Experiential education has long been emphasized as a part of undergraduate education in the sciences, technology, engineering, and mathematics (STEM) disciplines (Singer, Hilton, & Schweingruber, 2005), through laboratory and project-based coursework, as well as out-of-class participation in internships, co-ops, and research. In fact, however, the value of experiential education is largely presumed: evidence from well-designed research and evaluation studies is fairly sparse about the educational value of either course-based lab work (Hofstein & Lunetta, 2004; Nakhleh, Polles, & Malina, 2003) or more in-depth experiential education in STEM. Only recently, for example, have the benefits to students of undergraduate research been explored (for a review of recent literature, see Hunter, Laursen, & Seymour, 2007; Seymour, Hunter, Laursen, & DeAntoni, 2004). The value of internships and other professional opportunities has been even less well demonstrated (Anakwe & Greenhaus, 2000).

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Nonetheless, faculty, institutions, and funders continue to promote and support research and inquiry-based learning in STEM (National Research Council [NRC], 1999; National Science Foundation [NSF], 1996), and few would argue against this. The Boyer Commission (1998) urged that research-based learning become the “standard” in undergraduate education. Growing numbers of students participate in research as undergraduates, and the numbers and variety of institutions that are developing student research programs are also increasing (Boyer, 2002; Research Corporation, 2001; Russell, 2005). Many institutions are also exploring the addition of “research-like” components to regular courses and labs (see DeHaan, 2005). Given these trends, it is even more important to understand the role of research and other experiential educational activities in undergraduate STEM education.

Despite the widespread assumption that co-curricular activities augment undergraduate STEM students’ learning and development, no systematic, multi-institutional research has explored the outcomes of students’ participation in these activities on their learning and professional development. This paper will discuss findings from interviews with 62 graduating STEM majors from four liberal arts colleges who engaged in a variety of out-of-class experiences, including internships, professional jobs, and undergraduate research (UR) at government laboratories and research universities. We address the question of whether the array of benefits identified in the literature on UR experiences is applicable to other forms of experiential learning within STEM undergraduate education. Using the analytic framework developed to categorize benefits identified by a separate sample of students who participated in faculty-led summer research on their home campus (Hunter et al., 2007), we discuss what these graduating seniors report that they did or did not gain through their curricular and co-curricular experiences. We place our findings within the context of sociocultural theories of learning and discuss the implications of these findings for faculty and others who seek to foster deep learning and professional development in STEM undergraduates.

**Learning and Development Out of the Classroom**

First, we summarize the literature on UR and other college-level experiential learning outside of the classroom. Few studies have empirically documented student outcomes from participation in “the other curriculum” (Kuh, 1995), “out-of-class” activities such as work, internships, study abroad, or participation in campus organizations. However, student involvement in these activities is high. Three out of four stu-
Personal and Professional Gains for STEM Undergraduates

Students participate in an internship or cooperative educational experience during their undergraduate years (Coco, 2000). Additionally, thousands of undergraduates participate annually in research (Russell, 2005)—20% at research universities alone (Boyer, 2002), and higher at many colleges (Research Corporation, 2001).

Out-of-class experiences appear to have considerable potential for students’ intellectual, personal, social, and professional development (Astin, 1993; Kuh, Douglas, Lund, & Ramin-Gyurnek, 1994; Pascarella & Terenzini, 1991). Empirical studies of co-curricular experiences have demonstrated that these activities contribute to students’ cognitive development; increase communication, leadership and interpersonal skills (Astin, 1993; Baxter Magolda, 1992; Kuh, 1995; Pascarella & Terenzini, 1991); and help students to establish career goals (Cooper, Healy, & Simpson, 1994).

Despite their popularity with students, little is known about student outcomes from internships (Anakwe & Greenhaus, 2000). To date, research on internships has focused primarily on participants’ career outcomes, has not addressed STEM disciplines in particular, and has often produced contradictory results. Some studies have found no, or only a weak, relationship between internships and career development (Brooks, Cornelius, Greenfield, & Joseph., 1995; Callanan & Benzing, 2004), while other studies have demonstrated that former interns were better prepared for future careers and reported greater job satisfaction (Gault, Reddington, & Schlager, 2000). Internships have also been reported to help students to clarify career goals, gain a realistic understanding of career possibilities, and check for “fit” between personality, preferences, lifestyle and organizational environment (Greenhaus, Callanan, & Godshalk, 2000). In one of the only studies to examine outcomes other than career outcomes, Ziegler (1987) found that internships led to gains in self-confidence and oral communication skills. Other recent studies have found that internships enhance students’ personal growth (Hunter, 2006, 2007).

On the other hand, several systematic studies of the outcomes of undergraduate research have been conducted in recent years, and this literature has begun to demonstrate a range of benefits for STEM students. Most of the recent research on UR has focused on educational and career outcomes; our previous work has also addressed intellectual and affective outcomes (Hunter et al., 2007; Seymour et al., 2004). Among the educational and career gains identified in the literature on UR are 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, Gre-
german, Jonides, von Hippel, & Lerner, 1998); greater awareness of career options (Hunter et al., 2007); and enhanced 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. Although our research has demonstrated that UR participation serves principally to confirm or clarify pre-existing career and educational goals (Hunter et al., 2007; Seymour et al., 2004), 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 among minority students (Alexander, Foertsch, & Daffinrud, 1998; Hathaway, Nagda, & Gregerman, 2002). Undergraduate research has also been argued to increase graduation rates (Kim, Rhoades, & Woodard, 2003; Nagda et al., 1998), and retention in the major (Nagda et al., 1998).

Perhaps more importantly, 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' communication skills (Bauer & Bennett, 2003; Kardash, 2000), technical skills (Lopatto, 2004; Ward, Bennett, & Bauer, 2002), critical thinking and scientific analysis skills (Bauer & Bennett, 2003; Merkel, 2001) and scientific research skills (Kardash, 2000). Through UR, students begin to take greater initiative and responsibility for their own learning (Bauer & Bennett, 2003; Lopatto, 2004; Rauckhorst, 2001; Seymour et al., 2004) and gain confidence in themselves as independent learners (Hunter et al., 2007; Merkel, 2001; Rauckhorst, 2001; Russell, 2005, Ward et al., 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; Ward et al., 2002). Students have less often reported gains in desirable but difficult higher-order thinking skills such as identifying a research question, and experimental design (Hunter et al., 2007; Kardash, 2000).

Studies that have utilized comparison groups of non-participants have reported greater benefits derived by UR participants (Bauer & Bennett, 2003; Nagda et al., 1998; Rauckhorst, 2001). However, these studies addressed only one or two outcome measures, such as graduate school attendance or graduation rates. To date, empirical research has shed little light on whether the array of benefits from UR for STEM students can be gained through other means; this paper seeks to address this lacuna.
Sociocultural Theories of Out-of-Class Learning

Educational theory supports the role of experiential learning in STEM education: activities such as research and internships provide the opportunity to learn through engaging in authentic tasks within a social context. Learning is “situated” within a social and cultural context and mediated by experience and practice (Lave & Wenger, 1991; Vygotsky, 1978). While these theories place emphasis on learning through experience and apply to contexts outside of the classroom, they do not simply advocate “learning by doing.” Instead, they emphasize “learning by doing and learning from doing within a specific social context with a support group, or set, which helps members to engage in reflection upon their practices” (Jarvis, 2006, p. 154). In contrast, traditional conceptions view learning and knowledge as transmitted to the student from an authority figure, rather than obtained through a mutual process of discovery that occurs through dialogue and activity.

Learning and development, then, are deeply embedded in social and cultural practices, taking place through ongoing participation in a “community of practice,” or a group of people engaged in collective learning through a joint enterprise—such as a group of scientists working together on an experiment (Wenger, 1998). Through the process of legitimate peripheral participation, learners gain mastery of the knowledge, skills, and practices of the community of practice. Newcomers enter into “legitimate” communities of practice as “peripheral” members with limited responsibility for group projects and activities. Through authentic “participation” in the community and with the guidance of “old-timers,” learners move toward greater responsibility. In this way, learners begin to gain a greater understanding of the values and practices of the community, and the daily activities of participants. In this comparative study, we examine specific varieties of experiential STEM learning and the extent to which each contributes to students’ learning and development within communities of practice.

Research Design

This qualitative study was designed to address fundamental questions about the benefits (and costs) of undergraduate engagement in faculty-mentored research undertaken outside of class work. Longitudinal and comparative, the study explores the immediate and long-term benefits to students of participation in UR. An important, related question is whether the benefits identified by UR students are unique to UR, or if
they can be gained in other contexts both in and out of the classroom. This paper addresses this latter question.

The study was undertaken at four highly selective liberal arts colleges with a strong history of faculty-led UR. In the first round of data collection, we interviewed a cohort of 76 rising seniors and their 55 faculty advisors who were engaged in UR in summer 2000 on the four campuses. Findings from these UR student interviews and from a comparative analysis of student and faculty interviews are reported elsewhere (Hunter et al., 2007; Seymour et al., 2004). We re-interviewed this original sample of UR students two more times: just prior to their graduation, and two to three years after graduation. At the second time point, just prior to graduation, we interviewed a sample of STEM students—who had not participated in summer research in their home departments. As with the UR students, we interviewed this sample of non-participants a few years after graduation. Longitudinal analysis demonstrates that students’ reports of gains from their experiences were remarkably consistent across time for both samples of students (Laursen, Hunter, Seymour, Thiry, & Melton, 2010). Our findings confirm Miles’s (1979) contention that qualitative data “suffer minimally” from retrospective distortion (p. 590).

This paper focuses on results from interviews with the comparative group of 62 graduating seniors from the four colleges who had not participated in UR on their home campus. Departmental records identified them as not having engaged in summer research on campus, but most had participated in a range of activities in their discipline, including jobs, internships, research-like projects within science courses, and senior theses. Though we originally sought a comparison group to contrast outcomes between UR participants and non-participants, we discovered that some within the comparative group had in fact participated in research in other contexts, such as research universities or government labs. The difficulty of constructing a comparison group for UR students has been well documented (Bauer & Bennett, 2003; Katkin, 2003; Zydnei et al., 2002). Thus our comparative sample is comprised of students whose salient characteristic is not their lack of participation in UR, but rather their rich and varied—and quite typical—experiences with a host of experiential learning opportunities in STEM. Data from this group thus offer the opportunity for in-depth examination of the impact of such experiences on STEM students’ personal, professional, and intellectual growth. In this paper, we will compare findings from non-research students to a subset of research students within the overall comparison sample, because findings from the main UR sample have been extensively documented elsewhere (Hunter et al., 2007; Seymour et al.,
2004) and because the gains made by research students in both the main UR sample and the comparison sub-sample were strikingly similar.

Research Methodology

Our methods of data collection and analysis are qualitative, based on in-depth, semi-structured interviews with participants. Open-ended, semi-structured interviews seek to understand complex behaviors, interactions, and social processes that are relatively uninvestigated (Fontana & Frey, 2000). Semi-structured interviews enable researchers to explore specific themes identified in research questions, yet also allow interviewers to spontaneously follow up on interviewees’ comments. In this way, emergent issues invariably arise from the interview sessions.

To develop the interview protocols, we constructed a gains checklist from the research and descriptive literature on UR, based on what faculty report that students gain from participation in UR, such as career and graduate school preparation, and greater understanding of the research process. During the interview, students were asked to describe the gains they made both in and out of the classroom. Because, in part, we were testing hypotheses to determine whether students achieved gains that were identified—yet not always empirically supported in the literature—we structured the interview protocol to address these hypothetical benefits. Thus if, toward the end of the interview, a student had not mentioned a gain from our checklist, the student was asked about that gain and invited to add further comment. In response to such invitations, students offered a range of positive and negative comments that yielded a richer, more complete understanding of their gains and a more accurate collective response than from spontaneously offered comments alone. Students also mentioned gains that were not on our checklist. In-person interviews of 60 to 90 minutes were taped and transcribed verbatim, then submitted to The Ethnograph (1998), a qualitative computer software program.

To develop the coding framework, each transcript was searched for information bearing upon the research questions. In this type of analysis, text segments referencing issues of different types are tagged by code names. Codes are not preconceived, but empirical: each new code references a discrete idea not previously raised. Groups of codes that cluster around particular themes are grouped within “domains” (Spradley, 1980). The analysis of comparison student interviews was conducted using the analytic framework of six domains of benefits developed from interviews with the original sample of UR students: thinking and working like a scientist, becoming a professional, personal and pro-
professional gains, career clarification, enhanced career preparation, and skills. Although new codes were added as necessary, no new domains were identified. A taxonomic analysis revealed sub-categories within the larger domains. Ongoing discussions between researchers about the types of observations arising from the data sets helped to assess and refine category definitions and to assure content validity and inter-rater reliability.

Because students in the comparison sample discussed a variety of learning experiences, and some students had participated in multiple out-of-class experiences, detailed analysis of the sources of their gains became essential. Therefore, each gains-related code referenced the source of the gain identified by the student. For example, separate codes were developed for “gains in critical thinking skills from coursework,” “gains in critical thinking skills from internships,” etc. This detailed coding allowed us to accurately identify which sources led to particular learning outcomes; student comments quoted below also indicate these sources.

Because the sources of students’ gains are essential to the arguments we make, we report the frequency of student observations for each source in each of the six domain areas. These frequencies represent the number of observations, or comments, within a particular category, rather than the number of people who made a certain comment. Together, these frequencies describe the relative weighting of issues in participants’ collective report. As they are drawn from targeted, intentional samples, rather than from random samples, these frequencies are not subjected to statistical tests.

The Range of Students’ Curricular and Co-Curricular Experiences

We now describe the varied undergraduate experiences that constituted the sources of gains for students. Table 1 summarizes the overall range of students’ experiences and the number of students participating in each type of experience. Some students engaged in multiple out-of-class experiences and, as noted above, separate gains codes were developed for each source of gain to ensure that we accounted for the complex array of students’ experiences.

Almost all (85%) of the students engaged in one or more professionally enriching activities during their undergraduate years, with jobs or internships being the most common. The range of internship and jobs reflects the varied interests of this group of students, some of whom were more interested in the educational or political aspects of their disciplines than in scientific research. Students held internships or jobs in
industry (typically engineering or technology firms), education (K–12 classrooms, after-school programs); health care (hospitals, clinics), non-profit organizations (counseling, community agencies, or environmental organizations); and policy (government agencies or elected officials’ offices).

Approximately 42% of students \( (n = 26) \) participated in some type of research experience other than the classic on-campus summer research apprenticeship that we studied in our main UR sample. While most students only engaged in one research experience, a few students participated in multiple research experiences. Fifteen of the twenty-six research students pursued an off-campus, summer research experience at a government lab or research university, which we have labeled as off-campus research. Most of these students described research experiences that our team of analysts agreed closely resembled those of their peers who stayed on campus. These students engaged in apprentice-style research in which they worked on an authentic, independent project under the auspices of a faculty or graduate student research advisor. But a few students found themselves in labs where they received little or no guidance and engaged in tedious, routine tasks.

**TABLE 1**

<table>
<thead>
<tr>
<th>Experience</th>
<th>Number of students</th>
<th>Percentage of sample</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late research on campus</td>
<td>16</td>
<td>26%</td>
<td>42% of students conducted some form of research.</td>
</tr>
<tr>
<td>Alternative research off campus</td>
<td>15</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td>Internship off campus</td>
<td>28</td>
<td>45%</td>
<td></td>
</tr>
<tr>
<td>Clinic program on campus</td>
<td>10</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>General college experience</td>
<td>62</td>
<td>100%</td>
<td>42% of students participated in research-like classroom activities.</td>
</tr>
<tr>
<td>Coursework</td>
<td>62</td>
<td>100%</td>
<td>15% of students had only these experiences and no pre-professional experiences.</td>
</tr>
</tbody>
</table>

*Notes.* \(^1\) These numbers are used to weight the student observations by source as presented in Figure 1. \(^2\) The total number of students conducting research is less than the sum of the two sub-groups, because some students participated in both late and alternative forms of UR.
Sixteen of the 26 students, classified as *late* research participants, engaged in a senior thesis project or conducted research on campus under the guidance of a faculty member during their senior year. The thesis was typically an independent research project developed and implemented by the student with the assistance of a faculty advisor and undertaken during the academic year. Together, the *off-campus* and *late* sub-samples represent a variety of research experiences that STEM students may have during their undergraduate years.

Finally, 10 students participated in the *clinic* program offered at one site. The clinic program is a long-standing program in which students work in small, interdisciplinary groups (typically four or five students) to solve a real-world problem for a sponsoring company or agency. Students undertake applied projects, working closely in teams under the guidance of a faculty member, student team leader, and company liaison, and within budget and scheduling constraints. Students present a final written report and give oral presentations to the sponsor and the broader college community.

Nine students within this sample had no real-world, out-of-class experiences. However, the general educational experience at selective liberal arts colleges has been touted as offering superior preparation for a career in science (Cech, 1999). In addition, 26 students reported that some of their STEM courses, particularly upper division courses, included a research-like component where they engaged in small, open-ended projects, either individually or in small groups. Because all students took courses and experienced the general educational atmosphere of their residential colleges, the sub-samples labeled “courses” and “general college atmosphere” include all of the interviewees, and students often cited these as sources of particular benefits.

**Demographic Characteristics of Participants**

Our sample demonstrated gender diversity but lacked racial and ethnic diversity, consistent with the general enrollments of the study institutions. A little over half (55%) of students were women, and most students (88%) were White. Students represented a variety of disciplines: biology (35%), mathematics (19%), psychology (18%), physics (10%), computer science (8%), engineering (6%), and chemistry/biochemistry (6%). All students were STEM majors, but many had double majors that reflected their eclectic interests: Spanish, Chinese, business, communications, religion, music, African studies, anthropology, English, and political science.
Overview of Findings

Overall, students’ comments about participation in their curricular and co-curricular activities were positive, describing gains made (81% of all of students’ gains-related comments). However, a minority of students made negative and mixed comments about some of their undergraduate experiences. Negative observations were not negative in tone, but rather reflect students’ explicit statements in interviews about what they did not gain during college. For example, a typical negative comment expressing a lack of mentoring is: “I haven’t had as much one-on-one time with my academic advisor. So as far as a mentor, I would say that I have not had one. I just take care of myself.”

What we call mixed observations often described areas in which students reported limited or weak gains, and did not yet feel confident and independent. Mixed observations also included comments in which students asserted that they had made gains but, by their descriptions of those gains, we judged that they had not made the gain at a developmental level appropriate for college students. An example of a mixed observation describing limited gains in understanding the nature of scientific knowledge is: “I think my higher-level math classes have helped me to see that, but not on a deeper level in terms of how it would compare if I had a research experience.”

Because there were few mixed observations in our analysis (4% of all student comments), we have combined the negative and mixed comments into one group. Overall, nearly one fifth of student comments were negative or mixed, reflecting complete or partial failures to make some of the gains within the six domains.

Because of the range of students’ experiences and the multiple influences on their learning, the sources of students’ reported gains are an essential aspect of our analysis. Although learning is a continual process that occurs across various environments and contexts—as, indeed, the student interviews attest—we were struck by the clarity with which students described distinctive features of their diverse undergraduate experiences, including the nature and depth of gains they experienced in these different contexts. By analyzing the specific sources of student gains, we do not mean to assert that students’ learning was fragmented, or that each gain only occurred in a single context. Their learning was clearly cumulative, yet most students identified experiences whereby they received particular benefits, and articulated how these benefits built upon their prior learning in other contexts.

For example, while many students described making gains in presentation skills from both coursework and research experiences, the nature
of their reported gains differed in each setting. Coursework typically provided a first undergraduate exposure to presentation, and from classroom presentations, many students described gains in organizing and clearly communicating material, and increases in confidence in public speaking. Students described building upon these general gains during their research experiences, as they discussed learning to give and receive scholarly critique, and to tailor presentations to professional, scientific audiences. Students also noted that many of their learning gains from research transferred back to later coursework. Thus the strength of this analysis lies in careful categorization of students’ often-detailed descriptions of the sources of their own learning gains, and identification of the cumulative and complementary benefits that students noted as arising from both classroom and out-of-class experiences.

Because our sub-samples vary in size, our sources analysis must account for the fact that, although all students engaged in coursework, fewer engaged in internships or research, and fewer still participated in the clinic program. Therefore, we created a weighted proportion, demonstrated in the figure above. Figure 1 illustrates the sources of students’ positive and negative/mixed observations for each of the six domains of gains. The numbers in each category represent the proportion of student comments within that category that were derived from that particular source, weighted by the number of students participating in each type of educational experience as listed in Table 1. Population-weighted sources were determined by first computing the number of gains statements in each category per person for each source of gain. For example, 87 positive statements about “thinking and working like a scientist” were reported by 16 interviewees as deriving from late research experiences, yielding 5.4 gains statements per person from late research. This is compared to the number of gains statements in this category from all sources (e.g., 19.9 gains statements per person in “thinking and working like a scientist”). Figure 1 presents the weighted percentages (e.g., 5.4 statements per person from late research out of 19.9 from all sources, or 27%). Thus, of the six sources, late research participants contributed more than their “fair” share of positive statements about this benefit.

The six sources of gains included coursework, general college experiences, internships, clinic, and off-campus and late research experiences. The shading in Figure 1 further pairs these six sources into three groups: research experiences (in two forms, off-campus and late); work experiences (in two forms, internships/jobs and clinic); and campus experiences (courses and general). As is evident in the figure, research experiences often yielded a disproportionate number of positive statements, while coursework or general college experiences often yielded a larger
### Fig. 1. Sources of Benefits from College Experiences

<table>
<thead>
<tr>
<th>Category</th>
<th>% 0%</th>
<th>% 33%</th>
<th>% 67%</th>
<th>% 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All Gains</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal/Professional Gains</td>
<td>14%</td>
<td>20%</td>
<td>15%</td>
<td>11%</td>
</tr>
<tr>
<td>Thinking &amp; Working Like a Scientist</td>
<td>24%</td>
<td>44%</td>
<td>18%</td>
<td>7%</td>
</tr>
<tr>
<td>Becoming a Professional</td>
<td>19%</td>
<td>11%</td>
<td>30%</td>
<td>12%</td>
</tr>
<tr>
<td>Skills</td>
<td>22%</td>
<td>11%</td>
<td>30%</td>
<td>18%</td>
</tr>
<tr>
<td>Career/Graduate School Preparation</td>
<td>30%</td>
<td>19%</td>
<td>20%</td>
<td>9%</td>
</tr>
<tr>
<td>Career Clarification</td>
<td>5%</td>
<td>35%</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>Career/Graduate School Preparation</td>
<td>22%</td>
<td>43%</td>
<td>6%</td>
<td>15%</td>
</tr>
</tbody>
</table>

**Reported source of gain, weighted percentage**

- **positive**
- **negative/mixed**

---

*Fig. 1. Sources of Benefits from College Experiences*
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proportion of mixed or negative statements—again, reflecting not a negative response to courses but students’ self-reports of failure to make a gain.

Research Findings

We now present findings about the six major domains of student gains, and the sources of gains that led to particular outcomes. Though these domains were earlier identified in our analysis of interview data from on-campus, summer research students (Hunter et al., 2007), they applied remarkably well to other undergraduate experiences: we did not identify any new domains, though we did identify new codes within each category.

Thinking and Working like a Scientist

The category “thinking and working like a scientist” describes students’ reports of gains in the application of scientific knowledge and skills, understanding the process of scientific research and the nature of scientific knowledge, and increased conceptual understanding of the discipline. As shown in Figure 1, students’ positive statements resulted primarily from coursework and research experiences, while coursework and general college experiences yielded the greatest number of negative comments.

Through their undergraduate experiences, students reported increases in their critical thinking and problem-solving abilities. Almost all comments (87%) about gains in general critical thinking skills pertained to coursework or the college environment. Additionally, students described developing a greater understanding of the scientific research process; however, only 19% of students reported gains in understanding the research process from coursework or the general college experience. That is, students reported that they developed general critical thinking skills from their coursework and from the intellectual atmosphere on their liberal arts college campuses, but found coursework to be less effective in providing a deeper understanding of research design or the research process.

The research experience does give you an idea of how science is actually done in the real world, and you don’t get a feeling for that in your laboratory classes. Your laboratory classes are pretty much, you do this experiment in this set amount of time and you do all you can to get it done—whereas with research the time scale is much broader and you just do what you can each day. (Off-Campus Research, Positive Observation)
The intensity of research, or the amount of responsibility granted to students, was critical to students’ intellectual development. The student quoted below describes two research experiences, one that led to gains in understanding the process of scientific research and one that did not. Students reported greater gains when they engaged in authentic work within a community of practice that was working toward a common goal.

I worked for one summer in a molecular biology lab. While I learned a technique that most people don’t know before their sophomore year, it wasn’t authentic. It was as authentic as my mentor could make it while he’s writing a bunch of grants. As opposed to here, where every week I have to do a gel and report to my lab group. And interpreting the data on a weekly basis and thinking about what am I going to do next, so I think that that gave it the authenticity. … I had a role in this lab. (Off-Campus and Late Research, Negative and Positive observation)

In conclusion, students with research experiences reported disproportionate gains in their ability to apply critical thinking skills in a novel context, and gain a greater understanding of the scientific research process. Many students who did not participate in research reported gains in general critical thinking skills from their coursework, but out-of-class research experiences were more effective in helping students to develop the intellectual abilities and capacities particularly valued for doing research.

Becoming a Professional

Through research and other co-curricular experiences, students described adopting the behaviors and attitudes necessary to become a professional. Students reported that they learned to work independently, take “ownership” of a project, and developed an understanding of professional practice. As Figure 1 shows, students’ positive observations disproportionately referenced research experiences, while work experiences (clinic and internships) made up the next largest category, and coursework accounted for fewer gains.

Becoming a professional: Developing independence. Through coursework and out-of-class experiences, students described learning to work and think independently, to take responsibility for their own learning, and to take initiative to solve problems on their own rather than relying on experts for the answers. Unlike other areas, the sources of gains in independence and initiative were relatively evenly distributed (39% of positive comments came from research, 32% from clinic and intern-
ships, and 29% from coursework or the general college experience). In research experiences, students began to pay careful attention to details in their projects and took pride in the results of their work.

That experiment was mine. And knowing that I was in control of how it went, if we got results or if we didn’t get results, my work and my effort towards it was the thing that was making that go and making it work. *(Off-Campus Research, Positive Observation)*

Some internship students worked on real-world projects in which they were responsible for managing budgets and organizing and implementing project activities.

When I did the summer work [in my internship], I had the opportunity to take more time with a project. They’ll simply tell me, “All right, we have this problem. We don’t really know how you want to solve it—go to it, analyze different possibilities.” And so in that way you learn to work independently, and to reflect about different possibilities. *(Internship, Positive Observation)*

**Becoming a professional: Understanding professional practice.** A few students described gaining an understanding of how scientists or others practice their profession. Specific to research, some students observed scientists discuss and write grant proposals and journal manuscripts, undergo peer review and publish, and attend conferences to present papers. Students in other settings observed professionals coordinating and managing project budgets, timelines, resources, and personnel. None of the positive observations in this sub-category derived from coursework; the classroom did not offer the same access to professional communities of practice as did out-of-class experiences. The majority of students’ positive observations derived from research (64%), as illustrated by the quotation below.

I attended weekly staff meetings, where everyone would talk about the progress of their work. We would spend most of the time talking about whether their work was going to get funding for the next round. So I’ve had the experience that’s a lot closer to what I would be doing if I went on to be a professional in this field. *(Off-Campus Research, Positive Observation)*

However, some students did not describe gaining a better understanding of the habits of mind or everyday practices of scientists. For example, when discussing how scientists think about problems, this student described physical work environments rather than approaches to
problems. During her research experiences, she worked in isolation on low-level intellectual activities and had little opportunity to observe scientists at work.

People think in different ways. Some physicists, theoreticians, think exclusively in small, cold rooms with math and computers. Other physicists, experimentalists, think in large, cluttered labs full of lasers. (Off-Campus Research, Negative Observation)

Becoming a professional: Developing an identity as a scientist. Through out-of-class experiences, students described gains in “feeling like a scientist” and developing an identity as a scientist. The majority of positive comments (75%) referenced research experiences, while the rest were divided among internships, clinic, coursework, and general college experiences.

The linkage between professional experiences and identity development is particularly clear in contrasting remarks from a student who had participated in a business internship. Though she made gains in other areas, she did not become confident in her ability to “be” a scientist during her undergraduate experience. She saw herself as a lab technician, incapable of working independently, rather than as a “real” scientist.

If you put me in a lab with a professor and they were completely in charge of me, I would be a really good worker. I would be able to do everything—they would be like, “Do this technique” and I could do it well. (General College, Negative Observation)

On the other hand, her internship contributed to her development of a professional identity in marketing.

I’d say in taking that professional step, the more that I’ve done independent things, the more I’ve felt like a professional. (Internship, Positive Observation)

It is uncommon for undergraduate students to begin to develop a professional identity at all. Baxter Magolda (1999) found that most young adults did not undertake such identity development until after college, however, “when participants were encouraged to take initiative in their work, were rewarded for doing so, and had models to observe, they made progress moving toward internal self-definition” (p. 642). Likewise, in this study, students’ reported gains came through experiences that provided ownership of a “real-world” project while receiving adequate support and guidance from more experienced profession-
als within a community of practice. The formation of identity through engagement in an authentic enterprise is a critical component of the learning process within a community of practice (Lave & Wenger, 1991; Wenger, 1998). According to students, authentic experiences of many types socialized students into the identities and practices valued within certain professions. Nevertheless, research was a more effective method to develop the traits, attitudes, and habits of mind necessary to be a successful scientist.

Personal and Professional Gains

In this category students described the benefits of establishing a collegial relationship with a mentor and peers and noted increased confidence in their professional skills and abilities. As indicated in Figure 1, students’ positive statements were disproportionately focused on research. However, the majority of negative statements came from clinic and internships, where many students lacked access to mentoring from professionals.

Personal and professional gains: Increases in confidence. Students noted gains in confidence, particularly in their ability to undertake an open-ended project and to contribute to their field. The majority of positive comments in this sub-category derived from participation in research (59%), while 21% referenced coursework or general college, and 19% cited clinic and internships. One source of students’ increased confidence was the realization that their work would contribute to their field.

The thing I liked best was the feeling of creating something and polishing it and making it ready for other people to see, and contributing to science. (Late Research, Positive Observation)

When students participated in less effective experiences, they were more likely to report a lack of gains in confidence. Though she had participated in a summer internship related to science, this student had not found it intellectually challenging—she engaged primarily in office “busy work”—and remained uncertain of her mastery of her discipline.

I feel like I could learn how to do a lot of things if someone taught me. I’m a little sketchy in chemistry, if you tested my confidence in that I might not be so high at times because it’s really hard—I just don’t understand it like other people. (Internship, Negative Observation)

Personal and professional gains: Developing collegial relationships with professionals. In this sub-category, students reported build-
ing close, collaborative relationships with professionals in the field. Research was the most successful experience in helping students to establish a mentoring relationship: 62% of students’ positive observations came from research, and far fewer from internships, clinic, and courses. Students who engaged in research described the benefits of working side-by-side with a faculty member in a way that they did not in their coursework.

It is a definite different relationship. And it’s nice to work with someone and become interested in the same thing that they’re interested in, and work together towards that goal. And they become more of, a colleague, like a peer, someone that you both have the same goal in mind, and they’re entrusting you with a lot of responsibility. (Off-Campus Research, Positive Observation)

Personal and professional gains: Collegial relationship with peers. A smaller number of students described the development of a collegial working relationship with peers. Students who undertook late research were less likely to work with a group, while off-campus research experiences varied in the extent of peer interaction. Instead, 34% of positive comments came from students who had engaged in a collaborative project for a course, and 17% from clinic. In these contexts, students typically had less mentoring from faculty and other professionals than in research, so students often served as a source of support to each other when things did not go as planned.

I really didn’t get to do [teamwork] until my clinic project. Before that, my research experiences were pretty much independent work. (Clinic, Positive Observation)

Overall, in the personal and professional gains category, students described increased confidence in their ability to do research, and the development of collegial relationships with mentors and peers. These relationships enhanced students’ personal and professional growth, as mentors served as models of professional practice. Students reported more consistent benefits in mentoring from out-of-class experiences, particularly research, than coursework; however, students noted gains in teamwork skills from coursework and the clinic program.

Enhanced Career/Graduate School Preparation

From their out-of-class experiences, students noted that they enhanced their résumés, networked with professionals, and began to feel
prepared for future careers. As indicated in Figure 1, research, clinic, and internships were all significant sources of gain in this category. Though there were fewer negative comments in this category, they most often originated from research experiences.

Authentic experiences provided invaluable real-life experience that students thought would transfer to their future careers. As demonstrated in Figure 1, students’ positive comments most often referred to research. Students thought the real-world benefits of out-of-class experiences could not be gained through coursework. Even courses that stressed real-world applications did not provide access to an authentic community of practice.

I think [clinic and research] have been some of the highlights of my education here. There’s no doubt that they’ve been the most realistic applications of the theoretical information that I’ve learned here. The truth is it’s a lot more relevant to the work I’m about to go out and do than most of the classes that I’ve had here. (Clinic and Off-Campus Research, Positive Observation)

Research students felt prepared for graduate school and increased their confidence about their readiness for graduate school: 70% of comments in this area originated from research experiences.

Doing something of this size on my own was something that I think, if I hadn’t done it, I would have felt less prepared to go to grad school. (Late Research, Positive Observation)

In contrast, students with poor research experiences did not report gains in understanding what graduate school would be like. These students often worked in isolation and had no opportunity to learn about life as a graduate student; some even developed major misconceptions:

I’m not quite sure what to expect. I assume it’ll just be college with more physics and less humanities. (Off-Campus Research, Negative Observation)

In sum, a variety of out-of-class experiences offered students a chance to engage in authentic, professional work with real-world significance, through which students felt they received greater preparation for their future careers than from coursework alone. Undergraduate research most closely resembled the communities of practice found in graduate school in the sciences; for that reason, students felt most prepared for graduate school from research experiences.
Clarification, Confirmation and Refinement of Career/Graduate School Plans

During their undergraduate years, many students reported that they clarified, confirmed, or refined their career and educational goals. Students noted that they sustained or increased their interest in the field, gained knowledge about graduate school and career options, and clarified their graduate school or career paths. Although research experiences were the primary source of these gains, Figure 1 illustrates that research experiences were also the primary source of negative and mixed comments. Most negative statements came from a small subset of students whose poor research experience had caused them to change their career and educational plans. These research students were given little or no direction on their research activities, felt no sense of responsibility over a project, and often had mentors who were unavailable or too busy to provide adequate guidance.

As demonstrated in Figure 1, students most often referenced research as their source of career clarification gains. Work experiences (clinic and internships) were also secondary sources of gains, while coursework accounted for very few gains. Students noted that internships helped them to discern what type of work environment might fit their talents, interests, and lifestyle choices.

It helps a lot as far as what type of engineering I want to do and what type of company I want to work for. (Internship, Positive Observation)

Similarly, participating in research helped students to decide whether scientific research was a career goal that they wished to pursue: research was the source of 93% of comments in this area.

I have a better understanding of what it takes to be a researcher. I have a better understanding if research will work out for me, if it’s something that I want to do. (Late Research, Positive Observation)

Other students, particularly those with no professional experiences or weak experiences, reported no gains in clarity in their career or educational goals:

I’m sure there is an area of physics that would interest me and drive me wild and make me go screaming into graduate school with my hair on fire. But not at the moment. (Off-Campus Research, Negative Observation)
Research students described stronger gains than other students in clarifying and confirming their interest in graduate school (94% of positive comments stemmed from research). A student with two research experiences articulated how each had affected his educational and career goals.

My first research experience gave me a negative view of graduate school and what it was like. The second one made me feel like, “Okay, I can be a scientist.” Maybe graduate school is kind of this way, where you just have to publish papers and stuff, but if you can see around that and just do what you’re interested in, then it might be good for me. (Off-Campus Research, Negative Observation)

Some students simply performed mechanical tasks during their research experiences, causing them to lose interest in the work. The quotation below describes the negative consequences when students are not adequately mentored and do not have the opportunity to engage in the “big picture” of their work.

When I came to college, my plan was to do molecular biology research. I thought that was a pretty exciting field. But the more I did it. … I found pure research to be pretty mechanical. I felt a lot of times that some sort of well-designed robot could be doing my job. There wasn’t a lot of creativity in it at all. And there wasn’t a lot of human interaction. I found myself just being in a lab, sort of doing monkey work. Maybe it was an interesting experiment, on the whole, but the day-to-day procedures were pretty isolated interactions. (Off-Campus Research, Negative Observation)

Good research experiences, on the other hand, were influential in motivating a few students to pursue graduate school, especially those who had become discouraged in their majors or coursework.

I had an awful class schedule this last spring. I hated all of my classes, and when you’re trying to decide if you want to spend six more years doing this, it was extremely crucial for me to have this research experience. Because the field that I’m going into in grad school was one of the classes that I didn’t like, but I worked in that field during the summer and I realized, I actually like the research. And so it was important for me to have that positive experience to continue on. (Off-Campus Research, Positive Observation)

At the end of their senior year in college, 14 of the 62 students had been admitted to graduate school. Participation in research, or in other out-of-class experiences, did not significantly impact students’ career
and educational plans; rather, it often reinforced pre-existing plans. All of the 14 graduate school enrollees had plans to enter graduate school, or were at least considering graduate school as an option, upon entering college. Indeed, many students pursued research because of their prior interest in graduate school or a research career. Of the 26 research participants, 18 (69%) had a pre-existing interest in pursuing graduate school; the remainder were largely interested in medical careers. Three of the research students were derailed from their graduate school ambitions because of poor research experiences, the rest confirmed that their original goal was the right course for them. Therefore, a research experience—whether good or poor—was influential in helping students to decide whether graduate school was the correct path for them.

In conclusion, participation in an authentic, meaningful out-of-class experience was critical in helping students to determine whether their future plans were a good fit for their personality and interests. Coursework, even with assignments intended to lend authenticity to the classroom setting, generally did not provide the legitimacy of a “real” community of practice to help students clarify their future goals. The findings highlight the significance of co-curricular experiences, particularly research, in contributing to students’ decisions to remain in or leave the field. Poor research experiences turned off students from the discipline or graduate school, while good research experiences sustained or increased student interest.

**Gains in Skills**

A final commonly reported benefit was gains in skills. While students did not cite the same level of benefit from courses as out-of-class experiences in some areas, coursework, along with clinic and research experiences, were the primary source of reported gains in skill, as indicated in Figure 1.

**Skills: Gains in communication skills.** Students reported gains in both oral and written communication skills. Almost two thirds of students’ observations in this sub-category derived from coursework, with the remainder from research and clinic. Few internship students had the opportunity to present their work. Some research students presented at professional conferences or in formal symposia, while presentations in courses were largely limited to an audience of peers and the instructor. Formal and informal presentations were a large component of the clinic program.

In the clinic project, that’s one of the major focuses. You practice throughout the year giving presentations similar to what you might give in a work-
ing environment. It’s usually for a corporate working environment, around a report that focuses on your progress and whether you’re in the budget and the timeline. A little different from scientific presentations, but still really good for organizing your material and being able to present it. (*Clinic, Positive Observation*)

Students also discussed gains in writing skills, particularly from courses. In fact, 70% of students’ positive observations about writing skills derived from preparing formal lab reports and literature reviews in courses.

We’ve done a lot of writing where the professor will tell you, you need to write this as if it could be published. It’s never been anything that really would be put forward, but it was just the format and how high the quality was supposed to be. (*Coursework, Positive Observation*)

*Skills: Technical, organizational, and other skills.* Students also reported gaining other skills, including laboratory techniques, organizational and planning, computer, and teamwork skills. Students described gaining skill with equipment and instrumentation from research experiences more than from class labs: 56% of all positive comments came from research. The repeated use of specific equipment and the real-life consequences of mistakes in research fostered these reported gains, as the following quotations highlight:

I got a lot of skills, working with the PCR, knowing how to clean and sterilize and do all the instruments. With extracting DNA, to be able to transfer DNA—to be able to say, “I’ve done it so many times that I’m not making any more mistakes.” (*Off-Campus Research, Positive Observation*)

So I have a little bit of everything, but nothing if you’re comparing this to research, nothing like doing that repeatedly, knowing every time you pick up a pipette that you know how to work it exactly. (*Coursework, Negative Observation*)

In sum, students reported gaining a variety of skills through their undergraduate experiences. Research students emphasized the development of laboratory skills and oral argumentation skills. On the other hand, students noted that writing skills derived primarily from formal writing within their courses.

**Limitations of the Study and Future Directions**

Qualitative research, particularly in cases where little empirical
research exists, is inherently exploratory and descriptive. While 62 interviews is large for a qualitative sample, the subsamples within this study are modest. Interviewees provided rich and detailed descriptions of their learning and developmental gains from their undergraduate experiences, but the findings should not be generalized to a larger, more diverse population without further investigation—including quantitative measures with broader samples that allow for statistical testing. Our research group has recently developed a quantitative instrument to assess students’ self-reported gains from research, the Undergraduate Research Student Self-Assessment (URSSA) (Hunter, Weston, Laursen, & Thiry, 2009). The survey scales and items are based on findings from our qualitative research. The survey has been piloted with a large, diverse group of undergraduate research students and undergone rigorous statistical tests of validity and reliability.

Qualitative researchers can enhance the generalizability of their findings through comparison with other studies (Huberman & Miles, 2002), such as the degree to which the findings match, or “fit,” other similar situations (Lincoln & Guba, 1985), or the extent to which the components of a study, such as units of analysis or constructs, may be used as a basis for comparison with other studies (Goetz & LeCompte, 1984). By these criteria, the six domains of students’ gains identified in this study have held up remarkably well in other research and evaluation studies examining diverse populations in a variety of institutional contexts (Hunter, Thiry, & Crane, 2009; Thiry & Hunter, 2008; Thiry & Laursen, 2009). To a large degree, other researchers have also elucidated similar constructs—though with less breadth and depth—from studies with diverse populations of UR students in varying institutional contexts (Alexander et al., 1998; Bauer & Bennett, 2003; Kardash, 2000; Rauckhorst, 2001). An analysis aligning research and evaluation findings on the six domains of student gains, across over two dozen studies conducted at diverse institutions, appears in (Laursen et al., 2010).

One point of difference, however, between ours and other studies is the career and educational outcomes for research participants. In particular, UR seems to have a more significant influence on the career and educational outcomes of students from underrepresented groups (Alexander et al., 1998; Hathaway et al., 2002; Thiry & Laursen, 2009), than it did for the population of the present study. Because our study sample is rather homogenous, further research is needed on diverse students’ learning and career outcomes from participation in a broad range of out-of-class experiences, including internships and jobs.

Moreover, interview findings in this study are based on students’ self-reported experiences of growth and development in several domains
essential to the practice of science. In some domains, such as confidence or interest in a subject, self-report may be an ideal way to assess growth or development. However, in other areas, such as gains in disciplinary or conceptual understanding, self-report is not the only way to assess student learning. To strengthen our research findings on student gains, we triangulated reports of gains from the UR students in the original sample with their research advisors’ reports of their gains. For the most part, student and faculty assessment of learning and developmental gains were well aligned (Hunter et al., 2007), suggesting that students distinguished their own gains with a reasonable amount of clarity. However, faculty observations made evident one type of gain that was less crisply described by students, leading us to add to our formal categorization scheme the gains category we call “becoming a scientist,” or professional socialization—and thereby demonstrating the analytic value of comparing these multiple sources of data.

Triangulation against faculty observations was not possible for the “comparison” sample of students because of the vast range of out-of-class experiences they described in interviews, and the lack of mentoring and advising encountered by some of the students. However, the high degree to which the nature of gains described by comparative students (when such gains were present) matched reports by UR students and advisors, themselves well corroborated, and the forthrightness with which students in the “comparative” group described their gains (or lack thereof), all suggest that the comparative students provided similarly perceptive descriptions of their growth and development from their undergraduate experiences.

Lastly, the study sites were selective liberal arts colleges populated by bright and academically well-prepared students. Because the study sought to empirically establish the benefits of undergraduate research and comparable experiences to students, the study sites were chosen to represent “best case” scenarios, where apprentice-model UR has been long and expertly practiced (though by no means uniquely so). Such a choice means that the students in our samples were well positioned to make gains from their learning experiences, but it also means that many of students’ experiences—whether in and out of class—are “best cases” of their type. The students in both samples experienced small class sizes, high faculty contact, interactive learning methods, and other practices shown to have high impact on student engagement (Kuh, 2008). Thus, to the extent that the study demonstrates value added from UR and other experiential learning opportunities, it is against an educational background already high in quality. A greater impact of experiential
learning might well be found in contexts where students do not experience high-impact practices in the classroom. Further research is needed to test this hypothesis.

Conclusion and Implications

Findings from interviews demonstrate that students report greater gains from their undergraduate education in STEM disciplines if their coursework is supplemented with participation in legitimate, professional communities of practice. While the four liberal arts colleges in this study offered a rigorous education in a scholarly environment, courses were constrained in their ability to provide access to a scientific community or “real-world” work. Inquiry-based labs in courses offered students a taste of the nature of scientific research, but the depth and intensity of these activities was limited. In all domains, a greater proportion of students’ positive statements derived from research experiences than from coursework.

The personal and professional benefits of out-of-class experiences complemented classroom learning. Coursework enhanced students’ reported ability to work independently, think critically, and communicate effectively, but students described a range of additional benefits from out-of-class experiences. Work experiences, such as internships and the clinic program, offered students the opportunity to take ownership of a real-world project, clarify future career goals, and begin to develop an identity as a professional. Clinic students described developing teamwork skills as they collaborated closely with peers on an authentic task. Research students reported gains in understanding the scientific research process and experimental design and developing the temperament and identity of a scientist.

While clearly out-of-class experiences complement classroom learning and may enhance students’ learning and development in multiple domains, the quality of these out-of-class experiences was critical to students’ outcomes. Indeed, poor experiences led a few students to lose interest in their major or abandon educational and career goals. In contrast, good experiences demonstrated the value of pre-professional activities for STEM undergraduates. Critical components of a high-quality experience were adequate mentoring, supervision, and guidance by more knowledgeable professionals or peers; engagement in meaningful, authentic tasks that advanced the work of a community of practice; a sense of ownership over a real-world project; and ample opportunity to work independently and think creatively about a project.
These findings have implications for faculty, internship supervisors and others who facilitate students’ learning outside of the classroom or help them choose such opportunities. First, it is important to guide students toward tasks that challenge their intellectual abilities and skills. Students gain most when they extend their capabilities and are not relegated to non-educational, routine tasks, described as “monkey work” by one student. Likewise, students must not be left alone to grapple with tasks far beyond their intellectual capabilities. In this study, the former scenario was more common.

Research and internship supervisors can also do much to improve the quality of students’ co-curricular experiences. They can select appropriate, authentic projects and provide adequate training and supervision. They can include students in frequent discussions of the progress of the work and encourage students to participate in and present at team meetings. Campus departments and career centers can help by monitoring the quality of students’ out-of-class experiences. Through surveys or exit interviews with students who pursue off-campus “real-world” internship opportunities, they can identify placements that foster these markers of a quality out-of-classroom learning experience.

Campuses can also formalize the processes by which students engage in experiential work. Institutions can provide training to help on- and off-campus student supervisors develop an educational approach to students’ tasks based on factors that enhance student learning and development. Mentor training can educate faculty, graduate students, and others who work directly with students in appropriate project selection and supervision of students (Pfund et al., 2006).

Our findings suggest that undergraduate science education should be augmented by student engagement in high-quality, “real-world” experiences that meet students’ broad range of interests, talents, and career goals. Well-designed experiences supplement classroom learning in many ways, but our evidence indicates that undergraduate research, in particular, is an integral source of such learning for future scientists. More so than their peers, students who engaged in an authentic research experience, with adequate amounts of both challenge and support, described gaining an appreciation of the process of scientific research and an understanding of the everyday work and practice of research scientists. Though other out-of-class experiences clearly offered a host of benefits, student reports indicated that participation in research is a more effective way to socialize novices into the scientific research community by helping them to develop the mastery, knowledge, skills, and behaviors necessary to become a scientist.
References


