Student Outcomes from Undergraduate Research:

An Evaluation of Three Academic Year and Summer Undergraduate Research Programs in the Life Sciences at the University of Colorado, Boulder, 2007-2008

Report to the Biological Science Initiative (BSI) and the NIH/HHMI Scholars Program for Diversity in the Biosciences

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Executive summary

This evaluation study was designed and conducted at the request of the Biological Sciences Initiative (BSI) and the NIH/HHMI Scholars program for Diversity in the Biosciences at the University of Colorado at Boulder. The BSI has sponsored undergraduate research (UR) programs for several years, while the NIH Scholars program is relatively new. The BSI also provides a small stipend for NIH Scholars students. Prior evaluation of the BSI's UR programs indicated that although the vast majority of participants were highly satisfied with their experience and made strong gains in a variety of areas, a small portion of students may not have had access to authentic research activities or adequate mentoring (Coates et al., 2005). We designed the current study to build upon our past evaluation work documenting student outcomes and the influence of the research experience on students' career plans. We also sought to examine the quality of students' research experiences and the processes through which specific student outcomes arise. The study gathered information from BSI and NIH Scholars students through a comprehensive survey and in-depth interviews. This report will focus exclusively on findings from the survey.

Evaluation methodology

Survey instrument and data collection methods: The instrument developed for this evaluation, the Undergraduate Research Student Self-Assessment (URSSA) focuses on students' ratings of their gains in six specific areas: thinking and working like a scientist, personal/professional gains, becoming a scientist, enhanced career and graduate school preparation, clarification or confirmation of career/educational aspirations, and skills. Students also evaluated their satisfaction with various aspects of the research experience and associated programming. Most items are multiple choice, or numerical ratings, on a 4-point scale, with a few open-ended response items.

Analysis methods: The quantitative data were entered into the statistical software package SPSS where descriptive statistics were computed. Tests of statistical significance to determine differences among groups were not conducted because the small sample sizes for the surveys precluded meaningful statistical analyses. Write-in responses to the open-ended questions were entered into a spreadsheet and coded. Each new idea raised in a student's response was given a unique code name.

Characteristics of the UR programs

During the period studied, the BSI sponsored two undergraduate research programs, known as UROP and BURST, through their funding from the Howard Hughes Medical Institute (HHMI). The NIH Scholars program was funded through money provided by the National Institutes of Health and HHMI. UROP (Undergraduate Research Opportunities Program) is an established university program that supports UR experiences in all fields, not just science. BSI supports this program by providing individual grants for students undertaking UR in life-science related fields. The UROP students in this study tended to be more advanced or experienced students. BURST (Bioscience Undergraduate Research Skills and Training) was designed by BSI as an introductory research experience to meet the gap in UR opportunities for younger students.

Students also participate in a series of workshops and trainings to prepare them for research work and enhance their laboratory skills and understanding of scientific research and writing. Finally, BSI is a partner in the NIH/HHMI Scholars Program for Diversity in the Biosciences, which was developed and introduced during the 2003-04 academic year. This program targets ethnic minority and first-generation, low-income students and offers a multi-year research experience. Entry-level research students participate in a weekly laboratory skills training course in the fall and a weekly journal club in the spring.

Survey response rate and demographic characteristics of survey samples

Survey responses were received from 53 students in all, distributed among three distinct but related UR programs: BURST, BSI's program for beginning researchers (24 students); UROP, BSI's program for experienced student researchers (16 students); and NIH Scholars, a multi-year program targeted to underrepresented students in the life sciences (13 students). The survey response rate was 75% for BURST students, 42% for UROP students, and 68% for NIH Scholars students. The combined response rate was 59%.

The demographics of the survey samples from each program reflect the diversity among the three programs and the different emphases of each. For example, UROP students were more advanced in their undergraduate careers, while BURST students were generally younger. As the NIH Scholars is a multi-year research program, these students reflected greater variation in their year in college. As might be expected, NIH Scholars students came primarily from underrepresented groups in the biosciences, while BURST and UROP students were primarily white or Asian/Pacific Islander, groups traditionally overrepresented in the biosciences. All three programs have considerable numbers of women and have come close to meeting, if not surpassing, the proportion of women in undergraduate biological science nationally. In 2002, women earned 59% of all biological sciences baccalaureate degrees at U.S. colleges and universities (NSF, 2006).

Program outcomes

Support and guidance: Overall, students felt supported within their research labs and by their research programs. Students from all three programs rated the support and guidance they received similarly. Students in all three programs felt supported by their program staff and their research mentor; however, some students were dissatisfied with the amount of time spent with their research mentor.

Associated programming: Students were also satisfied with other aspects of their research programs, such as the application process, lab equipment, financial support, and the research lab selection and matching process. However, UROP students rated a few items lower than their peers in the BURST and NIH Scholars program, including financial support, and program workshops and seminars. Students in all programs were least satisfied with their program website, suggesting that websites for all of the programs may need to be updated to be more helpful or relevant for students.

Program workshops and seminars: Generally, students in all three programs were less satisfied with workshops and seminars than other aspects of their programs. Students in all of the programs were least satisfied with the initial orientation session, although they rated individual topics within this session, such as safety training, higher. Additionally, students in all programs were only "somewhat satisfied" (or "somewhat dissatisfied") with their training in lab techniques. NIH Scholars students were most satisfied with their lab training, perhaps because of the extensive lab techniques course in which they participate. Some students, particularly from the UROP program, indicated that workshop content was not new material for them nor relevant to their particular research placement. Students reported that the communication skills workshops, particularly the poster presentation and writing workshops, were more helpful to their learning. NIH Scholars students were also "somewhat satisfied" with the journal club. Overall, students reported that they gained more from workshops that focused on communication skills and professional dissemination of scientific results than they did from workshops that focused on basic skills, such as lab techniques or safety.

Research outcomes

Student satisfaction with the research experience: Almost all students were highly satisfied with their research experience. Students rated their overall research experience as follows:

- *NIH Scholars*: 64% excellent (n=7), 36% good (n=4)
- *UROP*: 69% excellent (n=11), 25% good (n=4), 6% fair (n=1)
- *BURST*: 67% excellent (n=10), 27% good (n=4), 6% fair (n=1)

We will briefly describe students' research outcomes from each program. Then we will summarize key findings from each of the six research gains scales.

BURST: BURST students made the strongest gains in the intellectual development of "thinking and working like a scientist," and the weakest gains in "clarification or confirmation of career and educational plans." Because they are novice researchers, basic cognitive gains in scientific thinking and conceptual knowledge of their project may have been more significant to them than more advanced research students.

UROP: UROP students made the strongest gains in developing the identity and temperament of a scientist, classified as "becoming a scientist" in our framework, and made the weakest gains in "career clarification and confirmation." Interestingly, UROP students tended to be older and more advanced in their undergraduate careers than BURST students, yet career clarification was still not an important outcome for them.

NIH Scholars: NIH Scholars' strongest gains were also in the identity development and professional growth of "becoming a scientist." Like the UROP students, NIH Scholars students tended to be somewhat more advanced in their undergraduate careers. However, there were a significant number of sophomores in the program. These younger students also made strong gains in "becoming a scientist." NIH Scholars' weakest gains were in "career clarification and confirmation," though NIH Scholars rated this category higher than their peers in the BURST or UROP programs. Underrepresented groups of students may have had less exposure to different

career and educational options and may have found the exposure to career options through research to be more helpful than their majority peers (Arnold, 1993; Asera & Treisman, 1995; Seymour & Hewitt, 1997).

We now summarize findings from the research gains scales.

Thinking and working like a scientist: The category of "thinking and working like a scientist" encompasses intellectual gains in the application of scientific knowledge and skills, understanding the process of scientific research, and increasing disciplinary and conceptual knowledge. Students in all three programs made greater gains in basic cognitive skills, such as understanding the research process and data collection methods, than higher-order scientific abilities, such as designing and refining an experiment, a finding corroborated in other studies of UR (Hunter et al., 2007; Kardash, 2000). UROP students, however, made stronger gains in data analysis and interpretation than their novice peers in other programs.

Personal/professional gains: In the category of "personal/professional gains," students noted increased confidence in their ability to do research, and to make a contribution to scientific knowledge. They also described the benefits of establishing a collegial relationship with a mentor and peers. With little variation among programs, students made gains in many different types of confidence, including increased confidence that they could "do" science, "be" a scientist, and contribute to their field. Though most students in all three programs seem to be satisfied with their relationships with their research mentors, some students expressed that their mentors were not available as often as they needed.

Becoming a scientist: Through participation in research, students began to adopt the behaviors and attitudes necessary to become a successful scientist. Students—particularly the more experienced students in the UROP and NIH Scholars programs—made considerable gains in developing an understanding of research and the temperament that is required to be a research scientist. Within this category, students in all three programs made weaker gains in independence than in other areas, such as taking care with lab procedures.

Enhanced career/graduate school preparation: Undergraduate research also helps students to feel prepared for graduate school and future careers. Research enhances students' résumés, and provides opportunities to network with faculty and other scientists. Students in all programs reported that research helped them to feel prepared for their future careers and graduate school, though this category was not rated as highly overall as were the intellectual gains of "thinking and working like a scientist" or the personal and professional benefits of "becoming a scientist." Students strongly believed that their résumés were enhanced through their research experience, yet they were slightly less convinced that research had prepared them for a job. UROP students felt the most prepared by research for graduate school, not surprising given that UROP students tended to be more advanced in their undergraduate careers and had more research experience. Their strong gains in "becoming a scientist" are consistent with the notion that they are the most likely to be planning graduate work or careers in science.

Clarification of career and educational aspirations and interests: Through their participation in research, students sustained or increased their interest in the field, gained knowledge about

graduate school and career options, clarified or confirmed their intentions to go to graduate school, and clarified whether scientific research would be a suitable career. Students in all three programs reported only slight gains in clarification of their career and educational paths. However, NIH Scholars students expressed a greater interest than UROP or BURST in a career in science as a result of their participation in research, indicating that career clarification may be a more important benefit for students from underrepresented groups. Participation in research also seemed to have some impact on students' educational plans; a majority of UROP students (73%) and a solid minority (40%) of NIH Scholars students reported that their research experience had influenced them to pursue a graduate degree in a STEM field. Students' responses in this category also indicate that the decision as to whether research is a suitable career path is typically made later in students' undergraduate career and after multiple research experiences.

Skills: Students in all programs reported stronger gains in communication skills than in other areas, such as laboratory or organizational skills, a finding echoed in our previous work on UR (Hunter et al., 2007; Seymour et al., 2004). UROP and NIH Scholars students, in particular, made the most extensive gains in communication skills, perhaps because of the oral presentation requirements of those programs.

Authenticity of the research experience: Due to our findings from the prior evaluation of BSI programs that some students may not have had access to authentic scientific research activities or adequate mentoring in their research positions, we added survey items to assess the authenticity of students' research experiences. We asked students to rate their level of participation in specific activities that appear to be markers of authentic science. In response, almost all students reported that they engaged in "real-world science research," with UROP students more likely to have engaged in authentic research than BURST or NIH Scholars students. Many students also reported that they "felt like a scientist" during their research experience. BURST students were slightly less likely to report that they felt like a scientist, perhaps because of their novice status in the lab. However, students in all three programs were not likely to have tried out new ideas or procedures on their own or to interact with other scientists outside the University of Colorado. Nevertheless, it appears that most students engaged in authentic research at a level appropriate for undergraduates. In fact, no students in any of the programs reported that they engaged in real-world research "not at all" or only "a little."

Conclusion and recommendations

In sum, the vast majority of students in all three programs were highly satisfied with their research experience and the support they received from their research program staff and activities. Interestingly, there were few differences among programs in either student outcomes or suggestions for improvement. Due to the similarity of students' responses across programs and the small number of survey participants, it is difficult, if not impossible, to make claims regarding programmatic differences.

Students were satisfied with many aspects of their programs, including the support they received from program staff, and the application and laboratory selection processes. On the whole, however, students in all three programs were less satisfied with program workshops than other

program elements. Students reported that they gained more from workshops that focused on communication skills and professional dissemination of scientific results than they did from workshops that focused on basic skills, such as lab techniques or safety. Some students felt that they had already gained knowledge about poster preparation or lab techniques through coursework or training in their research lab; therefore, they perceived program workshops as repetitive or irrelevant. We suggest that program staff articulate to students the learning objectives for program workshops and activities along with the importance of strengthening this knowledge for future scientists.

Additionally, students rated their program websites lower than other program elements, indicating that program websites could be updated to be more useful for students. While most students were satisfied with the level of financial support they received for their research work, a few UROP and BURST students were slightly dissatisfied with their stipend. Finally, a few students (particularly UROP and NIH Scholars students) desired to learn more from their program about the graduate school selection and application process and GRE preparation.

Overall, students in all three programs made strong intellectual, personal, and professional gains from their participation in research. Students' gains from research seemed to emanate from their access to original, authentic scientific work within a research group. The vast majority of students in all three programs appear to have engaged in "real-world" research under the guidance and support of a mentor in their lab. However, a few students indicated that they did not receive the mentoring that they needed in their lab. Moreover, the quality of students' relationship with their mentor and the amount of time they spent with their mentor was strongly correlated to their intellectual gains—though not their professional socialization gains—and their overall satisfaction with the research experience. Our previous research has demonstrated that a lack of support and guidance in the research experience can have negative consequences for students, including driving them away from graduate school or their discipline (Thiry et al., 2009). Nevertheless, the vast majority of students reported that they engaged in challenging, authentic research that benefited them intellectually, personally, and professionally.

Introduction

I. Program overview

This evaluation study was designed and conducted at the request of the Biological Sciences Initiative (BSI) and the NIH Scholars program at the University of Colorado at Boulder. The BSI has sponsored undergraduate research (UR) programs for several years, while the NIH Scholars is a newer program. Prior evaluation of the BSI programs indicated that although the vast majority of students were highly satisfied with their research experience and made strong gains in a variety of areas, a minority of students may not have had access to authentic science or adequate mentoring (Coates et al., 2005). We designed the current study to build upon our past evaluation work documenting student outcomes and the influence of the research experience on students' career plans. We also sought to examine the quality of students' experiences and the processes through which specific outcomes arise. The study was designed to gather information from students from a comprehensive survey and in-depth interviews.

During the period studied, the BSI sponsored two types of programs, known as UROP and BURST, through their funding from the Howard Hughes Medical Institute (HHMI). The NIH Scholars program was funded through money provided by the National Institute of Health and HHMI. These programs were designed to provide research opportunities to strengthen students' science education at the university, provide hands-on research experience, and draw students into advanced study or a career in science. We will now discuss each program in greater detail.

UROP (Undergraduate Research Opportunities Program) is an established university program that supports UR experiences in all fields, not just science. BSI supports this program by providing individual grants for students undertaking UR in life-science related fields. While the UROP students' grants are provided through the BSI, the program as a whole is administered through the central UROP office, with whom the BSI cooperates. Thus the BSI's ability to change aspects of this program is somewhat constrained. However, because the BSI provides a higher stipend than the standard UROP stipend, they do have some leverage by which they can require UROP students to attend training sessions, complete an evaluation or report, and meet other requirements that are specific to BSI-funded students. The UROP program was previously available only to upperclassmen, although it is now open to all full-time students, first-year to seniors. Thus UROP students in this study tended to be more advanced or more experienced students. The students are also required to present a poster at the end of their experience and attend two training workshops on creating and presenting scientific posters.

The BURST (Bioscience Undergraduate Research Skills and Training) program was designed by BSI as an introductory research experience to meet the gap in UR opportunities for younger students. No previous research experience is required and preference is given to sophomores and juniors. Students who plan to graduate during the term of the award are not eligible for the program. Like UROP, the program is designed to be an intensive engagement, with a recommended commitment of 10-12 hours per week during the academic year and 30-40 hours per week for the summer term. In addition, students participate in a series of workshops and trainings to prepare them for research work and enhance their laboratory skills and understanding of scientific research and writing. The workshops consist of a one-day orientation which covers safety, laboratory techniques, experimental design, and reading journal articles, followed by two

additional sessions on writing scientific proposals. The final two sessions are informative, working sessions designed to help students write their own scientific research proposal.

BSI is also a partner in the NIH/HHMI Scholars Program for Diversity in the Biosciences, which was developed and introduced during the 2003-04 academic year. However, the NIH Scholars program is organized and run by its own program staff. This program targets ethnic minority and first-generation, low-income students and offers a multi-year research experience. Entry-level research students participate in a weekly laboratory skills training course in the fall and a weekly journal club in the spring. The laboratory skills training course covers topics such as lab safety, keeping a lab notebook, introduction to instrumentation and laboratory techniques, ethics, and issues related to scientific publication. The journal club is designed to enhance students' analytical reading, writing, and presentation skills. Students choose articles related to their research work and discuss those articles with their peers. They also write and present aspects of their research to the class.

II. Evaluation design

This evaluation study was designed to gather information on student outcomes from these three undergraduate research programs sponsored by the Biological Sciences Initiative (BSI), and the NIH/HHMI Scholars Program for Diversity in the Biosciences. The study focuses on the gains students made from participating in research, student satisfaction with their research experience and their research program, and the influence of participation in research on their career or educational plans. Particular activities (e.g. communication of research results) and interactions (e.g. with research group members) within the UR experience were also probed, to determine how student outcomes arise.

This study was conducted through the use of in-depth interviews and survey instruments grounded in research and partially piloted on other campuses. Interviews were designed to probe student gains and to explore the factors that might enhance or interfere with gains, such as research group and mentoring interactions, the fit of the student to the project, intellectual participation in "authentic" research, not just technical work, and the availability of resources, among others. Analysis of student interviews is ongoing and a report will be completed in the spring. This report will focus exclusively on findings from the survey instrument.

This study is of interest not only to the BSI and NIH Scholars programs for improving and evaluating their own services but of national relevance, given high interest in UR programs and strong belief in their efficacy in recruiting and training the scientific workforce. However, until very recently, little was known about the actual benefits to students of participating in UR or the processes by which these benefits were achieved. Our research group, Ethnography & Evaluation Research, has been at the forefront of a recent surge of research and evaluation activity on this topic, and this project provided us the opportunity to apply our research findings toward understanding and improving outcomes for a specific UR program.

The evaluation questions addressed by this study are:

1. What gains do students make from their research experiences?
2. Are students satisfied with their research experience, and with the training and support provided by their programs?

3. What critical elements of the research experience can be identified from survey and interview responses (e.g. authenticity of experience, mentoring, etc.), and how do these contribute to student gains?
4. For each of these questions, can any differences in the UR experience and its outcomes be discerned for different student groups (if numbers permit)[1]: experienced vs. inexperienced UR participants, male vs. female participants, and white vs. minority participants?
5. What can be suggested for further refinement of the program itself, and for further evaluation studies both through refinement of this survey and through other methods?

We will discuss the survey instrument and evaluation methodology in detail in the Methods section, but first we will discuss findings from previous research on UR that informed the development of this survey.

1. Relevant findings from previous research on UR

Ethnography and Evaluation Research (E&ER) has long been interested in student gains from UR experiences. This previous work gave us insight about the types of gains to probe in this evaluation study and the factors that might be important in outcomes from the student UR experience.

Since 2000, E&ER has been engaged in a study of STEM undergraduates and faculty who did, and did not participate in summer UR programs at four liberal arts institutions with a strong history of UR. The study is both comparative—with student and faculty participants and non-participants of various types—and longitudinal, tracking both participating and non-participating students through their senior year and beyond graduation. Previous articles have described the benefits of UR as perceived by participating students (Seymour et al., 2004) and as compared to faculty perceptions of student gains (Hunter et al., 2007). A forthcoming article (Thiry et al., 2009) examines whether students' gains from UR can be achieved in other contexts, such as jobs, internships, or coursework. Collectively, these findings support the proposition that UR is an intellectual, personal and professional growth experience with many transferable benefits.

One of the main benefits to students from UR was the opportunity to engage in "thinking and working like a scientist." We noted in students a process that is encouraged by active engagement in research: many students improved their ability to bring their knowledge, critical thinking, and problem-solving skills to bear on real research questions; some students went further, gaining insights into how to generate and frame research problems; and a few developed a more profound understanding of how scientific knowledge is constructed.

However, the most distinctive characteristic of students' reports of benefits from UR was their focus on personal-professional transitions. Overwhelmingly, students defined UR as a powerful affective, behavioral, and personal-discovery experience whose dimensions had profound significance for their emergent adult identity, sense of career direction, intellectual and professional development. Students' comments in two categories ("personal/professional gains" and "becoming a scientist") described growth in confidence to do science, independence in their

[1] Sample size in this study did not permit the use of tests of statistical significance to discern group differences.

approach to both research and learning, responsibility for the direction and quality of their projects, and collegiality in their working practices.

Though the research literature on UR is sparse, our findings have echoed those found in other studies. Indeed, our findings have extended the previous research literature on UR as we documented many personal, professional, and affective gains from UR that had not been found in previous work. The majority of previous work on UR has documented the educational and career gains from participation, including increased interest in science careers (Bauer & Bennett, 2003; Russell, 2005; Zydney, Bennett, Shahid, & Bauer, 2002), particularly for students from groups underrepresented in STEM fields (Nagda, Gregerman, Jonides, von Hippel & Lerner, 1998). Participation in research has also been shown to increase students' awareness of career options (Hunter et al., 2007; Ward, Bennett & Bauer, 2002); and enhance their preparation for graduate school (Alexander, Foertsch & Daffinrud, 1998; Hunter et al., 2007; Merkel, 2001; Russell, 2005). The influence of undergraduate research on career choice is a subject of substantial interest but little consensus; it appears to depend strongly on the student group under study. Although our research has demonstrated that UR participation serves principally to confirm or clarify pre-existing career and educational goals (Seymour et al., 2004; Hunter et al., 2007), other studies have reported that participation in UR increases the likelihood that students will pursue graduate school (Bauer & Bennett, 2003; Kremer & Bringle, 1990; Russell, 2005), particularly for minority students (Alexander, Foertsch, & Daffinrud, 1998; Barlow & Villarejo, 2004; Hathaway, Nagda, & Gregerman, 2002). Undergraduate research has also been argued to increase retention and graduation rates (Kim, Rhoades, & Woodard, 2003), especially for minority students (Barlow & Villarejo, 2004; Nagda et al., 1998).

Perhaps more importantly, recent research on UR has begun to demonstrate the cognitive, personal and professional benefits to students of participation. Documented in our research and corroborated by other studies are increases in students' skills in communication (Bauer & Bennett, 2003; Kardash, 2000; Ward, Bennett & Bauer, 2002), technical and laboratory work (Ward, Bennett & Bauer, 2002; Lopatto, 2004), teamwork (Ward, Bennett & Bauer, 2002), critical thinking and scientific analysis (Bauer & Bennett, 2003; Ishiyama, 2002; Merkel, 2001) and scientific research skills (Kardash, 2000; Lopatto, 2004). Through UR, students begin to take greater initiative and responsibility for their own learning (Seymour et al., 2004; Hunter et al., 2007; Bauer & Bennett, 2003; Lopatto, 2004; Rauckhorst, 2001; Ward, Bennett & Bauer, 2002) and gain confidence in themselves as independent learners (Hunter et al., 2007; Merkel, 2001; Rauckhorst, 2001; Russell, 2005, Ward, Bennett & Bauer, 2002). A few studies have addressed students' awareness of the nature and character of scientific research, finding that students gained an increased ability to cope with setbacks and ambiguity (Hunter et al., 2007; Lopatto, 2004; Merkel, 2001; Ward, Bennett & Bauer, 2002). Though UR clearly has many intellectual benefits, students have less often reported gains in desirable but difficult higher-order thinking skills such as identifying a research question, and designing and refining an experiment (Hunter et al., 2007; Kardash, 2000). Collectively, these research findings have informed the development of the survey utilized in this evaluation, the Undergraduate Research Student Self-Assessment (URSSA).

Finally, it is important to note that our group's previous research refers specifically to summer research experiences at liberal arts colleges. While these colleges have a long history of supporting and conducting undergraduate research, and represent, we believe, some of the best available educational experiences from UR, many more students participate each year in UR

programs on research university campuses. We do not know to what degree our previous findings may apply to students' UR experiences in research universities, or how UR experiences differ in these two contexts. In addition, almost all of our study participants were affluent, white college students and there is less research available about how the nature of gains from UR may differ for first-generation college students or those from underrepresented groups. The present evaluation study and piloting of the URSSA survey instrument at other research universities may provide insight into the question of whether institutional type or demographic characteristics influence students' gains from the UR experience.

B. Study Method and samples

In this section we outline our measurement approach and trace its grounding in previous qualitative work and prior evaluation of BSI programs.

1. Development of the survey instrument

The present evaluation was designed to focus on the gains that participating students make in doing UR and the factors which support or interfere with these gains. Previous qualitative research from our group, as discussed, had identified these gains—some of which were consistent with gains hypothesized in the literature, and others which were not. The prior survey instrument used to evaluate the BSI's UR programs was based upon findings from this qualitative study; however, discrepancies between students' and advisors' responses to quantitative and open-ended items led us to believe that some survey items may not have been entirely valid and were not nuanced enough to capture the shades of difference in students' research experiences. We were particularly concerned to understand the authenticity of students' experiences and their access to adequate mentoring and advising. Therefore, we secured a grant from the National Science Foundation to revise and improve this survey in the hopes of creating an instrument that could be used as a general tool to assess students' outcomes from their research experience and the processes by which those outcomes were achieved. The revised instrument, utilized in the current evaluation of BSI's and NIH Scholars' UR programs, is called the Undergraduate Research Student Self-Assessment (URSSA).

Some aspects of the UR programs at the four original campuses are probably specific to colleges like these: undergraduate-only, teaching-oriented campuses with strong traditions of UR as part of their science programs and with science faculties who have deliberately chosen to teach at a college where their research activities focused on undergraduate students, and not graduate students. However, the broad and transferable nature of the benefits to students that were discovered in the four-college study suggested an opportunity to expand, on an experimental basis, the use of the new UR survey. The BSI-sponsored programs at CU-Boulder became one of the first sites beyond the original research locations where these gains items were used, piloting the URSSA instrument in the somewhat different UR environment of a research university. The survey was not piloted with previous cohorts of NIH Scholars students, though it has been piloted with a broad and diverse national sample of undergraduates in the summer and fall of 2008.

A new aspect that we hoped to bring to this study was the development of specific research gains scales grounded in the qualitative work of E&ER. The scales cluster around six major gains areas identified in our previous research:

- ***Thinking and working like a scientist***: This category describes students' gains in the application of scientific knowledge and skills to research work. Students develop an understanding of scientific research through hands-on experience and increase their knowledge and understanding of scientific concepts and theory.

- ***Personal and professional gains***: In this category, students demonstrate increased confidence in their ability to do research, and to contribute to their field. Students also establish collegial, working relationships with a more experienced mentor, faculty advisor, and/or peers.

- ***Becoming a scientist***: This category encompasses students' gains in the behaviors and attitudes necessary to become a research scientist, such as taking "ownership" of a project, and demonstrating initiative and independence. Students begin to develop an identity as a scientist and gain a greater understanding of professional practice.

- ***Enhanced career/graduate school preparation***: In this category, students benefit from real-world work experience, graduate school/job preparation, résumé enhancement, and career advice.

- ***Clarification, confirmation, and refinement of career and educational paths***: Participation in research helps students to clarify their career and graduate school intentions, gain greater knowledge of career and education options, identify a field of interest, and increase their interest in and enthusiasm for their field.

- ***Skills***: From research, students gain oral and written communication skills, as well as a host of other skills, such as laboratory and field skills, organizational and planning skills, and information retrieval and reading comprehension skills.

In addition to the above categories, we developed items to measure student satisfaction and to probe some aspects of the UR experience known to be important from the previous BSI evaluation, particularly the authenticity of the experience and students' interactions with their mentor, faculty P.I., and others in the lab. Overall, we sought to measure not only students' satisfaction with the experience, but the outcomes—student gains— of participation in UR, and to probe (where possible) the processes by which these were achieved.

2. Description of the survey instrument

The URSSA instrument focuses on students' rating of their gains in six specific gains areas (outlined above) that were originally described by students in the qualitative study. Students also evaluated their satisfaction with various aspects of the research experience and the program. Finally, they provided demographic data and answered questions about the specific activities in which they participated, the people with whom they interacted, their motivations to participate in UR, and their career plans, including changes in these plans prompted by the UR experience.

Most items are multiple choice or numerical ratings, with a few open-ended response items. For the gains items, ratings were scored on a four-point scale, with 1 = no gain, 2 = a little gain, 3 = a good gain, 4 = a great gain, (and NA = not applicable). Respondents also rated items regarding their satisfaction with the research experience on a 4-point scale, with 1=very dissatisfied, 2=somewhat dissatisfied, 3=somewhat satisfied, and 4=very satisfied. The helpfulness of program activities to students' learning was rated on a 4-point scale, with 1=not at all, 2=a little, 3=a good amount, and 4=a great deal. A few open-ended questions addressed the nature and quality of the experience, and sought advice for the program. The final instrument took approximately 20-30 minutes to complete and was administered online using the commercial tool, SurveyMonkey.

3. Procedures for obtaining the samples and response rates

We collected surveys from BURST, UROP, and NIH Scholars students in spring 2008 and from BURST students in summer 2008. All research students within these programs were invited to participate in the survey. Surveys, informed consents, and study procedures were approved by the Human Research Committee of the University of Colorado at Boulder.

BSI and NIH Scholars staff provided the evaluators with lists of research students and their contact information. E-mail invitations to participate in the survey were sent to 19 NIH Scholars students and 13 of them completed the survey for a response rate of 68%. In addition, e-mail invitations were sent to 16 academic year BURST students and 16 summer BURST students, 24 of whom completed the survey for a response rate of 75%. Finally, e-mail invitations were sent to 38 UROP students and 16 of them completed the survey for a response rate of 42%. The overall response rate was 59%. A total of three e-mail invitations were sent to each group. Approximately two weeks and four weeks after the initial e-mail, reminders were sent individually via e-mail to persons who had not returned the survey.

4. Analysis methods

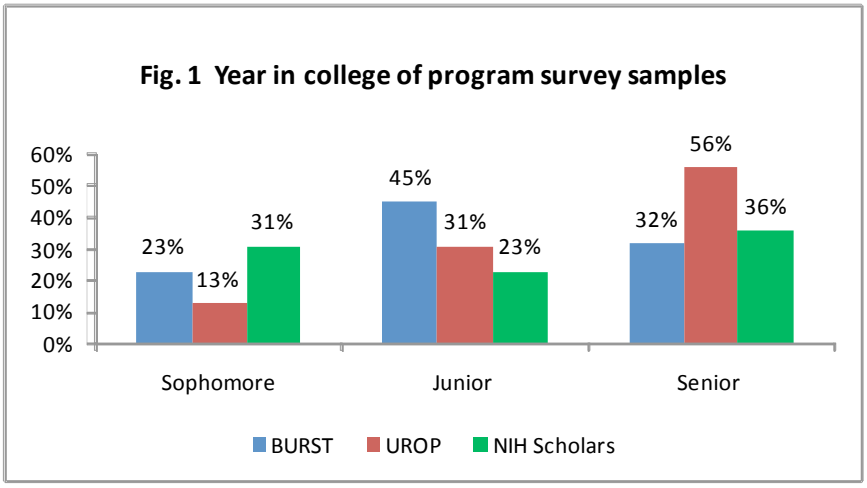
The quantitative data were entered into the statistical software package SPSS where descriptive statistics were computed. Means are reported for most of the ratings items, and frequencies for some of the multiple-choice items. Tests of statistical significance, such as t-tests or one-way ANOVAs, were not conducted because the small sample sizes for the surveys precluded meaningful statistical analyses of group differences.

Write-in responses to the open-ended questions were entered into a spreadsheet and coded as follows. Each new idea raised in a response was given a unique code name. As these same ideas were raised by later respondents, a tally was added to an existing code reflecting that idea. At times the write-in answers were brief and represented a single category, but more frequently, responses contained ideas that fit under multiple categories, and these were coded separately.

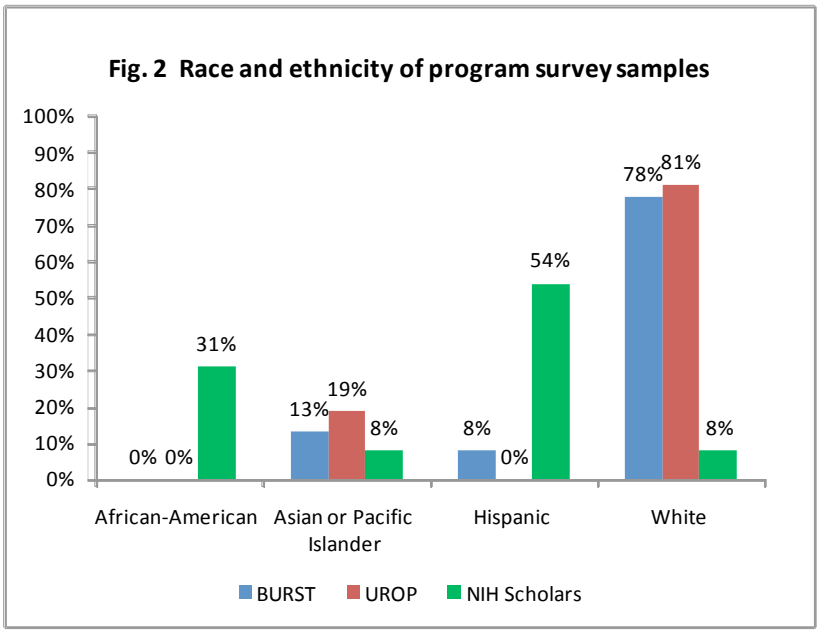
C. Demographic characteristics of survey samples

The demographics of the survey samples from each program reflect the diversity among the three programs and the different emphases of each. As Figure 1 demonstrates, UROP students were

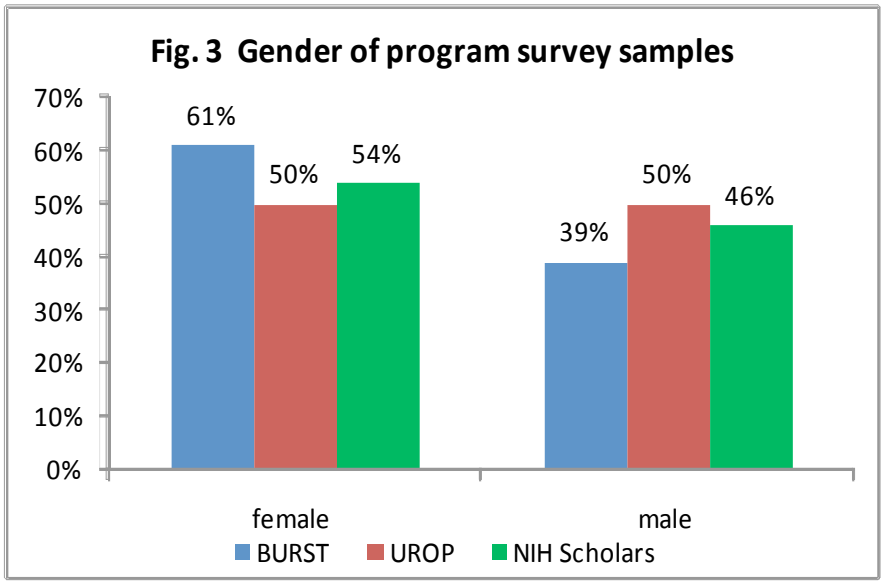
more advanced in their undergraduate careers, while BURST and NIH Scholars students were generally younger.



As might be expected, NIH Scholars students predominantly came from underrepresented groups in the biosciences, while BURST and UROP students primarily consisted of Whites or Asian/Pacific Islanders, groups traditionally overrepresented in the biosciences. Figure 2 illustrates the race and ethnic distribution of survey participants from each program.



All of the survey samples achieved gender parity. All three programs have a high proportion of women participants and have come close to meeting, if not surpassing, the proportion of women in undergraduate biological science nationally. In 2002, women earned 59% of all biological sciences baccalaureate degrees at U.S. colleges and universities (NSF, 2006). Figure 3 details the gender distribution of the survey samples.



D. Extent of students' research experience

As might be expected, the extent of students' prior research experience depended in part upon their program. BURST students had the least amount of experience, with most students reporting one summer of research experience—all but one of these respondents were summer BURST students—or only one or two semesters of academic year experience. However, there were a few BURST students with more extensive experience. UROP students were the most experienced researchers: more than half of them had three or more semesters of academic year experience, and almost all of them had participated in summer research. Because it is a multi-year research program, the extent of NIH Scholars students' prior research experience fell in between that of BURST and UROP. About half of the NIH Scholars students had only participated in one or two semesters of research, yet more than 2/3 of them had engaged in summer research. Tables 1 and 2 below outline the extent of students' academic year and summer research experience.

Table 1. The extent of students' academic year research experience

Extent of academic year research experience	BURST	UROP	NIH Scholars
None	39% (n=9)	0%	0%
1-2 semesters	38% (n=11)	40% (n=6)	54% (n=7)
3-4 semesters	9% (n=2)	33% (n=5)	31% (n=4)
5+ semesters	4% (n=1)	27% (n=4)	15% (n=2)

Table 2. The extent of students' summer research experience

Extent of summer research experience	BURST	UROP	NIH Scholars
None	33% (n=8)	13% (n=2)	31% (n=4)
1 summer	63% (n=15)	40% (n=6)	23% (n=3)
2 summers	4% (n=1)	20% (n=3)	46% (n=6)
3 summers	0%	27% (n=4)	0%

Findings

III. Program outcomes

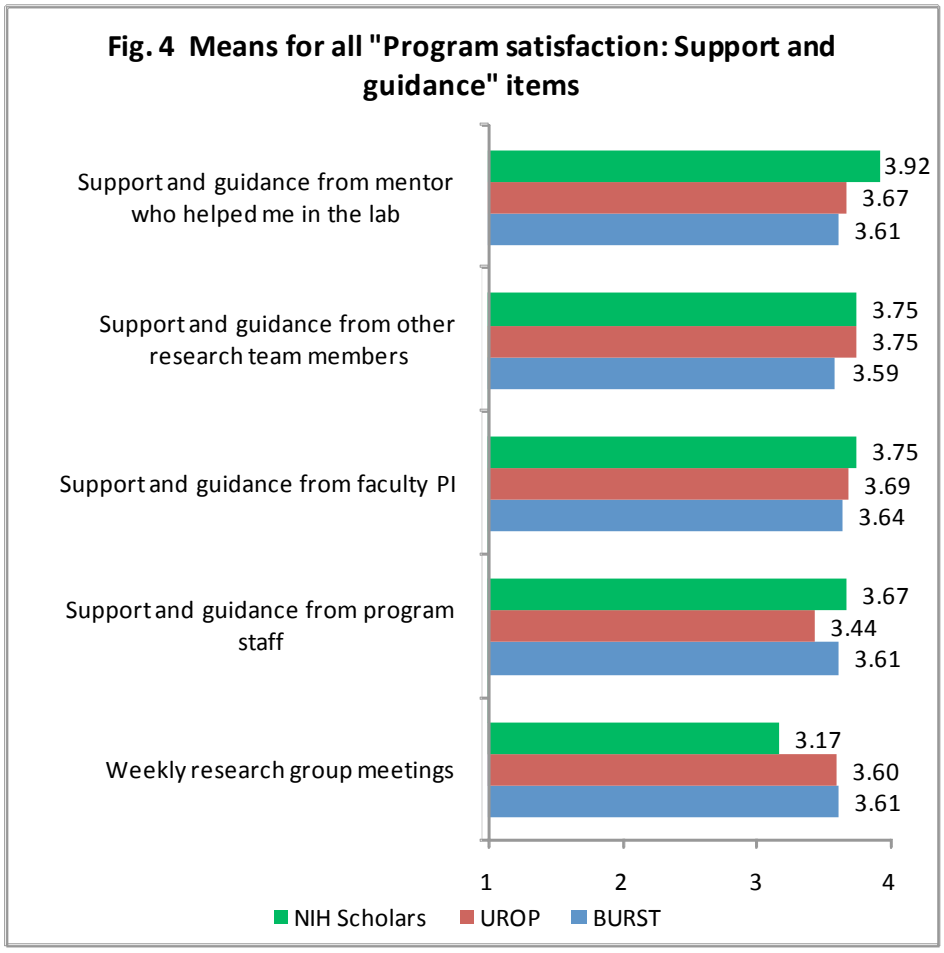
Students provided feedback about their satisfaction with their research programs. First, we will discuss students' satisfaction with the support and guidance they received within their research experience and from program staff. Then we will discuss students' satisfaction with program activities and workshops.

A. Support and guidance

On the whole, students felt supported by their research programs and their colleagues in their research labs. All of the means for these items were between 3.0 and 4.0 on a 4-point scale (between "somewhat satisfied" and "very satisfied"). Students in all three programs rated the amount of support and guidance they received similarly. NIH Scholars students were slightly more satisfied with the support provided by their research mentor, faculty P.I., and program staff than students from other programs, although they were less satisfied with their weekly lab meetings. Mentoring is important in all research experiences, but especially so for underrepresented groups of students who may not have received adequate support and access to advanced science prior to college (Adelman, 2006; Campbell, 1996; Wilson, 2000).

Responses from UROP and BURST students were similar, indicating that students in these programs did not perceive different levels of support from program staff or colleagues in their lab. Students in both programs were "somewhat" or "very" satisfied with the guidance and support provided by program staff.

In conclusion, students from all three programs were largely satisfied with the support they received in their research experience and from program staff. Indeed, 91% of BURST students, 92% of NIH Scholars students, and 94% of UROP students were "somewhat" or "very" satisfied with the support they received from program staff. Moreover, 100% of NIH Scholars students, 91% of BURST students, and 87% of UROP students were "somewhat" or "very" satisfied with the guidance they received from their research mentor. Figure 4 illustrates the means for these items.

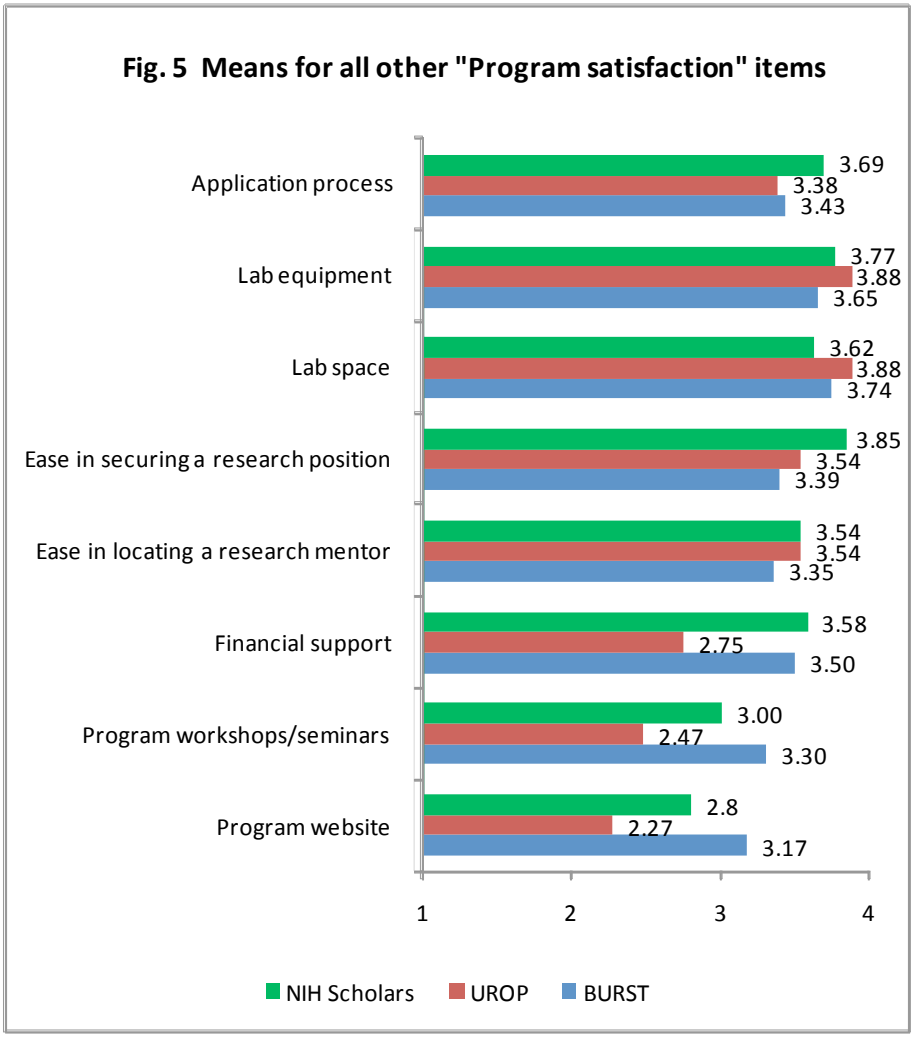


B. Program satisfaction

Students were largely satisfied with other aspects of their research programs. Again, almost all of the means for "program satisfaction" fell between 3.0 and 4.0 on a 4-point scale (between "somewhat satisfied" and "very satisfied"). However, UROP students were less satisfied with a few aspects of their program than BURST and NIH Scholars students, including financial support, and program workshops and seminars. For instance, two BURST students and two NIH Scholars were dissatisfied with program workshops, while seven UROP students expressed dissatisfaction with workshops. UROP students may be less satisfied with these elements because the UROP program is a campus-wide program and not administered directly by the BSI. In addition, UROP students also participate in fewer workshops and seminars than the BURST or NIH Scholars programs and tend to be more advanced in their undergraduate careers than BURST or NIH Scholars students. Thus UROP students may perceive that program workshops are less relevant or beneficial.[2]

[2] Preliminary analysis of UROP student interviews demonstrated that, for the most part, UROP students were less satisfied with workshops than BURST or NIH Scholars students and some students perceived them to be less relevant to their research experience. This perception originated, in part, from UROP students' advanced standing as students and because many of them received support and training in these topics from coursework and from their own research labs.

In general, students from all programs rated lab equipment and lab space, the application process, and the process of finding and securing a research position quite highly. Students in all programs were less satisfied with their program website, suggesting that websites for all of the programs may be updated to be more helpful or relevant for students. UROP students were also less satisfied with their financial support than BURST or NIH Scholars students. No BURST students and only one NIH Scholars student were somewhat or very dissatisfied with their financial support, while seven UROP students expressed this sentiment. Finally, UROP students were also less satisfied with program workshops and seminars. The means for these items are detailed in Figure 5 below.

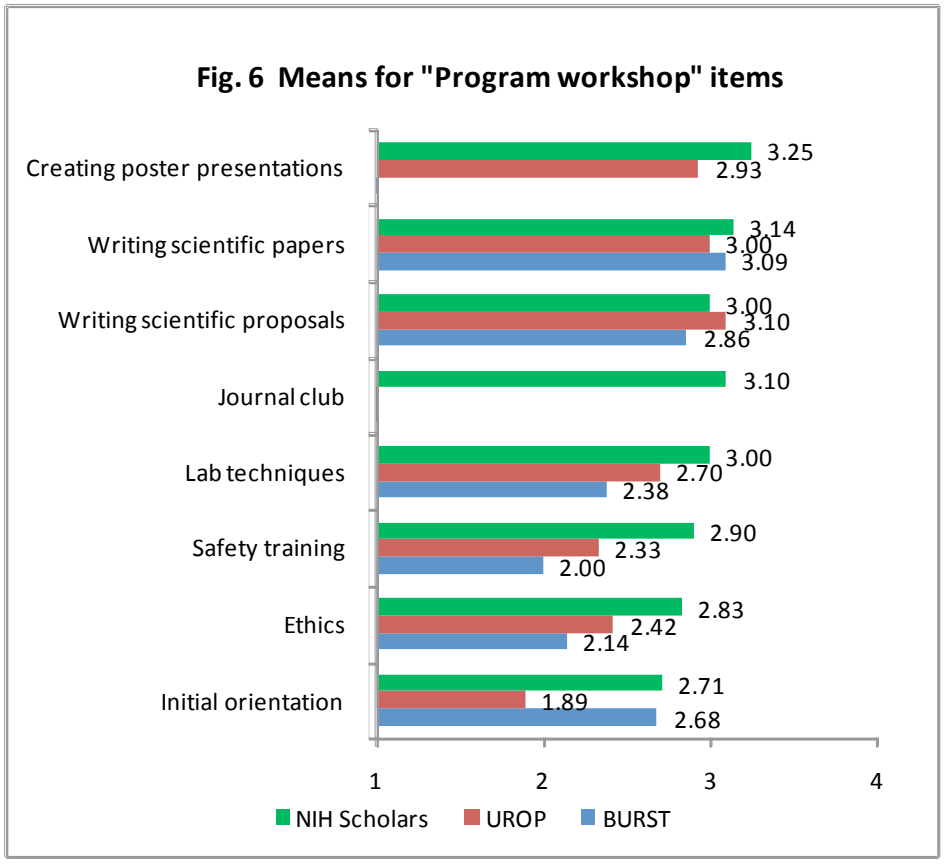


C. Program workshops and activities

As demonstrated in Figure 5, students in all programs were less satisfied with workshops and seminars than other aspects of their programs. Students in all programs were the least satisfied with their initial orientation session. Interestingly, students rated individual topics within the orientation session, such as safety training, as more helpful than the overall orientation. Thus,

students may have found some value in specific topics within the orientation session, though this did not necessarily translate to satisfaction with the orientation session in general. Additionally, students in all programs were only "somewhat satisfied" (or "somewhat dissatisfied") with their training in lab techniques.[3]

In contrast, students in all programs were most satisfied with workshops that focused on communication skills, particularly the poster presentation and writing workshops. NIH Scholars students were also "somewhat satisfied" (mean of 3.1) with the journal club—BURST and UROP students did not participate in this activity. In addition, summer BURST students were also "somewhat satisfied" (mean of 3.14) with their optional session on undergraduate research opportunities. Overall, students gained more from workshops that focused on communication skills and professional dissemination of scientific results than they did from workshops that focused on basic skills, such as lab techniques or safety, as demonstrated by the means in Figure 6 on items assessing particular program elements (not all of which were part of every program).

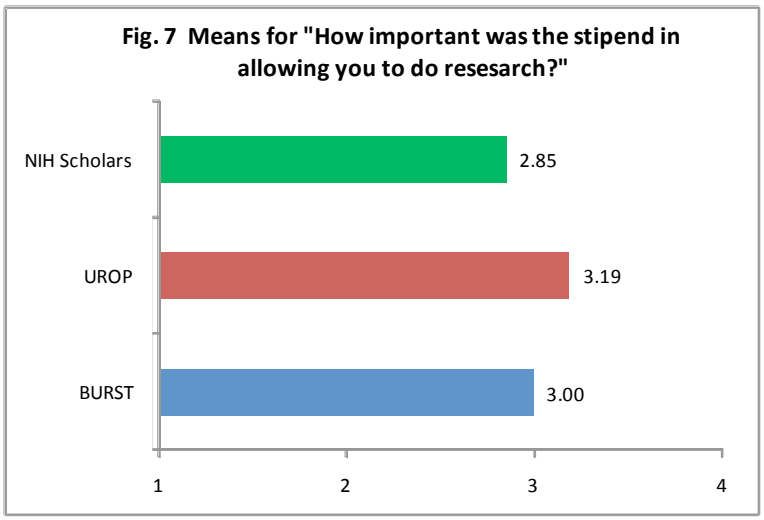


[3] Preliminary analysis of interviews with students in all programs indicates that many students felt that their training in lab techniques was a review of what they already knew. Additionally, some students felt the training was not relevant to their current research experience because it covered techniques and skills that they did not use in their research placement. In interviews, some students reported that lab training workshops were repetitive or redundant, while other students felt that they were a helpful "refresher" of basic lab skills.

In an open-ended question, students were also asked to provide additional commentary about program workshops. Only four students responded to this question, two each from the UROP and NIH Scholars program. All four students stated that they would have liked to have had workshops on applying to graduate school or taking the GRE.

D. Financial support

Students in all three programs generally rated financial support as "important." Students in the BURST and NIH Scholars programs rated the financial support between "slightly important" and "important," while UROP students rated it as between "important" and "very important." The greater financial need of UROP students than NIH Scholars students is somewhat surprising, given that many research programs for minority or first-generation college students are purposely designed to offer large financial incentives because of the greater financial need of many of these students (Arnold, 1993; Gandara & Maxwell-Jolly, 1999; May & Chubin, 2003). Nevertheless, very few students in any program found the financial support to be "not at all important," indicating that financial support is an essential element of support for each program.



E. Open-ended responses

1. Student feedback about program activities and workshops

Students were invited to add extra commentary about their experiences in their research program or specific program activities. Only eleven students in total offered a comment about their program. Four UROP students offered commentary about their program. Three of these students felt that the workshops were not relevant to their research experience or did not provide new skills and knowledge. The following quotes are representative of these sentiments.

> *The workshops didn't really provide any useful information to me. I learned more from my faculty advisor and lab members about how to make a poster and write and abstract. (UROP student)*

> *The workshops are by and large irrelevant for those of us who have participated in research more than once. (UROP student)*

Three NIH Scholars students offered mixed comments about their workshops. One student offered a comment similar to those of the UROP students, calling the workshops "repetitive" of what he already knew. Two NIH Scholars students indicated that they valued the journal club because it allowed them to build community with peers in the program and learn about other students' research projects.

> *The bi-weekly research meetings offered me a chance to learn about other research projects that were being worked on. There is a vast amount of wealth in the researching world and I am glad that I am a part of this growing community. (NIH Scholars student)*

> *The programs during the week were extremely beneficial. The weekly meetings where we reviewed research articles were extremely valuable. It would be nice to incorporate a component of bioethics into our weekly discussion and meetings; I feel this is a topic that is not always addressed. (NIH Scholars student)*

Finally, only four BURST students wrote in comments. One comment addressed the student's lab group and not the program itself. Nevertheless, she was satisfied with her interactions with her lab group and found them to be helpful to her learning.

> *I'm very privileged to work with such a great group of people!!! Everyone in my lab is smart, kind, and willing to drop what they're doing to teach us undergrads how to do different aspect of work/research in the lab. I am very honored to be part of their group. Thank you! (BURST student)*

Two students (both women) commented that their mentors were not helpful. However, one of these students wrote that the BURST program staff helped her to have a good experience in the program although she was dissatisfied with her mentor in the lab. These comments indicate that students' research experiences are variable and not all students receive the mentoring they need.

> *Mentors did not really understand the purpose of BURST, I ended up working by myself the entire time with very little guidance. I still am happy with my experience and managed to learn everything myself, but I think there should perhaps be more verification that the mentors will be responsible and actually work with the students in the future, because other students might not be able to adapt as well as I did. However, BURST staff have been very helpful with advising me throughout my lab issues, and I'm happy that they've been around to guide me when my lab wasn't. They've definitely made this experience comfortable and great, when otherwise it would have been a lot more daunting and possibly negative. (BURST student)*

> *I feel I would have benefitted more from the BURST program had my mentor been more helpful and supportive. She spent little time explaining methods and concepts and was not always willing to answer my questions. (BURST student)*

2. Students' suggestions for improvement of their research programs

In another open-ended question, students were asked, "What would improve your undergraduate research program?" Eighteen students responded to this question: seven NIH Scholars, six UROP, and five BURST students. There was no consensus among students as to how research programs may be improved, indicating that students do not perceive any glaring issues that need to be addressed among any of the programs.

The most common response to this question was that the student had no suggestions for program improvement. Four students (two NIH Scholars, one UROP, and one BURST) mentioned that they were satisfied with the program and that "nothing" would improve it.

Three BURST students—and no students from other programs—commented upon ways that program workshops could be improved. One student thought the orientation could be more relevant to the work that they would do in their research labs and two students suggested different subject matter for workshops but did not offer any ideas as to what this revised content should include.

> *More meaningful seminars and obligations, things that matter to the student instead of things we feel obligated to do. (BURST student)*

Three students (two UROP and one NIH Scholars) mentioned that they would like to receive greater financial support for their research work.

Two NIH Scholars thought that the program should be expanded to provide research opportunities for more students.

> *Allowing more potential candidates to experience research for those who are interested in it. This of course only applies if funding allows it. (NIH Scholars student)*

All other responses were individual responses. These responses included: provide more information about medical school (BURST student), require a greater time commitment in the lab (NIH Scholars student), provide more opportunities for building a scholarly community (NIH Scholars), continued exposure to lab techniques workshops (NIH Scholars student), provide opportunities for a multi-year research commitment (UROP student), have a panel of experts review program applications (UROP student), hold workshops that are discipline-specific (UROP student), and abolish the oral presentation and writing requirements (UROP student).

In conclusion, there was no consensus among students as to suggestions for improvement of their research program. Given that a small fraction of students did not see the value of program workshops or communication requirements, program staff may be advised to communicate the importance of these activities and the benefits that students receive from them.

IV. Research outcomes

In this section, we will discuss students' outcomes from their research experience, including their motivations to pursue research, their gains from the research experience, and the influence of the research experience on their educational and career interests and aspirations. We begin with a discussion of how students found out about their research program.

A. How students became aware of research opportunities

Students in all three programs commonly learned about research opportunities from a professor, academic advisor or friend in the program. NIH Scholars and BURST students were more likely to have found out about research opportunities through friends in the program, while UROP students were more likely to have heard about the program from a professor. Very few students knew about research opportunities before enrolling at CU. A few NIH Scholars students also learned about the program from multicultural programs on campus. On the whole, students tended to learn about research opportunities through informal methods, such as word-of-mouth from professors, advisors, or friends, and rarely learned about research opportunities through formal announcements or program websites.[4] Table 3 demonstrates the means by which students learned about research opportunities on campus.

Table 3. Students' responses to "How did you find out about research opportunities?" (select all that apply).

Item.	BURST (% yes)	UROP (% yes)	NIH Scholars (% yes)
From a professor.	50%	50%	15%
From an academic advisor.	21%	25%	31%
From a friend in the program.	25%	19%	54%
From a departmental announcement.	4%	6%	0%
From a program announcement.	4%	19%	0%
I already knew about research opportunities before enrolling at CU.	0%	14%	8%
From a professional conference.	0%	0%	8%
From a minority or multicultural program on campus.	0%	0%	15%
From website.	0%	0%	8%
From a graduate student.	4%	6%	0%

B. Students' motivations for engaging in research

Students expressed a variety of motivations for pursuing research opportunities. The most common motivations for students in all programs were to "explore my interest in science" and "to gain hands-on work experience in research." Many students also wanted to "find out what it is like to do research." Some students were also motivated to do research to gain letters of

[4] In interviews, several students from various programs mentioned that the programs could do more to inform students about research opportunities on campus. The results of this survey confirm this finding; students rarely learned about research opportunities through formal means or from the program itself.

recommendation or enhance their graduate school applications or résumés. However, students more often had intrinsic motivations to do research and seemed to be more motivated by the opportunity for intellectual growth or to explore their interests than by external factors, such as building their résumés.

Very few students were motivated by the reputation of the program. Given that many students learned about their research program through informal means, we can hypothesize that many students were relatively unfamiliar with the research program prior to their research experience and may not have been aware of its reputation. In conclusion, students' strong intrinsic motivations to pursue research suggest that most students engaged in research out of interest and passion, and did not think of it as just another job or line on their résumé. Table 4 outlines the percentage of students in each program who were motivated to participate in research by specific factors.

Table 4. Students' responses to "Why did you want to do research?" (select all that apply).

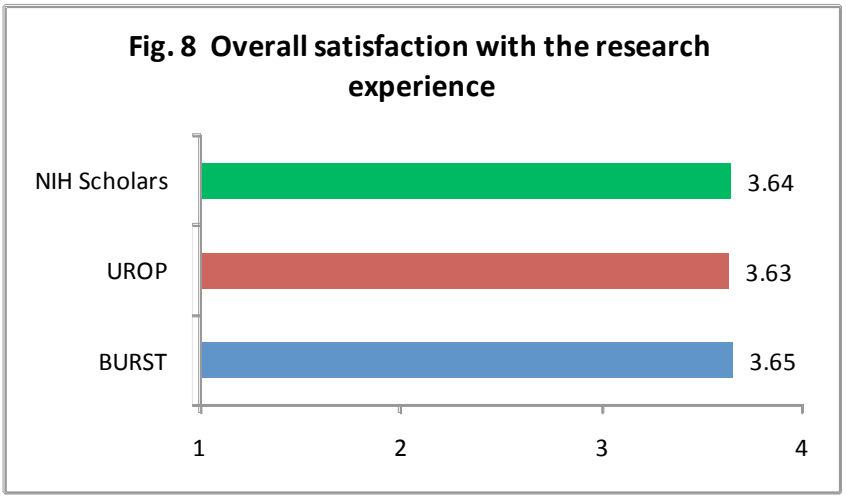
Item.	BURST (% yes)	UROP (% yes)	NIH Scholars (% yes)
To explore my interest in science.	79%	81%	100%
To gain hands-on work experience in research.	96%	94%	92%
To find out what it is like to do research.	63%	81%	77%
To clarify whether graduate school would be a good choice for me.	50%	50%	77%
To clarify whether I wanted to pursue a science research career.	54%	69%	62%
To enhance my application to graduate/medical school.	63%	69%	46%
To enhance my résumé.	50%	56%	46%
I wanted a good intellectual challenge.	58%	56%	38%
To clarify which field I wanted to study.	33%	50%	23%
To gain letters of recommendation.	42%	56%	8%
Because of the program's strong reputation.	21%	19%	15%
To work closely with a faculty member based on previous class experience.	21%	19%	15%

C. Students' satisfaction with the research experience

On the whole, students in all three programs were highly satisfied with their research experience. The means for all three programs were close to 4.0 on a 4.0 scale (3.0="good" and 4.0="excellent"). Only two students rated their experience as fair, and no students thought their research experience was poor. Students' ratings of their research experience were as follows:

- *NIH Scholars*: 64% excellent (n=7), 36% good (n=4)
- *UROP*: 69% excellent (n=11), 25% good (n=4), 6% fair (n=1)
- *BURST*: 67% excellent (n=10), 27% good (n=4), 6% fair (n=1)

As indicated above, the majority of students in all three programs rated their research experience as "excellent." Figure 8 illustrates the means for students' satisfaction with the research experience. [5]



V. Students' gains from research

Students provided feedback on their gains from research on the six scales described in the methods section: *thinking and working like a scientist, personal and professional gains, becoming a scientist, enhanced career and graduate school preparation, clarification or confirmation of career aspirations and interests, and skills*. We will discuss each of these scales in turn, but first we offer a brief overview of students' research gains from each program.

BURST: BURST students made their strongest gains in the intellectual development of "thinking and working like a scientist," and the weakest gains in "clarification or confirmation of career and educational plans." BURST students tended to be younger and less advanced in their undergraduate careers, so clarification of career plans may not be as significant to them at this point in their undergraduate career. Additionally, gains in basic scientific thinking may be more significant to novice students than to students with more extensive lab experience.

UROP: UROP students made their strongest gains in the identity and professional development of "becoming a scientist," and made the weakest gains in "career clarification and confirmation." Interestingly, UROP students tended to be older and more advanced than BURST students yet career clarification was still not an important outcome for them. This further indicates that students were motivated by intellectual and professional growth; career clarification may not have been a primary goal for them. Our prior research demonstrates that students who pursue undergraduate research are often interested in graduate school or a career in science prior to their participation in UR, and research is not a significant new influence on their career and educational paths (Hunter et al., 2007; Seymour et al., 2004). Instead, UROP students made gains in developing the professional identity of a scientist and adopting the traits, attitudes, and

[5] Items rated on a 4-point scale (1=poor, 2=fair, 3=good, 4=excellent).

temperaments necessary to be a successful scientist. However, these gains are indicative or their experience and advanced standing; UROP students were beginning to develop a professional identity as a scientist.

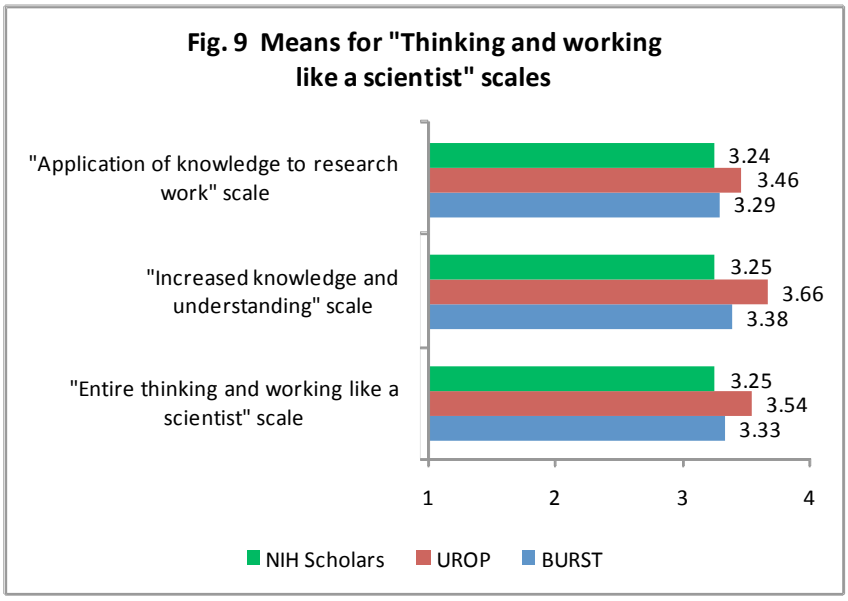
NIH Scholars: NIH Scholars' strongest gains were also in professional growth and development, in the category that we call "becoming a scientist." Because the NIH Scholars is a multi-year research program, some of the students were more advanced in their undergraduate careers or had extensive research experience. However, there was also a significant minority of sophomores in the program. These younger students also made gains in "becoming a scientist," though not to the extent of the more advanced students. Like their peers in other programs, NIH Scholars students weakest gains were in "career clarification and confirmation," though they rated this category higher than students in the BURST or UROP programs. Underrepresented groups of students may have had less exposure to different career and educational options than their majority peers and may have found this exposure through research to be slightly more helpful than the majority students in the BURST and UROP programs. Table 5 below illustrates the program means for students' research gains in each of the six benefits categories.

Table 5. Comparison of program means for students' gains from research

"Parent" categories: Grouping of gain-related codes and major subgroups of each Items rated on a 4 point scale (1=no gain, 2=little gain, 3=good gain, 4=great gain)	**BURST**	**UROP**	**NIH Scholars**
Thinking and working like a scientist (all items)	**3.33**	**3.54**	**3.24**
Application of knowledge and skills to research work: understanding science research through hands-on experience; understanding the nature of scientific knowledge; understanding how to approach research problems/design.	*3.29*	*3.46*	*3.24*
Increased knowledge and understanding of science and research work (theory, concepts, connections between/within sciences). Transfer between research and courses; increased relevance of coursework.	*3.38*	*3.67*	*3.24*
Personal/professional gains Increased confidence in ability to: do research, contribute to science, present/defend research, and in "feeling like a scientist." Establishing collegial, working relationships with professional mentor, faculty advisor and peers.	**3.27**	**3.38**	**3.22**
Becoming a scientist Demonstrated gains in behaviors and attitudes necessary to becoming a professional (student takes "ownership" of project; initiative; independent approach in decision-making). Greater understanding of the nature of research work and professional practice.	**3.33**	**3.67**	**3.50**
Enhanced career/graduate school preparation Real-world work experience; good graduate school/job preparation, résumé enhanced, career advice.	**3.10**	**3.45**	**3.15**
Clarification, confirmation and refinement of career/education paths Clarification of career and graduate school intentions; greater knowledge of career/education options; clarification of which field to study; greater likelihood of going to graduate school. Increased interest/enthusiasm for field; introduced new field.	**3.01**	**2.98**	**3.07**
Skills (all items)	**2.89**	**3.14**	**3.12**
Communication skills: presentation/oral argument; some writing/editing.	*2.70*	*3.11*	*3.19*
Other skills: Lab/field techniques; work organization; computer; reading comprehension; working collaboratively; information retrieval.	*3.00*	*3.15*	*3.08*

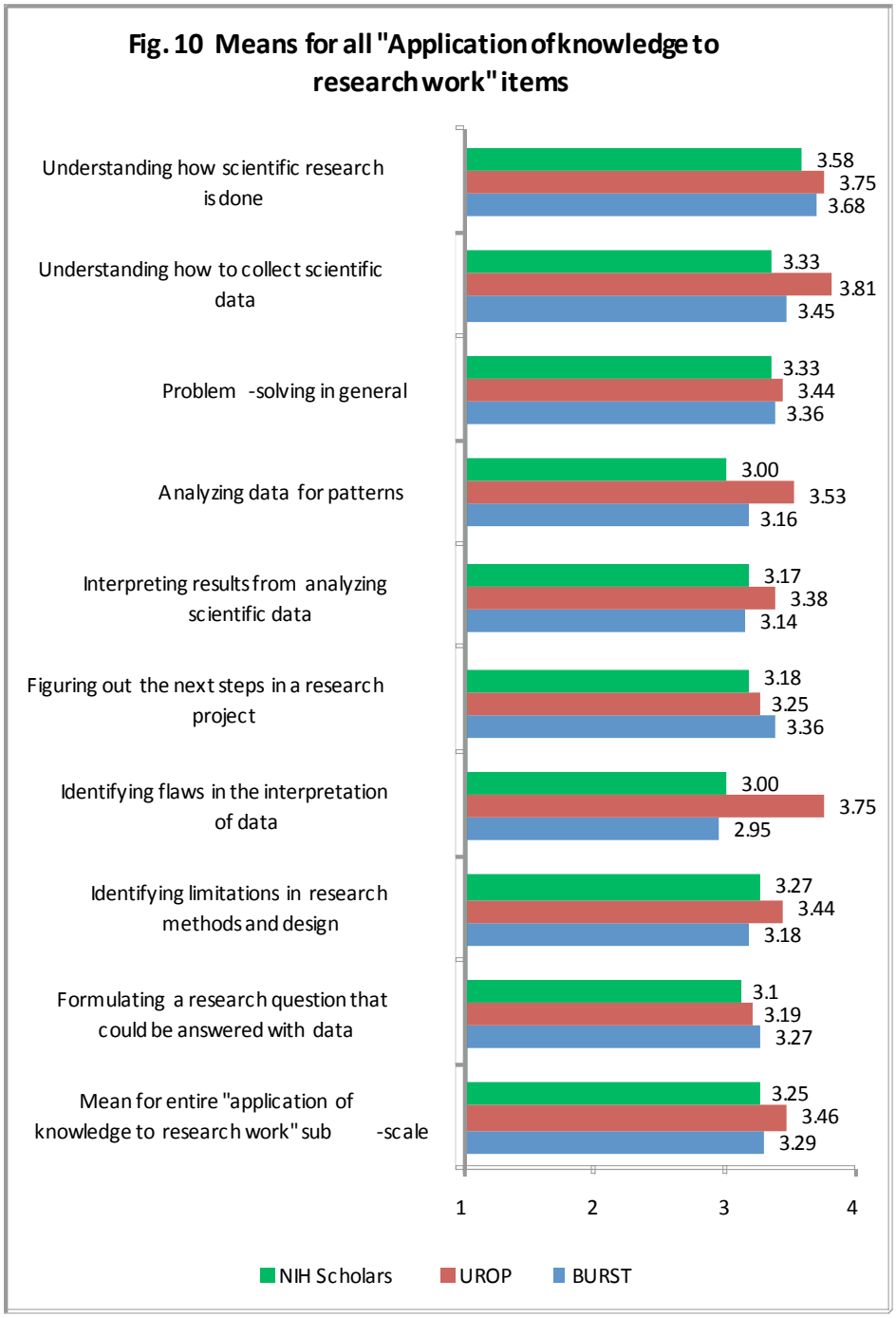
A. Thinking and working like a scientist

The category of "thinking and working like a scientist" encompasses intellectual gains in the application of scientific knowledge and skills, understanding the process of scientific research, and increasing disciplinary and conceptual knowledge. As mentioned previously, BURST students made their strongest gains in this category, although UROP students reported greater overall gains in this category than students in the other two programs. BURST students' intellectual gains may indicate that basic cognitive skills, such as understanding data collection methods, and problem solving, may be among the first gains in scientific skills and knowledge for novice research students. Figure 9 demonstrates the means for the entire "thinking and working like a scientist" scale and the sub-categories of "application of knowledge to research work" and "increased conceptual and disciplinary knowledge and understanding."



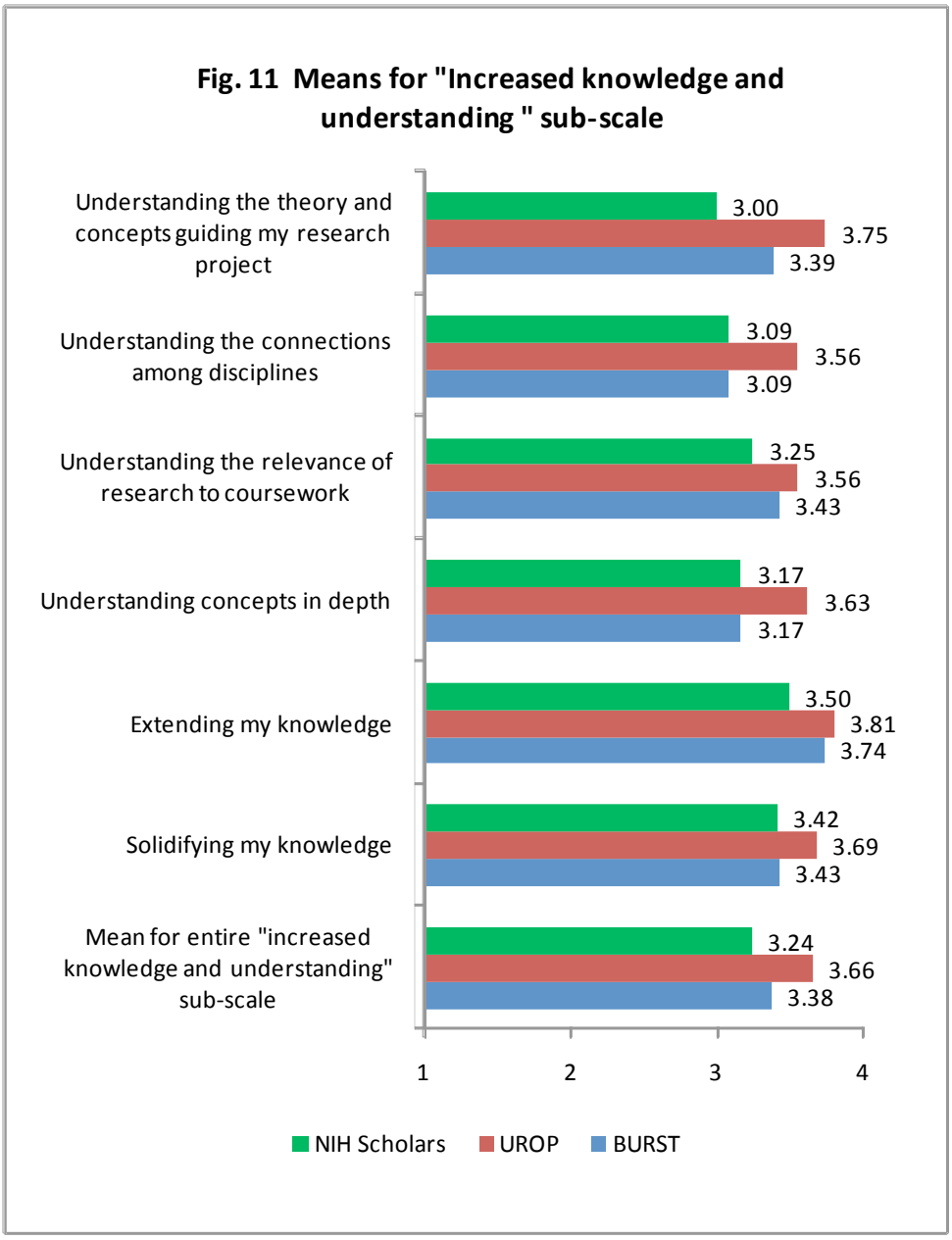
We will now discuss the two sub-categories of this scale in greater detail. Students' outcomes in the first subcategory comprise gains in the application of scientific knowledge and skills, and understanding the process of scientific research. In addition, some students gained a better understanding of the nature of scientific knowledge and that it is not absolute, but is subject to testing and revision.

For the most part, students made strong gains in basic research skills, such as understanding data collection and the scientific research process. However, students made weaker gains in the higher-order scientific thinking skills of research and experimental design, a finding corroborated by prior research on UR (Hunter et al., 2007; Kardash, 2000). Nevertheless, most students across all programs reported "good" or "great" gains on all items in this sub-category, indicating that the majority of students made substantial intellectual and scientific thinking gains from their exposure to "real-world" research.



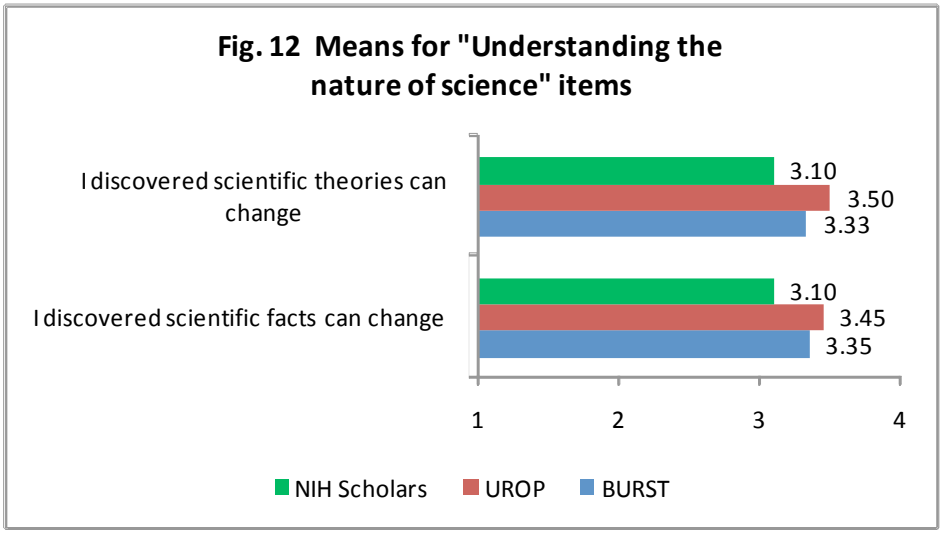
Benefits in the second sub-category of intellectual gains include increases in students' conceptual and theoretical understanding of their projects, deepening of their disciplinary knowledge, an increased appreciation for the relevance of coursework to their research, and an increased understanding of the connections within and between disciplines. BURST and NIH Scholars made gains in lower-level knowledge and understanding, while UROP students made greater gains in more advanced theoretical understanding of their projects. Overall, however, students from all programs reported increases in their disciplinary and conceptual knowledge and

understanding as all means for these items fell between 3.0 and 4.0 on a 4-point scale. Figure 11 below outlines the means for all items in this sub-category.



Prior studies have shown that undergraduate research students rarely gain higher-order scientific thinking skills, such as understanding the nature of scientific knowledge (Hunter et al., 2007; Kardash, 2000). On the other hand, students in this study rated their growth in understanding that scientific knowledge is falsifiable and subject to revision equivalently to some other areas of intellectual growth, such as understanding scientific concepts or analyzing data for patterns. Not unexpectedly, UROP students reported considerable growth in understanding the nature of scientific knowledge. Due to their more advanced status, UROP students generally had a greater foundation for achieving this level of cognitive growth and development. However, NIH

Scholars and BURST students still reported relatively strong gains in this area, which is particularly surprising for BURST students because they were research novices. Figure 12 details the means for "understanding the nature of science" items.



In an open-ended question, students were asked, "What did you discover about the nature of science?" Twenty-two students responded to this question: six NIH Scholars, twelve BURST, and four UROP students. There were a broad range of responses to this question, with little consensus among students about what they discovered about the nature of science. There were no differences among students from different programs in responses to this item. Moreover, some students mentioned issues about the research process (e.g. requires disciplinary knowledge) rather than the way that scientific knowledge is constructed by a scientific community. Despite extensive piloting of the survey instrument, students may not have understood the distinction between the two questions, one about the process of research and one about the nature of scientific knowledge. Students' responses were as follows:

Six students observed that scientific knowledge is not absolute, but is falsifiable and subject to revision.

> *Accurate description of methods and materials is essential to increasing the power of one's findings. Data can only suggest, but never offer 100% certainty. (UROP student)*

> *Science is always evolving and changing. Something you thought to be concrete one day may completely change, altering your view of the world. (BURST student)*

Four students commented that there is still a lot to learn in scientific fields.

> *It is more vast and complex than I ever imagined. There is a lot to still be understood. (NIH Scholars student)*

> *It's still quite murky at this point, and there is so much that is still unknown. (BURST student)*

Two students reported that scientific research requires a substantial amount of disciplinary and theoretical knowledge.

> *Science is a deep and complex field. There are so many theories and scientific processes that are used in research every day. It's very inspiring to be able to witness these theories in research in a hands-on environment. (NIH Scholars student)*

Two students mentioned that scientific results can be unpredictable.

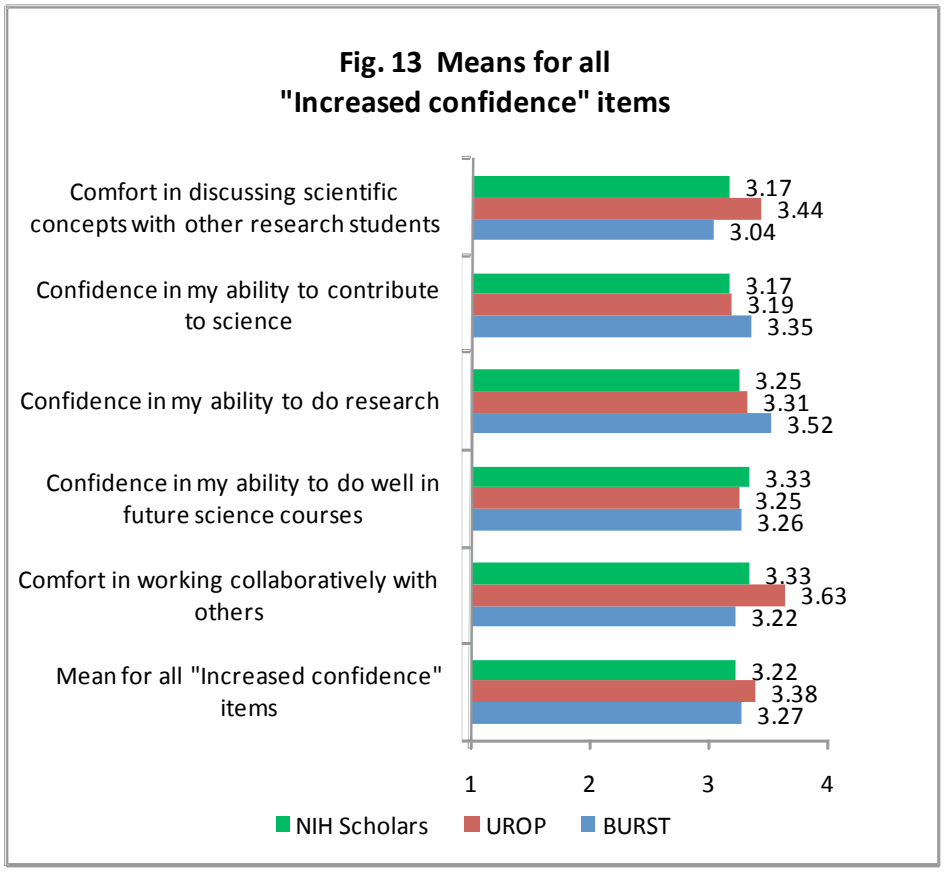
> *Science is completely unpredictable and you have to 'roll with the punches'. (NIH Scholars student)*

Individual students also commented that scientific knowledge is interdisciplinary, and that models are not always accurate. Two students learned about experimental design and a UROP student learned that anyone can participate in science and that scientists are "real people." A few students also discussed aspects of the *process* of scientific research (e.g. that it is slow or prone to failure and setbacks).

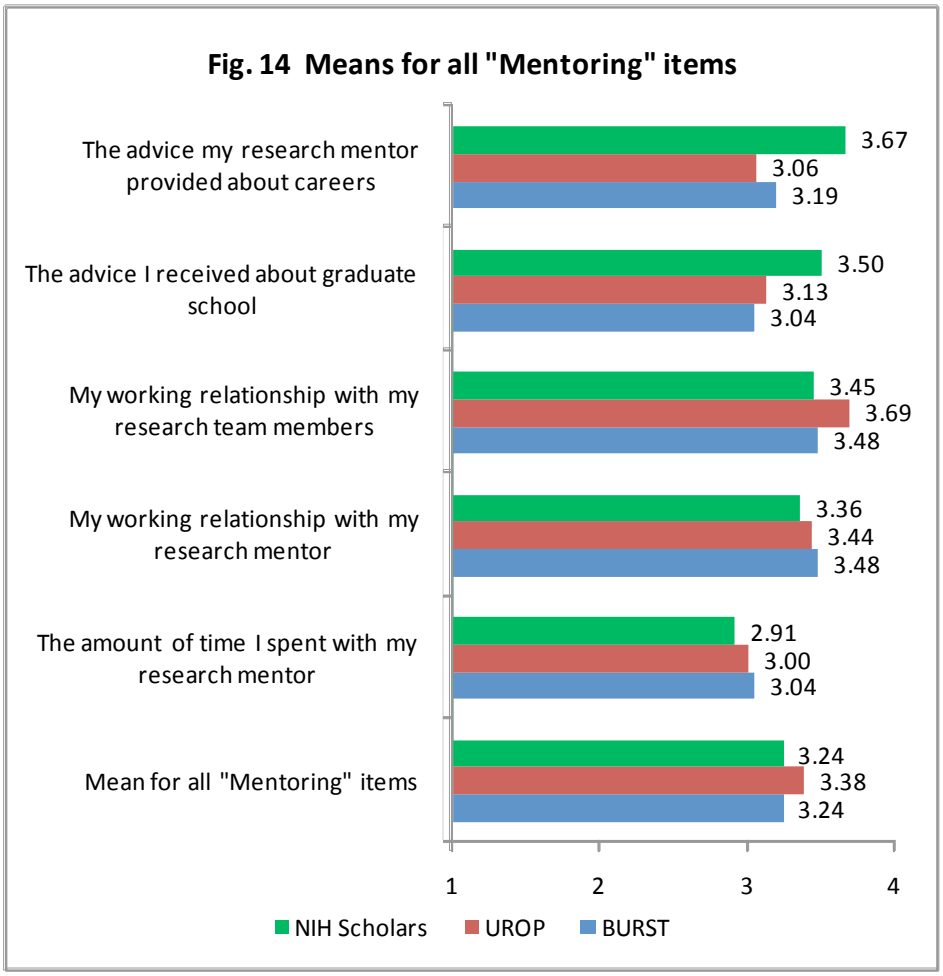
B. Personal/professional gains

In the category of "personal/professional gains," students noted increased confidence in their ability to do research, and to make a contribution to scientific knowledge. They also described the benefits of establishing a collegial relationship with a mentor and peers.

The first sub-category of "personal/professional gains" describes increases in confidence, particularly in students' ability to undertake an open-ended research project and to contribute to their field. There were no large variations by program among gains in this sub-category. Means for almost all items were between 3.0 and 3.5 on a 4-point scale (3.0= "good gain" and 4.0= "great gain") for all programs. There was also little difference in the nature of students' gains in confidence; students made gains in many different types of confidence, including increased confidence that they could "do" science, "be" a scientist, and contribute to their field. Figure 13 below displays the means for all of the "increased confidence" items.

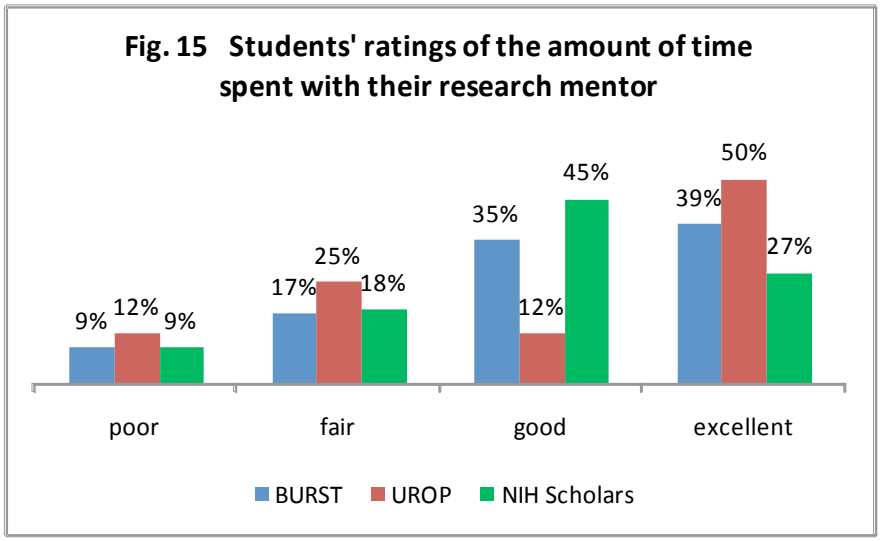


Another "personal/professional gain" identified through our previous research on UR is the opportunity for students to develop collaborative and collegial relationships with scientists. At the liberal arts college sites of our previous study, this relationship was most often with a faculty research advisor, while UR students at research universities are more likely to develop collegial, working relationships with graduate students, postdocs, or other colleagues in the lab (Coates et al., 2005). As with other categories, means fell within a specific range (between 3.0 and 4.0 on a 4-point scale). However, means were generally higher in the "mentoring" sub-category than in the "confidence" sub-category. NIH Scholars students were the most satisfied with the career and graduate school advice they received from their mentor. Students from underrepresented groups may have less prior knowledge about career and educational paths in the sciences and may have a greater appreciation for this advice than their majority peers (Arnold, 1993; Asera & Treisman, 1995; Seymour & Hewitt, 1997). Figure 14 illustrates the means for all of the "mentoring" items.



As demonstrated in figure 14, students in all programs held their relationships with their research mentors in high regard (means were between 3.0 and 4.0 on a 4-point scale, 3.0= "good" and 4.0= "excellent"), although they were less satisfied with their mentor's availability and the amount of time spent with their mentor.

In contrast to our findings in the previous evaluation of the BSI's UR program, students with poor mentors were not disproportionately minority or female. In fact, there was no pattern according to race or ethnicity: 32% of whites (n=6), 33% of African-Americans (n=1), and 25% of Hispanics students (n=2) rated the amount of time they spent with their mentor as "fair" or "poor." Interestingly, men were much more likely to be dissatisfied with the amount of time spent with their mentor than women: 50% of men and only 10% of women rated the amount of time they spent with their mentor as "fair" or "poor." Without larger samples of students we cannot make definitive claims about differences in the quality of mentoring that different groups of students received in their research experience. Figure 15 details the overall frequencies of students' responses regarding the amount of time spent with their research mentor.



Our previous work on undergraduate research has demonstrated that the quality and quantity of students' interactions with their research mentors are critical to students' outcomes from the research experience, particularly in terms of intellectual and professional growth, future aspirations, and overall satisfaction with the experience (Thiry et al., 2009). Indeed, in the present study, the quality of students' relationship with their research mentors was strongly correlated with their overall satisfaction of their research experience (r=.550, significance at the .001 level). Additionally, the amount of time that students spent with their mentor was also highly correlated to their satisfaction with their experience (r=.602, significance at the .001 level). Students' relationship with their mentor was also correlated to their intellectual gains (r=.448, significant at the .001 level), and the amount of time spent with their mentor (r=.603, significant at the .001 level). Interestingly, the quantity and quality of students' relationships with their mentors was not significantly correlated to the development of their identity as a scientist—"becoming a scientist" in our categorization schema.

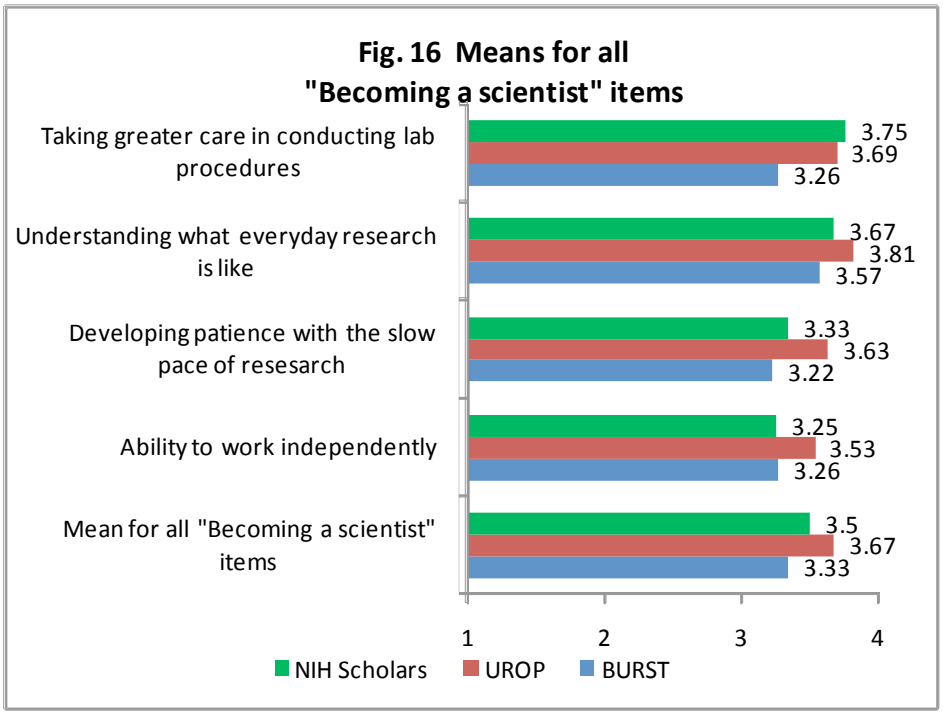
In sum, most students in all three programs reported that they were satisfied with the quality of the mentoring that they received in their research experience, although a few students did not seem to have as much access to their research mentor as they needed. Further, students' relationships with their mentors are strongly linked to their intellectual gains and their overall satisfaction with their research experience.

C. Becoming a scientist

Through participation in research, students begin to adopt the behaviors and attitudes necessary to become a scientist. Our qualitative research has shown that UR students learn to work and think independently, to take responsibility for their own learning, and to take initiative to solve problems on their own rather than simply relying on experts for the answers. Students also begin to pay careful attention to details in their research projects and take pride in the results of their work. Students develop a better understanding of the scientific research process and come to recognize that research is slow, can be boring and tedious at times, and is often rife with failure

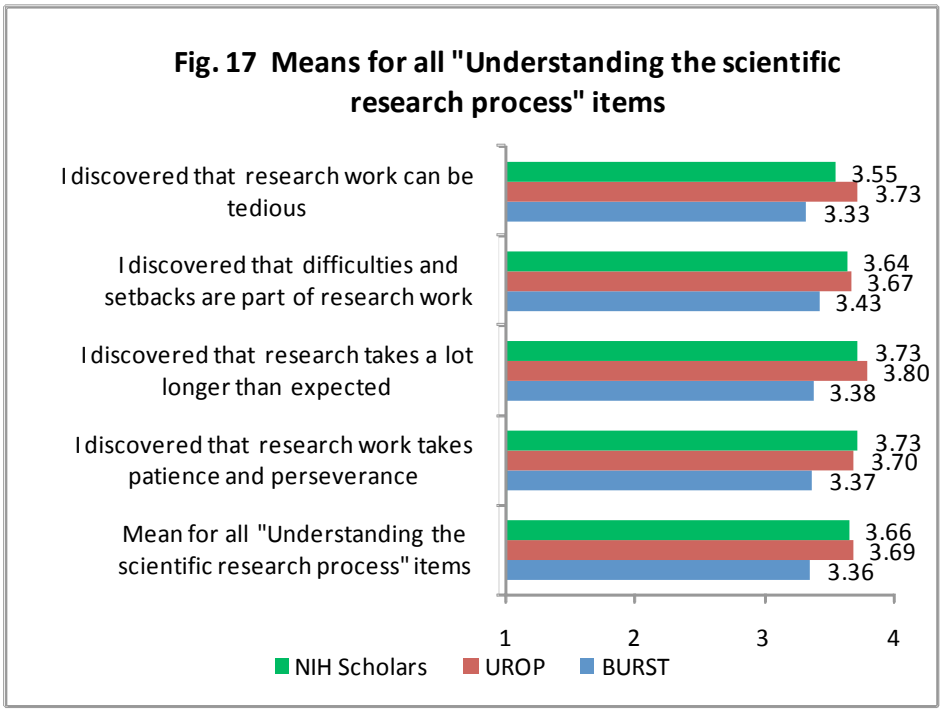
and setbacks. In sum, students gain a better understanding of the temperament, traits, and characteristics that are required to succeed in science.

Students—particularly advanced students in the UROP and NIH Scholars programs—made considerable gains in developing an understanding of research and the temperament that is required to be a research scientist. Students in all three programs made the strongest gains in taking care in conducting lab procedures correctly and understanding everyday research. Most students made slightly lower gains in independence. Figure 16 below details the means for all of the items within the "becoming a scientist" category.



UROP students' sizable gains in "becoming a scientist," and BURST students' sizable gains in "thinking and working and like a scientist" suggest that novice students first develop basic cognitive and intellectual understandings of the research enterprise, then begin to fashion a professional identity as a scientist with a more sophisticated understanding of the professional practice of scientists as they advance in their research careers.

Through participation in research, students also began to understand the nature of everyday scientific research work with its inherent difficulties, setbacks, and failures. UROP and NIH Scholars exhibited slightly greater gains in this area than BURST students, who tended to be research novices. Figure 17 below illustrates the means for all of the "understanding the scientific research process" items.



Students were also asked to respond to the open-ended question, "What did you discover about the process of scientific research?" Twenty-four students responded to this question: eight NIH Scholars students, thirteen BURST students, and three UROP students. There were no discernable differences in students' responses according to program.

The most common discovery about the nature of scientific research was that it is a slow process that requires substantial time commitment. Students also developed a greater understanding of the patience and perseverance required to be a successful research scientist. Eleven students (46%) responded that scientific research takes a long time to achieve results, as demonstrated by the following quotes.

> *One has to be very patient because collecting data take[s] a long time. (NIH Scholars student)*

> *The process of scientific research is a long one. But it is rewarding after spending a lot of time on a project and benefiting from your labor. (NIH Scholars student)*

> *Research can't be done overnight and the results from the research take time to understand, often with the help of others. (BURST student)*

Seven students (29%) commented that setbacks and failures are an inherent part of the research process. Students learned that they had to be careful in planning and conducting procedures.

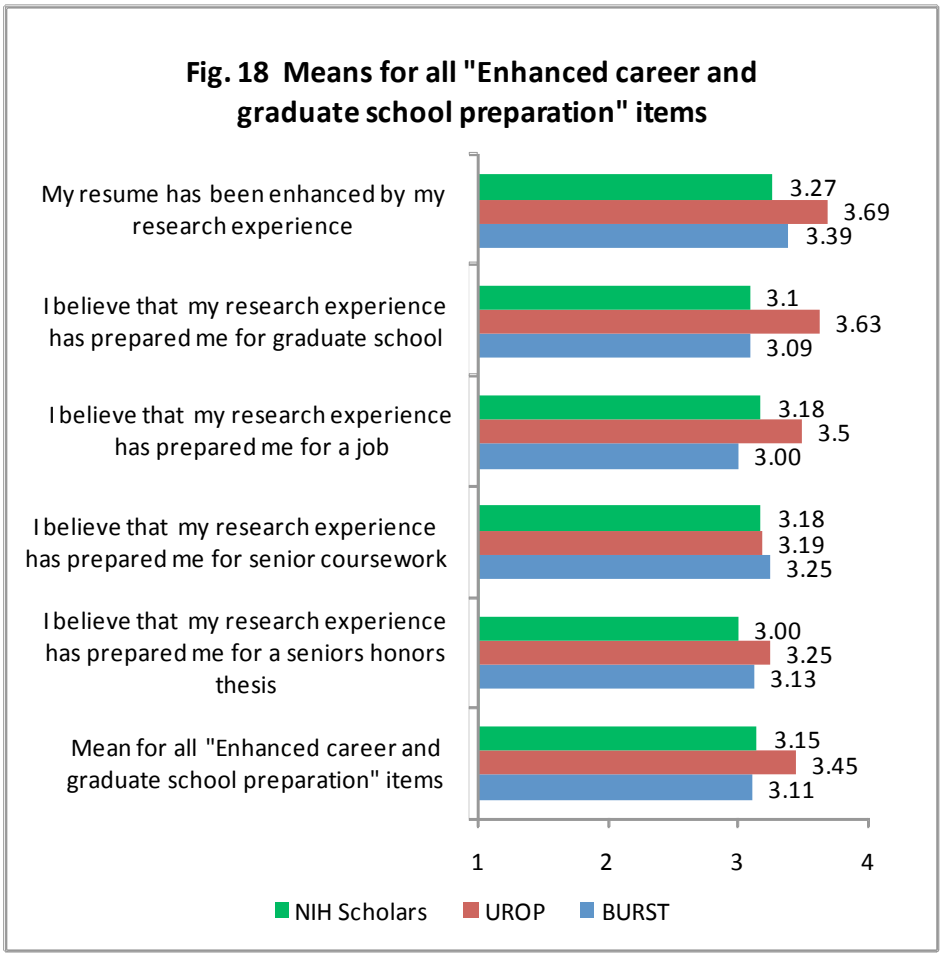
> *To anticipate things not working correctly the first time around. I also learned that things take a lot of planning and trial and error. (NIH Scholars student)*

> *My work used an animal model and I found that a biological system presents a plethora of challenges. I had mice die from unknown causes, results that did not corroborate, and standard errors that made the data inconclusive. (UROP student)*

Individual students also responded that scientific research requires teamwork and collaboration and that one must be interested in the project. One student mentioned that he learned how to apply disciplinary knowledge to a real-world project. A few students also commented on what they learned about the nature of scientific knowledge. Two of these students noted the difficulty of advancing scientific knowledge because of the rarity of ground-breaking discoveries. One student also learned that scientific knowledge is falsifiable and subject to revision. Another student stated that the process of building and constructing scientific knowledge from the work of others is a lengthy endeavor. These responses about the nature of scientific knowledge again demonstrate that students may not have understood the distinction between the nature of scientific *research* and the nature of scientific *knowledge*. However, although fewer than half of survey respondents offered commentary about the nature of the scientific research process, these students' responses demonstrate that they had access to authentic scientific work that helped them to learn about the nature of the research enterprise and the construction of scientific knowledge.

D. Enhanced career and graduate school preparation

Undergraduate research also helps students to feel prepared for graduate school and future careers. Participation in research enhances students' résumés, provides opportunities to network with faculty and other scientists, and exposes them to new experiences. Students in all programs reported solid gains in career and graduate school preparation, though this category overall was not rated as highly as the intellectual gains of "thinking and working like a scientist" or the professional socialization gains of "becoming a scientist." Students strongly believed that their résumés were enhanced through their research experience, yet they were slightly less convinced that research had prepared them for a job. UROP students felt the most prepared by research for graduate school, not surprising given that UROP students tended to be more advanced in their undergraduate careers and were probably more focused on graduate school than younger students. Figure 18 demonstrates the means for all of the "enhanced career and graduate school preparation" items.



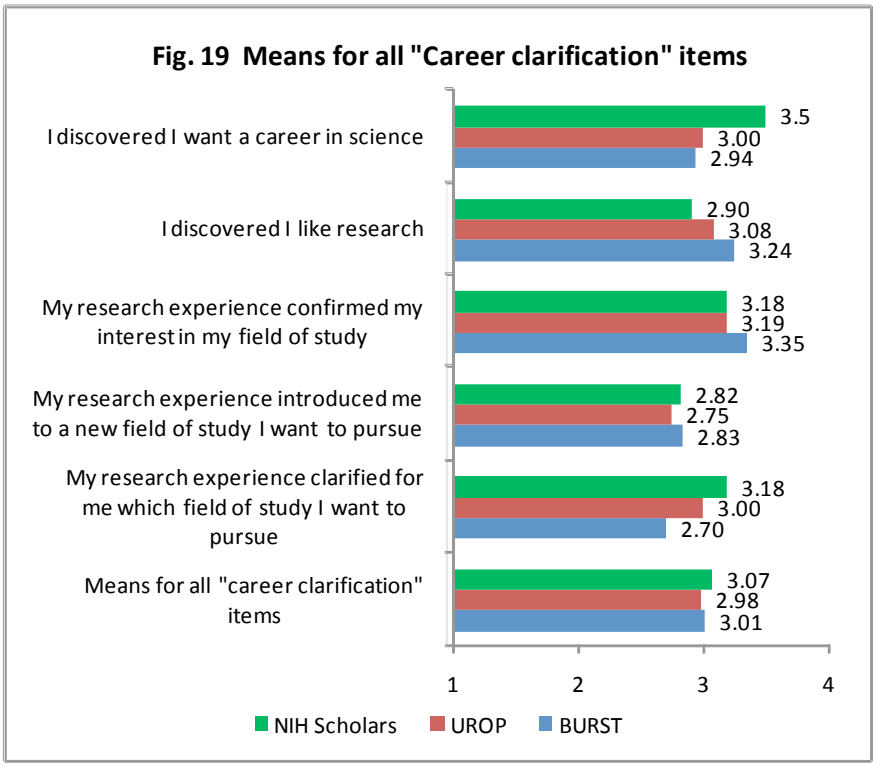
E. Clarification and confirmation of career and educational interests and aspirations

Through their participation in research, students sustained or increased their interest in the field, gained knowledge about graduate school and career options, clarified or confirmed their intentions to go to graduate school, and clarified whether scientific research would be a suitable career. Research experiences helped students to "try out" a scientific career to see whether it would be worth pursuing after graduation. Students also expressed an increased interest in research, the discipline, or field of study.

Students in all three programs reported the lowest gains in clarification of their career and educational paths. However, most students did not participate in research for instrumental reasons alone; therefore, it might be expected that they made stronger gains in other areas, such as intellectual and professional growth. For the most part, many of the means on this scale were close to 3.0, though some fell below that number.[6] With one notable exception, none of the means approached 4.0. However, NIH Scholars strongly felt that "I discovered I want a career in

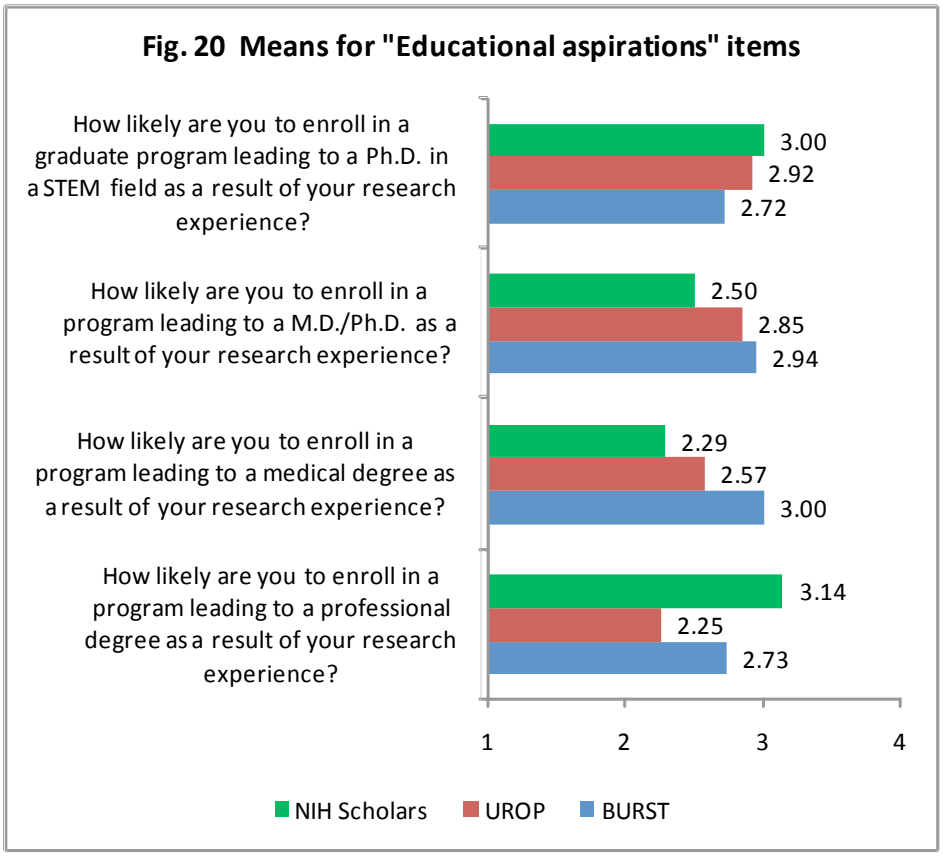
[6] Items were rated on a 4.0 scale, with 1=strongly disagree, 2=disagree, 3=agree, and 4=strongly agree.

science" (mean=3.5). One-hundred percent of NIH Scholars students agreed or strongly agreed that "I discovered I want a career in science," while 73% of UROP students and 71% of BURST students expressed the same sentiment. Therefore, career clarification seems to have been a slightly more important outcome for students from underrepresented groups than majority groups. Figure 19 below details the means for all of the "career clarification" items.



In keeping with our findings from the four-college study that research helped students to confirm or clarify pre-existing plans to attend graduate school more often than introducing the idea of enrolling in graduate school, research had a slight impact on students' educational aspirations in this study. As a result of their research experience, BURST students expressed slightly less interest in enrolling in a scientific graduate program leading to a Ph.D. than UROP or NIH Scholars students. On the other hand, BURST students expressed greater interest in medical school as a result of their research experience. Overall, most students were "somewhat more likely" to want to enroll in a Ph.D. program because of their research experience. There was no link between students' year in college and the influence of research on their educational aspirations. The means for all of the "educational aspirations" items are detailed in Figure 20. [7]

[7] Items rated on a 4.0 scale, with 1=much less likely, 2=somewhat less likely, 3=somewhat more likely, 4=much more likely.



Students also expressed mixed views about the influence of research on their decision-making processes concerning graduate school or medical school. For instance, BURST students were more interested in attending graduate school prior to enrolling in college, whether in pursuit of a Ph.D., medical or professional degree, than UROP or NIH Scholars students. On the other hand, UROP and NIH Scholars students reported that research had a stronger influence on their educational paths. A majority of UROP students (73%) and a solid minority (40%) of NIH Scholars students reported that their research experience had influenced them to pursue a graduate degree in a STEM field. Students in all programs thought that the research experience was less influential in their decisions to pursue a medical or professional degree. Table 6 documents the actual number of students who responded positively to the given survey items. These numbers tend to be quite small; without higher numbers of students, we cannot make strong claims about the influence of research on students' educational paths.

Table 6. The influence of research on students' educational goals.

Item.	BURST (# of students who replied "yes")	UROP (# of students who replied "yes")	NIH Scholars (# of students who replied "yes")
I planned to get a **graduate degree** in a STEM field:			
Before I entered college	7	0	0
Before I did research	4	2	3
Because of research	4	8	3
Research had no influence on my plans	5	1	0

I planned to get a **medical degree**:			
Before I entered college	9	6	5
Before I did research	8	5	0
Because of research	1	1	2
Research had no influence on my plans	2	1	0
I planned to get a **professional degree**:			
Before I entered college	12	2	1
Before I did research	2	1	1
Because of research	2	0	0
Research had no influence on my plans	1	3	0

Students were also asked in an open-ended question, "How did your research experience influence your thinking about your future career and graduate school plans?" Twenty-five students answered this question: six NIH Scholars, five UROP, and fourteen BURST students. The only notable difference among programs is that BURST students were more likely to state that research had no effect on their plans or had clarified that they wanted to pursue a career in medicine. Novice BURST students may have been more inclined to "test the waters" with research and it is not surprising that they expressed less commitment to a research career or graduate school than students with more extensive experience.

The primary benefit of research for students was clarification of whether a career in research or enrollment in graduate school was the correct path. Four students (two NIH, one UROP, and one BURST) clarified that graduate school is "not for me," while four students (two UROP and two BURST) decided that they would like to pursue a graduate degree in their field. Additionally, three students (two BURST and one NIH) clarified that a medical or professional degree would best suit their interests and goals. The following quotes typify students' clarification of whether graduate school and a research career are desirable paths for them.

> *It really proved to me that graduate school is not for me, in the sense of research anyways. But it is definitely a learning experience and I am glad and grateful for this opportunity. (NIH Scholars student)*

> *It makes me want to go into research now. (UROP student)*

> *It has shown me that I love working in a lab, and that research combines all the things I enjoy doing, from writing, to science, to creativity, and to constructing experiments. I feel more certain than ever that grad school is right for me. (BURST student)*

Two NIH Scholars students also commented that the opportunity to observe professionals in the field helped them learn what life may be like as a graduate student or scientist.

> *It gave me access to conferences and opportunities to be around people working in those fields. Also it gave me access to a deeper understanding and appreciation of science not provided in my courses. (NIH Scholars student)*

> *The research experience that I had allowed me to work alongside graduate students who I am able to converse with every time I'm in the lab. This allowed me to find out what grad school is like as well as how research influences decisions on research careers. (NIH Scholars student)*

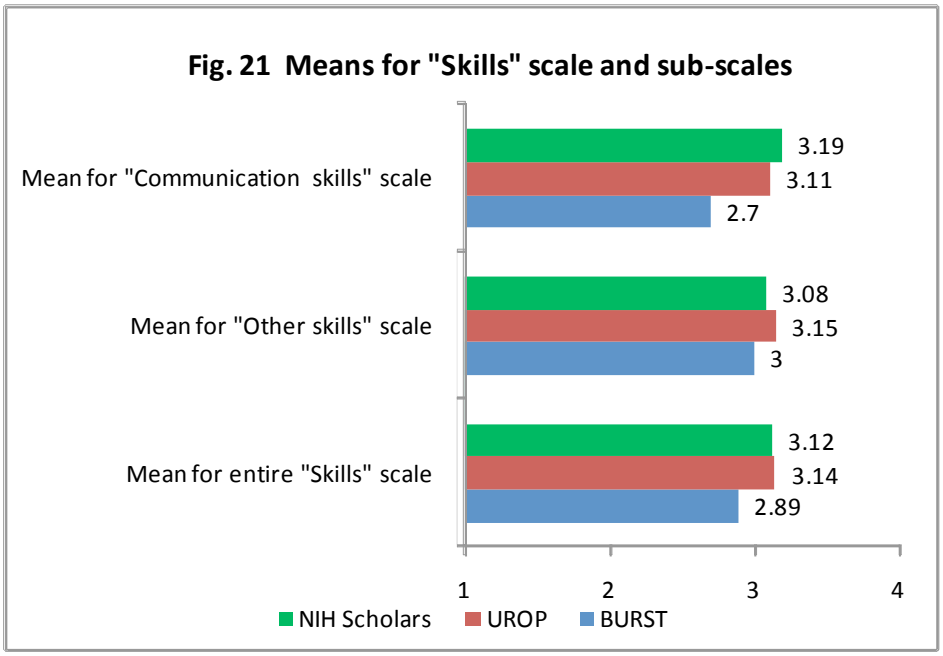
Finally, two UROP students commented that they gained confidence that they could succeed in their fields. Increased confidence helped to cement students' commitment to graduate school and/or a career in research.

> *That I could pursue a career in science with confidence in my abilities. (UROP student)*

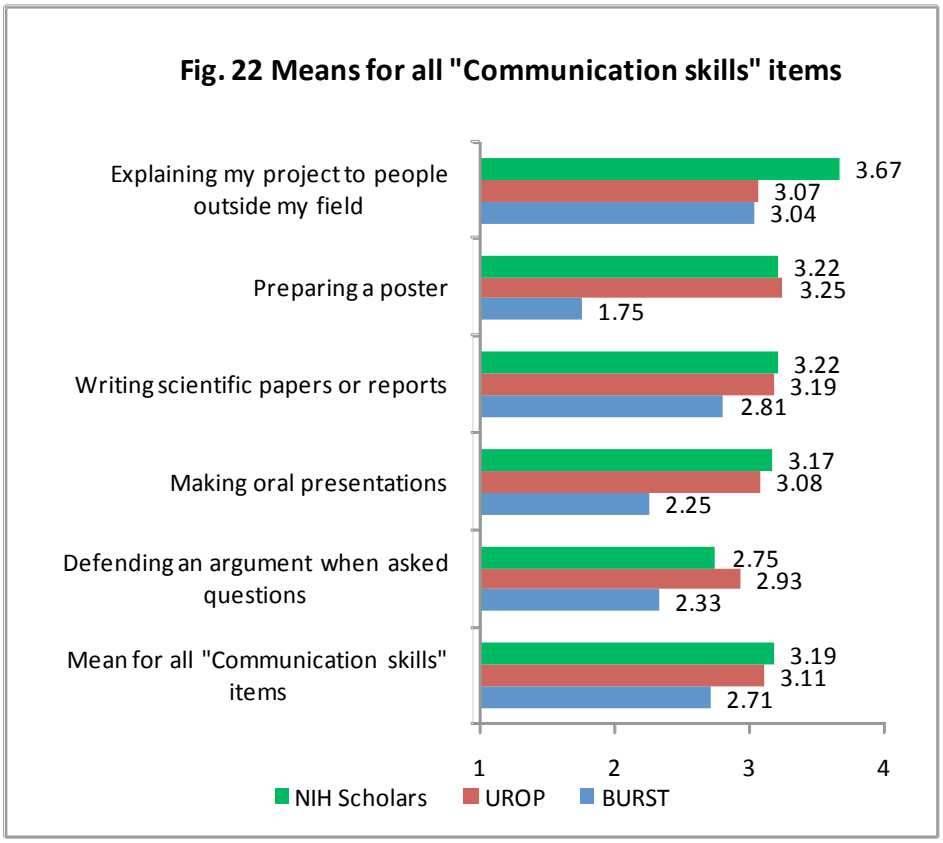
F. Skills

In our qualitative study of UR, students mentioned gains in written and communication skills, mastery of new research and laboratory techniques, and gains in organizational and time management skills. Students also mentioned augmentation of their reading comprehension skills, particularly for scientific journal articles, information retrieval skills, and abilities to work collaboratively with peers, faculty, and other professionals. Our previous research has shown that students make greater gains in communication skills than other types of skills from their research experiences (Hunter et al., 2007; Seymour et al., 2004).

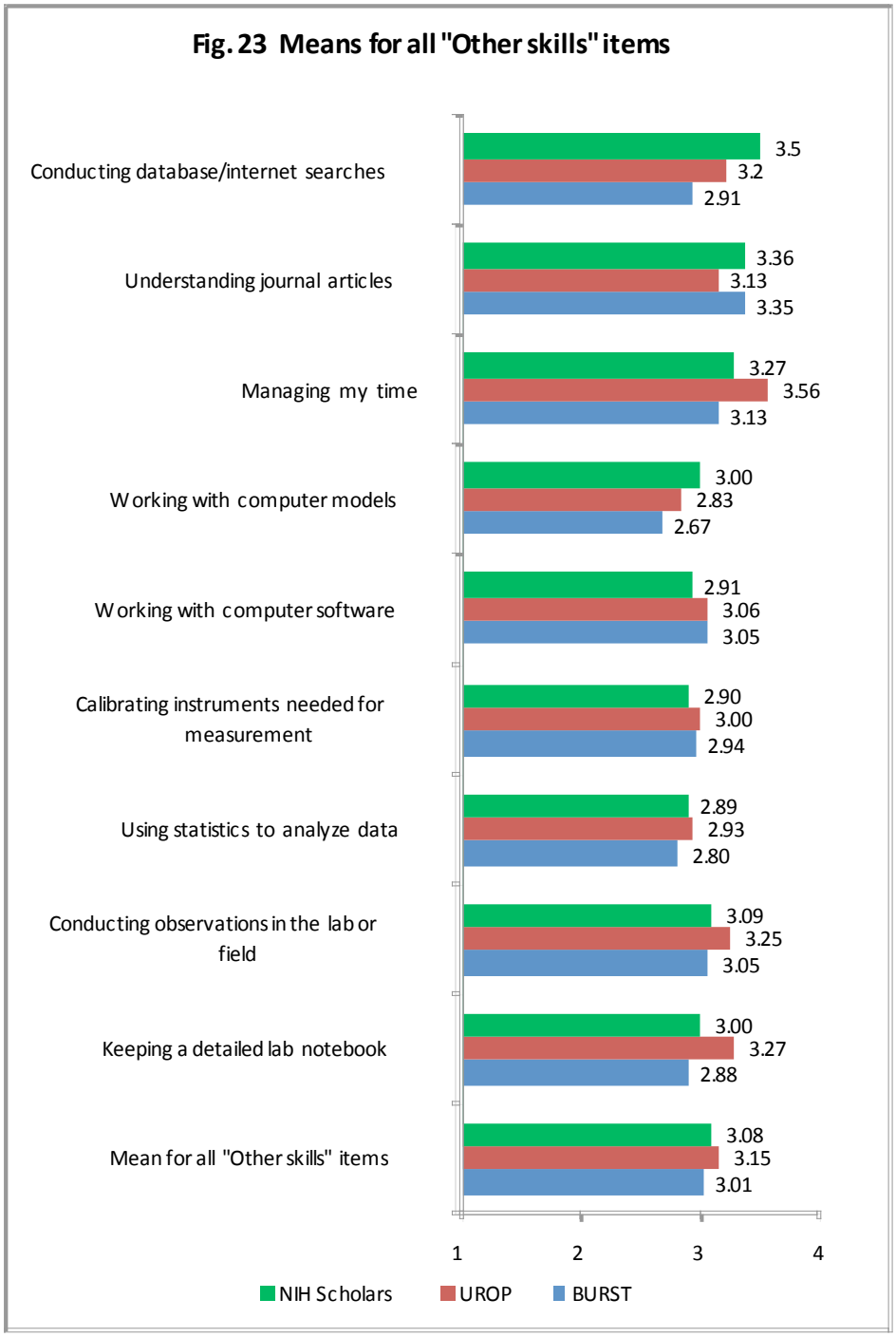
Likewise, students in this study reported stronger gains in communication skills than in other areas, such as laboratory or organizational skills. UROP and NIH Scholars students, in particular, made the most extensive gains in communication skills, perhaps because of the oral presentation requirements of those programs. The BURST program does not have an oral presentation requirement, though it does have a scientific writing requirement. Overall, though, students' gains in skills were not as strong as their intellectual or professional growth in other areas. The means for the entire skills scale and the "communication skills" and "other skills" sub-categories are shown in Figure 21.



Students gained a variety of communication skills from their research experiences. Students in all programs rated their progress in defending an oral argument as lower than their progress in other areas of communication. Defending an oral argument is a higher-level communication skill than preparing a poster and may take more time and practice to develop. In sum, students in the UROP and NIH Scholars programs felt they acquired both oral and written communication skills. On the other hand, BURST students felt they made only "a little" progress in oral communication skills, such as giving presentations and defending arguments. Figure 22 below displays the means for "communication skills" items.



Research also enhances students' organizational, laboratory and technical abilities, reading comprehension, and record-keeping skills. Within this sub-category, students reported the most extensive gains in conducting literature reviews and understanding journal articles. There was little variation in students' responses among programs. NIH Scholars students reported slightly stronger gains in "conducting database/internet searches," perhaps because of the journal club requirement of that program. Overall, students made moderate gains in a variety of skills necessary to be a successful scientist. The means for all of the "other skills" items are detailed in Figure 23.



VI. The quality of students' research experiences

A. Authenticity of the research experience

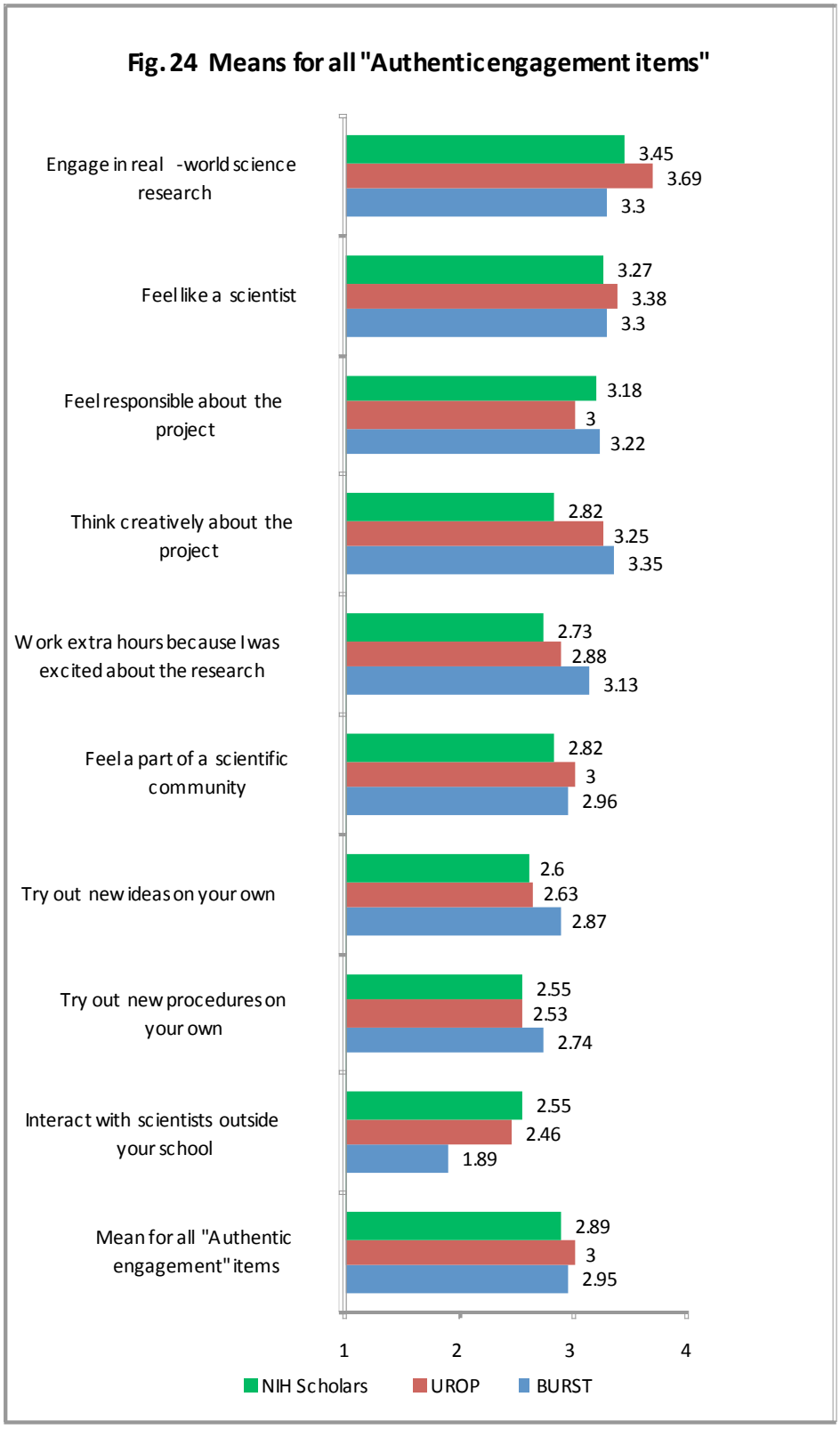
Our previous evaluation of the BSI's UR programs led us to believe that the quality of students' experiences and the authenticity of their scientific work varied (Coates et al., 2005). The

majority of students seemed to have had high-quality experiences in which they had access to authentic research work and guidance and support from a mentor in the lab. However, a minority of students did not seem to undergo the same intellectual and professional development as their peers. Moreover, research advisors' responses to survey questions indicated that some of them viewed undergraduate students as merely "extra hands in the lab" (Coates et al., 2005). Thus, we revised the survey to include several items meant to assess the quality and authenticity of students' research work. These items represent markers of an authentic research experience, such as independence and responsibility. On many of these items, students' mean ratings indicated that they participated in authentic research "a good amount" or "a great deal." [8] However, a few items fell below a mean of 3.0, indicating that students may have engaged in these activities only "a little."

Almost all students engaged in authentic research at a level appropriate for undergraduates. In fact, no students in any of the programs reported that they engaged in real-world research "not at all" or only "a little." Indeed, students universally thought that they had a high level of engagement in authentic scientific work, findings that are not entirely supported by our preliminary interview analysis. In interviews, a few students discussed engaging in "busy" work such as setting up labs or filing invoices. We can conclude that while most students engaged in intellectually challenging scientific work, a few did not.

It appears that the survey items we designed to capture the variability of students' experiences may not have accurately portrayed the extent of students' involvement in "real-world" science. Survey items may be revised in the future to focus on specific behavioral indicators of engagement in authentic research, rather than attitudinal indicators, as is the case with this survey. Students may not have enough experience with research work to accurately judge whether they participated in "real" research or not, and specific behavioral markers may provide greater accuracy than attitudinal markers. Finally, we must also consider the possibility that the number of students who did not engage in authentic research is so small that the experiences of this group could not be captured without larger sample sizes over multiple years. Figure 24 displays the means for the "authentic engagement" items.

[8] Items rated on a 4.0 scale, with 1=not at all, 2=a little, 3=a good amount, 4=a great deal.



As another marker of authentic experience, students reported the extent of their participation in scientific communities, particularly through dissemination of their research results to other

scientists in professional venues. Many students had the opportunity to disseminate their research results to the campus community and a limited number of students had the opportunity to disseminate their research to a larger scientific community. Additionally, many students planned to present papers at professional conferences or co-author articles in the future, indicating that most students had access to authentic research opportunities that yielded publishable results. Table 7 below details students' responses to items related to the dissemination of their research to scientific communities.

Table 7. Students' engagement with scientific communities.

Item.	BURST (% yes)	UROP (% yes)	NIH Scholars (% yes)
Presenting a talk or poster on this research to students and faculty:			
I *did* this activity	22% (n=5)	53% (n=8)	73% (n=8)
I *plan* to do this activity	78% (n=18)	87% (n=13)	73% (n=8)
Presenting a talk or poster at a professional conference:			
I *did* this activity	0%	7% (n=1)	9% (n=1)
I *plan* to do this activity	35% (n=8)	50% (n=8)	55% (n=6)
Attending a professional conference related to this research:			
I *did* this activity	17% (n=4)	25% (n=4)	18% (n=2)
I *plan* to do this activity	52% (n=12)	66% (n=10)	64% (n=7)
Writing or co-writing a paper that was published in a refereed, academic journal:			
I *did* this activity	0%	11% (n=2)	9% (n=1)
I *plan* to do this activity	57% (n=13)	87% (n=13)	82% (n=9)
Writing or co-writing a paper that was published in an undergraduate research journal:			
I *did* this activity	0%	0%	0%
I *plan* to do this activity	44% (n=10)	13% (n=2)	45% (n=5)

B. Improvement of the research experience

In an open-ended question, students were asked, "What would make your research experience better?" Twenty-five students responded to this question: seven NIH Scholars, seven UROP, and eleven BURST students. Thirteen students (3 NIH Scholars, 7 BURST, and 3 UROP) expressed satisfaction with their research experience and had no suggestions for improvement, as demonstrated in the following quotes.

> *I thought the research experience is great and I don't have any ideas for improvement. (NIH Scholars student)*

> *I can't think of anything that could've improved it. This has been an excellent experience. (BURST student)*

My research experience was great. It is still ongoing and I think it will only get better! At this time I have no complaints. (UROP student)

NIH Scholars students were more concerned with under-preparation issues than UROP or BURST students. For instance, two NIH Scholars students mentioned that they would have like to have started their research experience with more confidence and greater knowledge in their field.

Having more background knowledge in the field. (NIH Scholars student)

Entering with more confidence. (NIH Scholars student)

Surprisingly, UROP and BURST students, rather than NIH Scholars students, were concerned about funding. Two UROP and two BURST students commented that they would like to receive more funding for their work so that they would not have take a second job to meet financial needs.

More funding so that I could spend more time in the laboratory and not have to get a second job. (UROP student)

As a student with no family financial support, it was difficult at times to provide for myself. I'll also mention that because of this problem I had to get two separate jobs to support myself. Something perhaps unnecessary if the pay is a bit better. I realize most students at CU are rather well off, but the ones from poor families have a different game to play. (BURST student)

Finally, UROP and BURST students, but not NIH Scholars, were concerned about mentoring and guidance in the lab. Three UROP and two BURST students reported that they would have liked to receive more guidance and support from their research mentor, while one student reported that he would have liked more interaction with the faculty PI of the project. Three of these students were female and two were male, reflecting the gender distribution of the samples. Therefore, there did not seem to be any gender differences in the quality of mentoring.

More consistent guidance from my research mentor. (UROP student)

A better relationship with my mentor. (UROP student)

More talk to the actual PI in my lab versus my mentor. (UROP student)

Having a mentor to actually show me how to do everything, I felt scared and unsure at many points since I had to learn how to do procedures by myself and had nothing to refer to except a protocol from a lab in a different country. While getting good results in spite of having to be self-taught was a wonderful experience, it was so nerve-wracking learning how to do everything by myself that I still think it might have been better to have had someone to work with this summer. (BURST student)

More support and guidance from my mentor. (BURST student)

In sum, the majority of students who responded to this question were highly satisfied with their research experience and offered no suggestions for improvement. However, NIH Scholars students' responses indicate that a few of them faced issues of lack of confidence or under-preparation in their discipline, particularly at the start of their research experience. Finally, a few UROP and BURST students were concerned with financial support and the quality of mentoring and support they received in their research experience.

VII. Conclusion and recommendations

In conclusion, the vast majority of students in all three programs were highly satisfied with their research experience and the support they received from research program staff and activities. Interestingly, there were few major differences among programs in student outcomes or suggestions for improvement.

Students were satisfied with many aspects of their programs, including the support they received from program staff, and the application and laboratory selection processes. On the whole, however, students were less satisfied with program workshops than other program elements. Some students felt that they had already gained knowledge about poster preparation or lab techniques through coursework or training in their research lab; therefore, they perceived program workshops as repetitive or irrelevant. We suggest that program staff articulate to students the learning objectives for program workshops and activities along with the importance of strengthening this knowledge for future scientists. Students also rated their program websites lower than other programmatic elements, indicating that program websites could be updated to be more beneficial or useful for students. While most students were satisfied with the level of financial support received for their research work, a few UROP and BURST students were slightly less satisfied with their stipend. Finally, a few students (particularly UROP and NIH Scholars students) desired to learn more from their program about the graduate school selection and application process and GRE preparation.

In general, students in all programs made strong intellectual, personal, and professional gains from their participation in research. By and large, UROP and NIH Scholars made their strongest gains in the professional socialization of "becoming a scientist." BURST students also made solid gains, though they were weaker in a few advanced areas, such as developing a professional identity as a scientist. BURST students may have made slightly weaker professional gains than their peers because of their novice status and their less advanced class standing. On the other hand, BURST students and novice NIH Scholars students made their greatest gains in the intellectual skills and understanding of "thinking and working like a scientist," suggesting that novice students may need to gain basic scientific and analytic thinking skills before they can advance to the development of a professional identity.

A few NIH Scholars indicated that they began their research experience with low confidence in their abilities and were under prepared as far as disciplinary knowledge. Students from underrepresented groups may lack access to adequate preparation in secondary school, particularly in scientific fields (Oakes & Guiton, 1995). However, survey samples were too small to confirm this hypothesis with tests of statistical significance. Nevertheless, NIH Scholars

students gained enthusiasm for science and began to develop professional identities through their research work. These are important outcomes for minority students who are more influenced to remain in their major by their interest and enthusiasm for their field than by their academic achievement (Grandy, 1998).

Participation in research seemed to have only a minor impact on students' educational and career goals, a finding corroborated by our previous research (Hunter et al., 2007; Seymour et al, 2004). BURST students, who were generally younger and novice researchers, reported that their research experience had little to no impact on their educational plans. A few BURST students reported that they became more committed to their original goal of medical school from their participation in research. Participation in research seemed to have a slightly greater impact on UROP and NIH Scholars students, some of whom reported that research had influenced their decision to attend graduate school in a scientific field. However, the numbers within these sub-categories are small so it is difficult to draw definitive conclusions about the influence of research on students' career or educational goals.

Students' substantial gains from research seemed to emanate from their access to original, authentic scientific work within a research group. The vast majority of students in all three programs appear to have engaged in "real-world" research under the guidance and support of a mentor in their lab. However, some students were not satisfied with their relationship with their mentor or the amount of time spent with their mentor. Moreover, the quality of students' relationship with their mentor and the amount of time they spent with their mentor was strongly correlated to their intellectual gains, though not their professional socialization gains, and their overall satisfaction with the research experience. Therefore, a few students may not have had the support that they needed to develop as scientists in their research experience. While these numbers are small, our previous research has demonstrated that poor-quality research experiences can have negative consequences for students, including driving them away from graduate school or their discipline (Thiry et al., 2009). Nevertheless, the majority of students in all programs received many intellectual, personal, and professional benefits from their participation in research.

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