frequently, interviewees reported that during or after he or she carried out an AREA project, their success created positive pressure on peers at their institution. After seeing their AREA-funded colleague receive and conduct research with a R15, others applied for their own R15s. As one AREA PI at a research university (RU, 2006) explained:

> I was the first one to apply for this program in my department. I figured out that we were eligible. There was someone in the Biology Department—which is a different college—that had an award, an R15. I knew he had one. After I applied and got one, two…there were three or four more investigators that were successful.

Another PI (PUI 2010) said that since other faculty at her institution have seen how positive her experience has been conducting research and mentoring students as a R15 recipient, she is currently helping three others at her institution prepare their R15 applications.

AREA PIs reported that historically, faculty at regional colleges and universities and primarily teaching institutions were less likely than they are today to be active researchers. Receipt of the R15 award was sometimes the first step toward building research activity within a department. It was common for PIs we interviewed to report that they were the first faculty member in the department of their regional public, or primarily undergraduate, institution to be awarded NIH funding. In fact, one PI at a primarily undergraduate institution (PUI, 1990) said his college was so unprepared for the R15, that when the notice of his award was received by the college's business office, "They called me up and asked me, 'What's this?'"

Effects on the institutional reputation. AREA PIs acknowledged that it was obvious that bringing funds into their university or college department contributed to the "bottom line" and provided relief to already stretched departmental resources for research, since 97 percent of respondents to the Awardee Survey said that they applied to the AREA program because the funding available from their institution was insufficient for their research (see Appendix E). Even so, many interviewed PIs reported that another major effect of winning an R15 was an increase in prestige for the department or institution of higher education. For example, a PI at a Master's College or University who had an award in 2005 (MCU, 2005b) said, "In terms of things like dollars, and increases in indirect cost returns, I don't think that [the] effect [of money] was as great as the perception, 'We now have National Institutes of Health money!' regardless of the amount." Likewise, another PI (MCU, 2010) said, "They [the department] certainly like to have faculty who have NIH funding. It certainly makes them feel good."

In some AREA-eligible institutions, being able to show that the department or school had NIH funding drew top-notch students or junior faculty. Regarding the latter, a PI (PUI, 2001) described how the receipt of his grant helped his department recruit faculty that were strong researchers:

> One of the things that happened during the period in which I had the AREA grant, is that my department hired three people. They were all junior people—three out of a total of eight [department members]…. We were able to say to them—because we were hiring them—"This is a place for you to come and be a research-active scientist. It's true that we are a school that values teaching undergraduates and that's going to be a central part of your job. [But] it is also possible to get external funding, to carry out a research program, to publish, and so forth." All of them succeeded.

This PI felt that winning the award was one of the factors that contributed to a change in expectations around research productivity in his department. The long-term effect of the award was an increased expectation that faculty would be strong researchers. He reported that his department had completed an external review recently, and was described as “the most research active undergraduate biology departmet in a liberal arts college they had ever seen.”

Transformation of institutional expectations. Other PIs voiced similar experiences in which winning the R15 contributed to a change in the culture of the institution and “raised the level of what we’re able to do [at the college]” (PUI 2014b). At a regional research university, a PI who received an award in 1988 (RU, 1988) felt that, although he was only one of three in the department receiving external funding, his department has since changed so that “now of course you can’t get tenure without having a research grant.” Receipt of the R15 “really fit into the way the university was evolving.” The AREA PI (PUI, 1990) cited above as causing confusion in his college’s business office with the receipt of his R15, reported that his R15 funding

> …was part of the beginning of a transformation from having no real science department to having really good ones. It had a tremendous impact because ever since then, although not just because of that [the R15]…. It’s now an expectation for all the science faculty that they’ll conduct research, publish, and write grants in order to get tenure and after.

Increase of institutional infrastructure and resources. Another important effect of the R15 was that it facilitated the updating, purchasing, or renewal of scientific equipment and supplies. Some faculty at PUIs with large endowments reported that their institution assisted them by “matching” their R15, or purchasing supplies and equipment to supplement their AREA project. Others reported that the grant created the need for the school to update the infrastructure and the support it was providing to carry out research. For example, a PI (PUI 2010) reported that she “was able to advocate for getting some upgrades on campus to our animal facilities.” Another PI (PUI 2014a) said that the R15 improved the research infrastructure of his department by permitting the purchase of some scientific instruments that have facilitated his colleagues’ research, as well as his own:

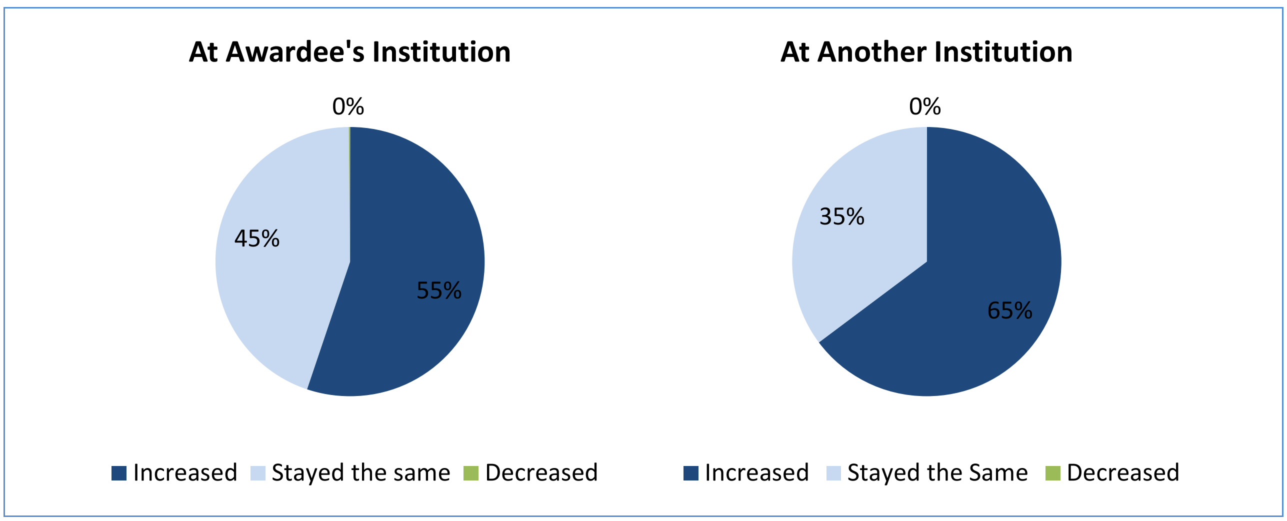
> Colleagues in the Chemistry Department—I’m in the Biology Department—come in and use this equipment in my lab all the time. That’s a great thing.

The art of creating a R15 project. PIs emphasized that R15 projects are qualitatively different than R01 projects, and that they are neither scaled-down, nor second-rate, R01 projects. A number of PIs were clear that R01s were not feasibly-sized awards for small laboratories staffed by novice researchers (i.e., undergraduates). Many PIs agreed that “a NIH R01 grant would be more than you could reasonably accomplish” (PUI 1990) given their other responsibilities. Even so, PIs asserted that R15 research can have a scientific impact. Backing up the scientific importance of R15 research, a PI (MCU, 2005b) asserted, “You look at the publications that come from the R15; they’re all in peer-reviewed journals in top-notch places. They get cited quite a bit, so it shows that you can do these sorts of things…without being at an R01-type of institution.”

According to these PIs, the type of project appropriate for an R15 is a high-quality scientific investigation that does not require a lot of overhead and can be staffed by undergraduates. PIs said that with creativity and thoughtfulness, it is possible to create a project that is not expensive, is appropriate for undergraduate researchers, and yet is scientifically meaningful. PIs who conduct AREA projects[1] develop a "philosophy" of implementing "good ideas…that don't require a R01 award but may be important for the research area in general" (RU, 1988). For example, a PI (RU, 2007) said that after completing his own scientific training in large laboratories at very high intensity research institutions, it took some time as a junior faculty member to understand how to create a project appropriate for undergraduates. A more seasoned PI (PUI 2001b) explained that when he selected his AREA project topic, he took into consideration the small size of his lab, the fact that most of his technicians are undergraduates, and selected a research question that was "…intellectually and contractible for a small lab to handle. There were a lot of people working in that area [of investigation] at that time. It seemed like that was the place where I can make a contribution. All one wants to do is find something new that turns out to be interesting."

Collaboration within institution. AREA PIs were less unanimous about the positive effect of the R15 on collaboration with peers at their institution. While 77 percent of AREA PIs who responded to the Awardee Survey indicated that an increased ability to collaborate with others at their institution was at least "somewhat important" in their decision to apply to the program (see Appendix E), only 55 percent of respondents increased their collaboration with others within their institution as a result of the AREA grant, while the remaining reported that their collaboration with colleagues at the same institution did not change (see Figure 5-1). When interviewed, however, PI opinions about the effect of the R15 on their collaboration were mixed, with some PIs reporting idyllic-sounding partnerships, and other describing reservations.

Figure 5-1. The effect of participation in AREA project on collaboration internal and external to the awardee's institution



Awardee Survey question 21.
Table C-28 in Appendix C contains more detail on these data.

[1] PIs with whom we spoke frequently had at least one graduate student in a laboratory with a number of undergraduate students. Of the PIs quoted in this paragraph two PIs (RU 1988, RU 2007) had one graduate student each and numerous undergraduate students working on their AREA projects. The third, (PUI 2001b) worked only with undergraduate students. Opinions may differ for PIs at professional schools (as opposed to those at research universities, masters' universities, and colleges) but insufficient numbers were interviewed to determine how planning an AREA project for professional student participation may differ.

As an example of a good within-institution collaboration, a PI who received his award in 2005 while at a Research University (RU, 2005), described the process of applying for, and carrying out, the R15 as involving significant partnership with at least two other PIs in his department. His description of collaboration may be near to the ideal outcome of R15 research environment enhancement. He worked with collaborators to design the project, collect preliminary data, which then contributed to high-quality scientific discussions among colleagues. He explained:

> We just started talking. The two that were with the AREA grant are in my department. One person…we just had a conversation one day and it expanded into: "Wouldn't it be cool if we did this?" Then we started doing experiments to try and address those kinds of questions. Eventually we had enough preliminary data that the AREA people wanted to support us…. As a result of doing the research we ran into other people that were not our collaborators but who are interested in similar kinds of things, and we had various discussions with them in the intervening years.

However, other AREA PIs were more reserved about collaborating with colleagues at their institution who were less established as strong researchers than they were. For example, the AREA PI (PUI, 2010), described above as assisting others in preparing their R15s, said she worried about infringing on others' development as independent investigators. This PI said she shares AREA-funded resources with two colleagues, but tries not to usurp their autonomy. She explained

> We've been giving some [samples] to a chemist who is interested in assaying them. I don't want them all to be tied to me because…for their own career I want them to have their own thing. I'm giving him [samples] and he's already published a paper…but I'm not a co-author on that paper…. We're also working with someone in biology whose been doing microbiome work and she's now getting our [samples]. She wants to write an R15 on some different…that's her specialty microbiology…. I don't know if I'll be a co-author on that. We haven't discussed that.

Another PI (Prof, 2009) said he worried that selecting a co-PI from his institution might weaken an otherwise strong R15 application. He explained:

> You want to increase the idea of asking colleagues? Sometimes that could be a challenge. Reviewers could pick on you by...you are involving a colleague who does not have any research credentials, and that could be a weakness…. I bring in a colleague who does not have a research portfolio and the reviewer sees that as a way to ding me.

A third AREA PI (Prof, 2008) said that he had been collaborating with someone who ended up "flaking out" on him. A fourth (Master's, 2010) lost an informal within-institution collaborator when the collaborator left the institution for personal reasons.

Collaboration outside the institution. Collaborating with investigators outside of AREA PIs' institution was more robust and seemed less problematic than collaborating within the institution. Results from the Awardee Survey indicated that 65 percent of respondents increased collaboration at other institutions, with the remaining respondents reporting that their collaboration outside of their institution remained similar to how it had been before receiving the award. Interview data demonstrated that all PIs who collaborated outside of their institution did so with investigators at very high intensity research universities.[2] Some of these collaborations were with former graduate school or postdoctoral mentors, other partnerships were formed by the AREA PI in order to make use of expensive, specialized equipment, and still others began while the PI was on sabbatical at a very high intensity research university.

PIs felt that collaboration with prominent investigators was both a benefit of AREA grant receipt and a factor strengthening their R15 applications. PIs found that "It's relatively easy to collaborate with research universities." The following PI (PUI, 2014a) described both concisely in his interview:

> The AREA grant program gives me the ability to be productive and be taken seriously among scientists who are at the research universities, both [because] of [increased] productivity and the credential of being a NIH-funded scientist. That creates opportunities for collaboration that wouldn't be there otherwise. I've also seen, though, that by having collaborators and named supporters in a grant application that that's very well-received by reviewers. It's a cycle: the grant enables you to collaborate, but reviewers in turn reward proposed collaboration with funding.

The PI working at a selective liberal arts college (PUI, 1990) reported that investigators at very high intensity research university leverage their collaboration with him in order to staff their laboratories with well-trained graduate students. He explained, "People from research universities are immediately after you to send them graduate students…. If you're at a liberal arts college were you're turning out students that are good candidates for grad school." These collaborations, from the point of view of investigators running large, well-funded laboratories at research universities, have an added benefit of providing opportunities to "scope-out" emerging scientific talent.

Summary. The obvious ways in which receipt of the AREA grant strengthens the research environment of the institution where it is held is in creating or improving the infrastructure, supplies and resources available for AREA PIs and their peers at their institutions. However, in many ways, less tangible changes to the research environment as a result of holding the grant are just as important. Receipt of a R15 at a small institution or department where faculty are not likely to hold external research grants encourages AREA PIs' peers to seek external funding—especially R15s. Second, receipt of R15 grants increased the institutions' reputation and prestige, which allowed for the recruitment of high-quality students and active research faculty. Third, PIs reported that the R15 was one among other factors that fit their institutions' growing commitment to supporting active research. Some PIs, who had a longitudinal view of the evolution of their institutions, reported seeing the institutions' expectations change over the years from rewarding high-quality teaching and service but remaining indifferent to research productivity, to only rewarding with tenure those faculty members who have active research programs in addition to excellent reputations as teachers.

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[2] With the exception of one PI (Master's, 2010) who described work he had contracted to a commercial laboratory as collaboration.

For the purpose of this evaluation, we operationalized “strengthening the research environment” as involving collaboration with peers within the PIs’ institutions of higher education. We found that this objective is fraught for PIs. AREA PIs worried that collaboration with a peer whose research portfolio is weaker than theirs might not be in the best interests of either themselves (the AREA PI) or their less-developed peers. Instead, some of the AREA PIs with whom we spoke preferred the stance of “noblesse oblige” toward their peers, in which they provided mentorship and access to equipment and other research supplies, but do not collaborate as peers.

On the other hand, collaboration with those at very high intensity research universities was seen as unconditionally positive and in the interests of the AREA PI. PIs gained access to the use of expensive equipment, scientific and methodological expertise, and intellectual stimulation through collaboration at very high intensity research universities.

PIs stressed that the R15 project is qualitatively different than the R01 project, and should not be regarded as second to R01 research. The challenge of designing and carrying out a project that (1) can be accomplished with little overhead, (2) can be implemented by undergraduates, and yet (3) is scientifically important, can be formidable. Meeting these three requirements requires intellectual flexibility, creativity—or “a philosophy” of the AREA program project.

6. AREA Evaluation Summary and Conclusions

This report comprises the first full-scale evaluation of the NIH AREA program. Westat was tasked by NET Esolutions to evaluate the extent to which the AREA program was meeting its objectives to:

1. Support meritorious research,
2. Expose students to research, and
3. Strengthen the research environment of the institutions of higher education receiving the award.

As described by the AREA program logic model (Figure 1-1), our theory of the AREA program holds that biomedical and behavioral scientist faculty and researchers at AREA-eligible institutions of higher education who implement the R15 funding mechanism will fulfill the three objectives of the program. Our assessment of the AREA program demonstrates that its objectives are being met. The AREA program is funding meritorious research, exposing students to research, and strengthening the research environments of the institutions where they are held. The following summarizes how we reached this conclusion for each evaluation question.

6.1 Evaluation Question 1: Is Meritorious Research Funded?

To understand whether or not the projects receiving NIH funding through the R15 mechanism were producing meaningful scientific contributions, we operationalized the merit of AREA-funded research in the following three ways: the extent to which the AREA program was competitive, the research productivity of AREA projects, and the degree to which the lines of research begun with an AREA grant were sustained through further funding in the scientific community. Since there are no absolute standards of application competitiveness, research productivity, and successful grantmanship in the scientific community, we made use of two comparison groups that had face validity and were feasible within the scope of this evaluation.

The first group was a matched sample of R01 projects. R01 projects provided a comparison group for the competitiveness of the AREA program, and of research productivity. Research productivity of the R15 projects in comparison to the R01 program was assessed through analysis of bibliometric outputs in terms of quantity of peer-reviewed papers, citation count (as a proxy for scholarly significance) and cost per peer-reviewed paper and citation. The second group were never-successful AREA applicants, who provided a comparative assessment of the impact of the grant on the sustainability of lines of research begun at AREA-eligible schools, all of which are teaching intensive—not research intensive—institutions.

We conclude that in the period beginning after the restructuring of the AREA program in 1998 through 2010, the scholarly impact of R15 projects are nearly comparable to R01 projects *per dollar of funding*. The costs of R15 projects are approximately 11 percent of R01 projects 1998-2010.

Examining the treatment effect of the R15 on the productivity of PIs working at small, regional, and teaching intensive institutions of higher education demonstrates limited increases in research productivity due to receipt of the AREA grant. PIs are more likely to publish after receiving an AREA grant than PIs who do not receive an AREA grant. This finding is likely to be due to other factors in addition to receipt of the R15 grant. Characteristics of the PIs, or of their institutions, may predict who receive funding and who does not, since AREA PIs were significantly more likely to have published before receiving the R15 than the comparison group of never-successful AREA applicants.

However, AREA PIs' projects appear to be sustained more robustly in the post-R15 grant period, than do the research projects of PIs who did not receive a R15. AREA PIs received significantly more subsequent internal and external funding than did PIs who did not receive a R15. The extent to which the lines of research begun during the AREA grant were sustainable differed for AREA PIs who were at well-endowed primarily undergraduate institutions (PUIs) versus those who were at regional, public institutions. PIs at PUIs with large endowments found that their colleges were willing to help sustain their research project in the absence of external funding once the active period of the R15 was complete. In contrast, PIs at regional, public institutions were more likely to find no subsequent support from their institutions for continuing their research.

AREA PIs report that the R15 was crucial to their careers. Many felt that receiving the R15 helped them receive tenure at their institution.

6.2 Evaluation Question II: Are Students Exposed to Research?

Research demonstrates that a large proportion of the nation's biomedical and behavioral sciences begin their scientific education as undergraduates in AREA-eligible institutions of higher education. Hence, a primary justification for the existence of the AREA program is that it provides an opportunity for students to develop enthusiasm for scientifically meaningful, real-world research. We evaluated whether or not the AREA program is meeting its objective to provide research experiences to students at AREA-eligible institutions by investigating: the quantity of students involved in AREA research, the nature of their involvement in AREA-funded projects, and the extent to which the participated as co-authors on papers, presentations, and conference posters. We also sought to understand the long-term effect of participation in AREA research by investigating education and career outcomes for former students who participated in AREA-funded projects.

We gathered information about the participation of students in AREA-funded research. We relied on three sources of data: surveys of AREA PIs, surveys of students of AREA PIs and AREA Final Progress Reports submitted by AREA PIs to NIH shortly after the completion of the project. In addition, we also surveyed AREA non-awardees about students who participated in their laboratories in order to assess any effect of the R15 on student participation and outcomes.

We found that AREA PIs were able to provide research experiences for students, that these research experiences were educationally meaningful, and that students did participation in co-authorship, and a majority continued with education, training, and employment in the biomedical and behavioral sciences. Undergraduates were overwhelming represented as the recipients of AREA research experiences. They comprised more than 70 percent of the students reported as involved in AREA research.

Results of the surveys of AREA PIs and students indicate that a majority of students participating in AREA research were involved with all phases of the research process: research design, experiments, data analysis, and planning future research. Students who responded to the survey were overwhelmingly satisfied with the experience. Over 80 percent reported satisfaction.

AREA PIs were able to involve significantly more students in research than were the comparison group of unsuccessful AREA applicants. Even so, rates of co-authorship, educational, and career outcomes for students of both AREA PIs and the comparison group suggest that other factors in addition to the receipt of the R15 grant, effect whether or not the student becomes a co-author and continues in science.

A majority of students involved in PIs' laboratories continue in the biomedical or behavioral sciences, receiving further training, education, and pursuing scientific careers. More than one-third of students responding to the survey had obtained PhDs or MDs.

6.3 Evaluation Question III: Is the Research Environment Being Strengthened?

Operationalizing a "strengthening research environment" for the purpose of evaluation is probably the most difficult of the three AREA program objectives to evaluation since a stronger "research environment" is difficult to quantify. If researchers at the institution of higher education that received the AREA grant have greater research productivity, if more students are being exposed to real world research experience, if researchers are collaborating more frequently and if more faculty members are applying for, and receiving, competitive research grants, than we might conclude that the research environment has been strengthened. Even so, a whole host of factors in addition to receipt of the AREA grant contribute to these outcomes, making the effect of the AREA award on the institution difficult to separate from other factors.

We relied heavily on AREA PIs' reports of how they believed the research environment was strengthened by their receipt of the award. We also surveyed PIs about the extent of their collaboration before and after the award with peers within, and outside of, their institution.

PIs reported that the research environment of the institution where they held the grant was strengthened in a number of ways. First, receipt of the R15 grant allowed for the creation or improvement of infrastructure, supplies, and resources available at the institution of higher education. Second, the prestige of having an active research program funded by the NIH facilitated the recruitment of other faculty who were active researchers and higher quality students. Third, since many PIs were among the first of their institutions to receive a R15, their success motivated colleagues at their institution to seek external research funding for their own research agendas.

More than three-quarters of AREA PIs reported that collaborating with colleagues at their institution was at least somewhat important to them, and a majority said their collaboration with colleagues at their institution increased due to receipt of the R15 award.

Finally, some AREA PIs emphasized that the R15 is qualitatively different than the R01, or the other research grant mechanisms of NIH, and should not be regarded as inferior to the R01, or of lower NIH priority. Meeting the challenge of designing and carrying out a scientifically important project that can be staffed by undergraduates with little overhead requires considerable scientific creativity, pedagogical skill, and intellectual flexibility, or, in the words of one PI, "a philosophy."

6.4 Conclusion

Our finding that the research productivity and scholarly significance of AREA projects, when adjusted for dollars of funding, is not significantly different than that of R01 projects supports the conclusion that AREA research is scientifically meritorious. AREA PIs are able to sustain their line of research inquiry after the termination of the R15 grant period with competitive external and internal research funding. AREA PIs expose significantly more students to high-quality research than a comparison group of AREA-eligible PIs. The AREA grant meets its objective to contribute to the development of the biomedical and behavioral sciences workforce pipeline, since a majority of students who participate in AREA research continue with further education, training, and eventual employment in the sciences. Finally, the AREA grant facilitates the development of institutional infrastructure, collaboration and healthy competitiveness among colleagues, and a culture of research activity in smaller, regional, and primarily undergraduate institutions of higher education.