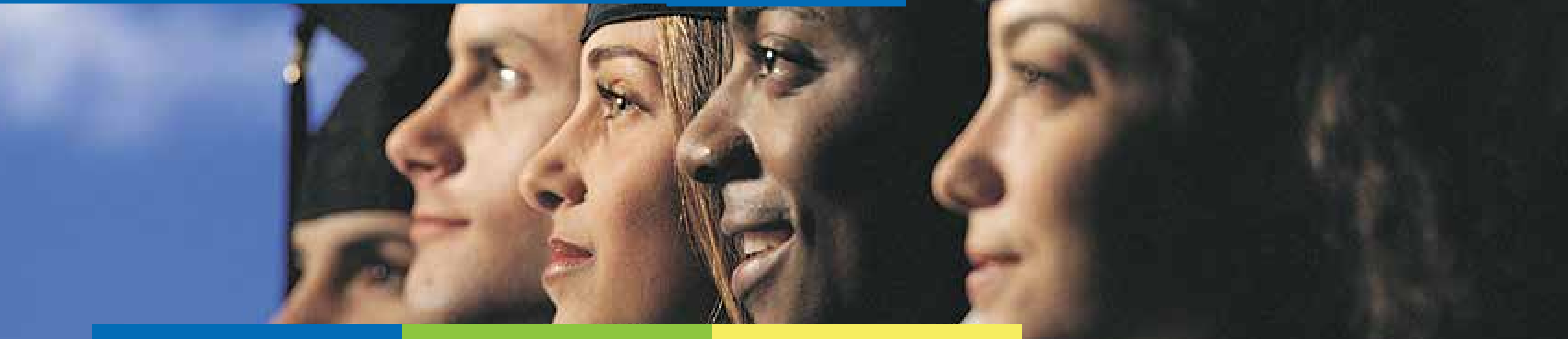
Quality Approaches in Higher Education



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Editor's note: This issue of *Quality Approaches in Higher Education* is focused on STEM education and partnerships among universities, industry, and government that enhance and provide experiential learning to STEM and engineering majors. This issue celebrates the ideas and planning behind the upcoming ASQ Education Division's Advancing the STEM Agenda Conference, co-sponsored with Grand Valley State University's Seymour and Esther Padnos College of Engineering and Computing on June 3-4. Significantly, the theme of the conference is "Collaboration with Industry on STEM Education." We asked Dean Paul Plotkowski to introduce this issue with a commentary on the engineering program at Grand Valley State University and the collaboration it has with industry. We further highlight advances in STEM learning, education, leadership, and collaboration with articles from NASA's Langley Research Center, The Ohio State University, and Southern Illinois University Carbondale. Together, these articles represent different and critical perspectives on how the STEM agenda is impacting STEM programs to develop better prepared professionals.

—Cindy P. Veenstra, special issue editor

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NASA's LARSS program shows the benefits and lessons learned from its collaborative internships.

Using Assessments to Determine the Quality and Effectiveness of a Collaborative Internship Program in Research

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Abstract

The Langley Aerospace Research Student Scholars (LARSS) program is a nationally ranked, highly competitive, and collaborative internship program that uses NASA research opportunities to inspire and motivate students to complete a degree in science, technology, engineering, or mathematics (STEM). The program's ultimate goal is to prepare students to be work-ready for employment and research. Formative and summative assessment is used to help determine the quality and effectiveness of the LARSS program. We present data from one portion of our annual (formative) program assessment—mentors' and student interns' overall perception of the internship and their assessment of interns' acquisition of 21st century workplace skills. We provide a detailed description of a (summative) longitudinal study presently underway that will provide a long-term view of the program's quality and effectiveness.

Keywords

STEM, Career Development, 21st Century Skills

Introduction

The success of the Langley Research Center, NASA, as well as the United States in the 21st century depends on the education, innovation, and skills of its people. The ongoing value of these assets will be determined in no small measure by the quality and effectiveness of science, technology, engineering, and mathematics (STEM) education in the United States. STEM education must produce the engineers, mathematicians, scientists, and technologists who will:

- make the fundamental discoveries that will advance our understanding;
- create new ideas, new products, and innovation-based growth, as well as produce new industries and occupations; and
- help retain America's position as a world leader in science and technology.

Collaboration and Experiential Learning

In the 21st century, innovation and engineering may hold the key to the economic growth and prosperity, security, and competitiveness of the United States. Consequently, the engineering community continues to devote considerable effort to keeping engineering education relevant, flexible, and adaptable, and to predicting the elements and practices essential to preparing a 21st century engineering workforce. A number of factors, individually and in combination, influence the discussion:

- a doubling of engineering and scientific knowledge about every 10 years (Wright, 1999);
- dynamic advances in instrumentation, communications, and computational capabilities;
- multiple issues associated with workforce recruitment, education, training, and retention;
- lack of public understanding and concern about STEM;

- the rate of technological change and the introduction of disruptive technology;
- the increasingly interdisciplinary nature of science and technology, dramatic advances in such fields as biotechnology and nanotechnology, and the creation of new disciplines; and
- cuts in funding for higher education and a meteoric rise in the cost of a college education.

Added to the discussion are two important facts: Engineering requires a four-year degree for entry-level employment and the "disconnect between the system of engineering education and the practice of engineers appears to be accelerating" (National Academy of Engineering (NAE), 2005, p.13). The challenge for academia is "how to produce engineering graduates that are immediately work-ready and who understand that they have a commitment to life-long learning" (NAE, 2005). To help meet that challenge, the academic engineering community is increasing its use of collaboration and experiential learning.

A variety of programs have been developed to make engineering graduates more work-ready. Two that have the greatest support are collaboration and experiential learning. Organizationally, collaborations occur at the institutional level; between institutions; and among academia, government, industry, and professional organizations. These collaborations include engineering faculty spending summers and sabbaticals in government and industry research facilities, and engineers from government and industry joining advisory boards of engineering schools and teaching courses on campus and online.

Experiential learning has a long history in engineering education in the form of cooperative education programs. Co-op students devote a fixed amount of time to working in industry as part of their academic studies. Cooperative education remains a time-tested method of merging education and practice to make engineers work-ready. The term "internship" is also applied to engineering work-experience programs. Curricula that combine education and practice provide universities opportunities to collect data that can be used to determine the quality and effectiveness of their programs. For example, data in the form of feedback from mentors of student interns can be used to determine the acquisition of essential workplace skills such as:

- adaptability—the ability and willingness to cope with uncertain, new, and challenging assignments;
- communications—the ability to effectively process and interpret both verbal and non-verbal information and instructions;
- non-routine problem solving—the ability to examine and interpret a broad spectrum of verbal and non-verbal information and develop solutions;
- self-management—the ability to work autonomously and in groups, to be a leader and to be led, to be self-motivating; and
- systems thinking—the ability to understand how an entire system works; how an action, change, or malfunction in one part of a system affects the rest of the system.

These same data can be used by universities as assessment tools to demonstrate to accreditation groups like the Accreditation Board for Engineering and Technology (ABET) that an engineering curriculum is relevant, thorough, and does, in fact, prepare individuals to transition from students to professionals.

Benefits of Collaborative Internship Programs

The benefits of participating in an internship program have been cited in various research studies (Linn, Ferguson, & Egart, 2004; Maletta, Anderson, & Angelini, 1999; Pelton, Johnson, & Flournoy, 2004; Westerberg & Wickersham, 2011). An internship provides benefits not only to the student but also to the academic institution and business/industry (Cooperative Education and Internship Program (CEIP), 2009; Scholz, Steiner, & Hansmann, 2004). Student benefits include:

- gaining experience in the chosen career field,
- applying skills and knowledge from the classroom,
- engaging in collaboration with colleagues and teams,
- developing technical skills,
- enhancing the potential for job opportunities after graduation,
- gaining insight into ethical guidelines in the workplace, and
- understanding real-life expectations (CEIP, 2009; Couch, n.d.; Scholz et al., 2004).

Research by Schouurman, Pangborn, and McClintic (2008) shows that undergraduate work experience usually results in the greater likelihood of receiving a job offer prior to graduation and a higher starting salary. Benefits to academia include increased visibility for programs, enhanced experiences for students, feedback from potential employers, and partnership development with business/industry (CEIP, 2009; Schouurman et al., 2008).

The benefits for business/industry include the ability to see and evaluate potential employees in a workplace setting, interns bringing current and relevant skill sets to the workplace, and a possible pipeline for future hires (Pilon, 2012; CEIP, 2009). The National Association of Colleges and Employers (NACE, 2010) notes that roughly 75% of potential employers prefer to hire recent graduates who have had prior work experience. Converting an intern to an entry level, full-time employee can save the employer from $6,200 to $15,000 per person when recruiting and training costs are factored in (Gault, Leach, & Duey, 2010).

The LARSS Program

The NASA Langley Research Center (LaRC) is an ecosystem for innovation, problem solving, and creativity. Since 1917, LaRC engineers and scientists have performed breakthrough research and development to pioneer:

- the future of flight (including entry, descent, and landing) in all atmospheres;
- the characterization of all atmospheres;
- space exploration systems and technology; and
- materials concepts, analysis, and integration.

LaRC researchers are also engaged in innovative challenges including atomistic materials; Earth systems science; affordable, safe, and sustainable space exploration; and "green aviation."

LARSS is a paid (stipend), highly competitive, and collaborative research internship program for undergraduate and graduate students pursuing degrees in the STEM fields. A year-round program, LARSS has 3 sessions—fall and spring (15 weeks) as well as summer (10 weeks). Eligibility requires U.S. citizenship; full-time student status at an accredited U.S. community college, college, or university; and a cumulative GPA of 3.0 on a 4.0 scale. Although small numbers of talented high school students are accepted, the primary focus is on higher education. Of approximately 1,500 students who apply annually, about 250 are selected. Multiple collaborations with universities, professional/technical societies, and organizations are used to ensure geographic diversity and the participation of female students and underrepresented minorities, first-generation college students, students from economically-disadvantaged backgrounds, and military veterans (students).

For 26 years, the LARSS program has provided exceptional students the opportunity to work with Langley researchers on some of the nation's most important, difficult, and challenging problems that require multi-disciplinary, novel, and collaborative solutions. Vault Career Intelligence recognizes the LARSS program as one of the top ten college internship programs in the United States (Vault Editors, 2012).

Anticipated outcomes for LARSS interns include the following:

- learning to apply basic engineering and science concepts and principles to developing research-based solutions using research methods, experimental designs and techniques, data analysis, and interpretation;
- gaining proficiency in presenting scientific and technical concepts—including study design, analysis, research findings, and interpretations—to peers and colleagues;
- learning to use the physical and intellectual (analytical and computational) tools necessary for experimental design and research;
- developing the skills needed to succeed as professional engineers and scientists, fulfill professional responsibilities, and make sound, ethical decisions;
- learning to work and successfully function as a member of a team composed of individuals with divergent backgrounds and life views; and
- developing an appreciation for and the skills necessary to engage in life-long learning and to understand the need to exploit those skills in refining and updating one's knowledge base.

A variety of assessment tools are used to measure the program outcomes. Many of the skills listed above are based on the 21st century skills; a skill set developed by the Partnership for 21st Century Skills that outlines the knowledge and skills that are needed to prepare future professionals (Partnership for 21st Century Skills, 2004). These skills include basic and applied skills, with a focus on applied skills such as communication, teamwork, and critical thinking (Cavanagh, Kay, Klein, & Meisinger, 2006). A complete list of the 21st century skills included in this assessment appears in Table 2.

Formative Assessment

Each program year, student interns and their mentors are interviewed and surveyed after completing the summer session of the LARSS program. We use third-party evaluations to collect basic demographics, perceptions of the internship experience, and information about the development of 21st century workplace skills. The data that follow were obtained from students and mentors who participated in the summer 2012 program.

Student interns. The study included 199 students participating in the 10-week LARSS summer internship program. Participants included eight high school seniors, 19 college freshmen, 22 college sophomores, 46 college juniors, 47 college seniors, 36 master's students, and 21 doctoral students. One hundred students (50.3%) were first-time interns and 138 (69.3%) were first-time LARSS participants. Seventy-one (35.7%) of the participants were women and 128 were men. Even though the internship is open to students from around the country, the majority of the LARSS participants came from Virginia (44.7%); the next highest number of participants came from North Carolina (9.0%); and the rest of the students came from 41 other states, the District of Columbia, and the

U.S. territory of Puerto Rico. The majority of student interns, 149 (76.4%), indicated their race/ethnicity as Caucasian; 15 (7.7%) as African American; 15 (7.7%) as Asian American; eight (4.1%) as Hispanic; six (3.1%) as Native American/Alaska Native; and four did not answer this question.

Mentors. Two hundred twenty-three (223) professionals served as mentors for the 2012 LARSS program. Seventy-one (31.8%) had completed an internship as part of their undergraduate education. Thirty-six (16.1%) were first-time mentors. Fifty-nine (26.5%) were females. One hundred ninety-two (87.7%) were classified by NASA as engineers, scientists, mathematicians, or technologists. Ninety (40.5%) of the mentors held a doctorate. The mentors' total years of professional work experience ranged from one year to 40 years with the mean and median number of years being 23.5 and 25.0, respectively. The race/ethnicity of the mentors was Caucasian, 171 (78.4%); African American 12 (5.5%); Asian American 28 (12.8%); Hispanic six (2.8%); Native American/Alaska Native zero (0.0%); and five did not respond to this question. Eighty-two (37.8%) of the mentors had more than one intern.

Results

Our survey, given to interns and mentors, included their overall perception of the internship and their assessment of interns' acquisition of 21st century workplace skills. A 1-4 point scale (disagree, somewhat disagree, somewhat agree, agree) was used to measure agreement. There were 59 questions. Results are presented for two aspects of the 10-week (summer) internship experience: mentors' and interns' overall perceptions of the internship (Table 1) and ratings of 21st century workplace skills (Table 2).

Statistical significance was found for all variables in Table 1 based on t-tests for equality of means for comparing the interns' and mentors' perception scores. Although mentors and interns indicated growth in interns' self-confidence over the course of the internship, mentors indicated stronger growth in this area than interns did. Both indicated an increase in the interns' learning new skills and procedures and gaining new knowledge. Both mentors and interns agreed that the interns had a better understanding of NASA, its role, and missions by the end of the 10-week internship. Both mentors and interns agreed that the interns had a better understanding of what a full-time job in research was like.

A 1-4 point scale (disagree, somewhat disagree, somewhat agree, agree) was used to measure agreement ratings of interns' 21st century workplace development skills (Table 2). Overall, both mentors and interns agreed that interns' workplace skills were appropriate for their educational levels. T-tests of equality of means were performed to determine statistical significance for the difference between the interns' and mentors' rating scores.

Table 1: Mentors' and Interns' Overall Perceptions of the Internship

Type	Description	$\bar{\chi}$	N
Intern	I acquired new skills, learned new procedures, and gained new knowledge	3.86*	196
Mentor	My intern acquired new skills, learned new procedures, and gained new knowledge	3.95	222
Intern	I learned what a full-time job in research is like	3.67*	191
Mentor	My intern learned what a full-time job in research is like	3.84	205
Intern	The internship improved my confidence in my abilities	3.84*	198
Mentor	My intern gained confidence in her/his abilities	3.94	221
Intern	The goals established for my internship were met	3.67*	196
Mentor	My intern accomplished the goals established for her/his internship	3.89	221
Intern	I now have a much better understanding of NASA, its role, and mission	3.70*	198
Mentor	My intern now has a better understanding of NASA, its role, and mission	3.80	222

*Indicates significance at or below the .05 level for comparison of the mean scores between mentors and interns.

Statistical significance was found for eight of the 16 21st century workplace skills. For each of the eight significant skills, mentors rated the interns higher than the interns rated themselves. Mentors rated their interns' skills highest in the following categories: professional behavior ($\bar{\chi}$ = 3.94), collaboration ($\bar{\chi}$ = 3.93), and working as part of a team ($\bar{\chi}$ = 3.93). Interns rated their flexibility/adaptability ($\bar{\chi}$ = 3.87), professional behavior ($\bar{\chi}$ = 3.86), and thinking critically ($\bar{\chi}$ = 3.85), solving problems ($\bar{\chi}$ = 3.85), and working independently ($\bar{\chi}$ = 3.85) highest. Mentors rated their interns' workplace skills lowest in the following categories: creating and innovating ($\bar{\chi}$ = 3.72), communicating in writing ($\bar{\chi}$ = 3.73), and critical thinking ($\bar{\chi}$ = 3.80). Interns rated their workplace skills lowest in the following categories: time management ($\bar{\chi}$ = 3.56), communicating in writing ($\bar{\chi}$ = 3.57), and creativity/innovation ($\bar{\chi}$ = 3.65).

Discussion

Interns' and mentors' overall perceptions of the internship and their assessment of interns' acquisition of 21st century workplace skills were analyzed using a t-test for equality of means. Significance was set at 0.05. Results suggest that for all of the overall perceptions (Table 1) and eight of the 21st century workplace skills (Table 2) mentors rated interns higher than interns rated themselves. For the remaining eight skills there was no statistical difference between mentor and intern ratings.

The majority of items addressed in the survey reflected positively on student interns, mentors, and the internship experience. Mentors indicated they had seen growth in their interns' self-confidence after the interns' participation in the LARSS program ($\bar{\chi}$ = 3.94). The interns also noted improvement in their own self-confidence, but the ratings of their self-confidence (($\bar{\chi}$ = 3.84) was significantly less than the ratings by their mentors ($p \leq 0.05$). According to both groups, the interns were successful in building new skills, gaining more understanding about the role of NASA, learning what a full-time job in research is like, and meeting the goals set by the mentors.

The survey results from mentors reflect some of the same concerns expressed by human resource personnel and senior executives in a study conducted by the Society for Human Resource Management (Casner-Lotto, Barrington & Wright, 2006). This 2006 study noted two primary areas of concern to business and industry in regard to recent college hires: deficiencies in written and oral communication. In our study, written communication was one of the lowest-rated skill sets by both mentors and interns (see Table 2). However, LARSS interns noted improved skills in oral communication over the course of the internship, suggesting that the internship experience positively influenced the development of skills in this area. Business and industry consider oral and written communication among the key general skill sets, regardless of college major (Bok, 2003, 2006). Certainly the internship experience provided opportunities for student interns to improve skills in these areas as well as to gain an understanding of the importance of these skills in a work setting.

Mentors rated their interns highest in terms of professional behavior, collaboration/working

Table 2: Interns and Mentors' Ratings of 21st Century Workplace Skills

Type	Description After this internship, I think … After this internship, I think …	$\bar{\chi}$	N
Intern	I am good at thinking analytically	3.80	197
Mentor	My intern is good at thinking analytically	3.82	216
Intern	My computational skills are good	3.69*	189
Mentor	My intern's computational skills are good	3.83	200
Intern	I am good at solving problems	3.85	196
Mentor	My intern is good at solving problems	3.88	216
Intern	My technical skills are good	3.72	189
Mentor	My intern's technical skills are good	3.81	207
Intern	My computer skills are good	3.68*	192
Mentor	My intern's computer skills are good	3.87	214
Intern	I am good at working independently	3.85	198
Mentor	My intern is good at working independently	3.87	219
Intern	I am good at collaborating/working with others	3.75*	194
Mentor	My intern is good at collaborating/working with others	3.93	216
Intern	I am good at working as part of a team	3.67*	184
Mentor	My intern is good at working as part of a team	3.93	204
Intern	I am good at communicating orally/verbally	3.66*	197
Mentor	My intern is good at communicating orally/verbally	3.83	221
Intern	I am good at communicating in writing	3.57*	197
Mentor	My intern is good at communicating in writing	3.73	214
Intern	I am good at being flexible and adaptive	3.87	198
Mentor	My intern is good at being flexible and adaptive	3.88	219
Intern	I am good at thinking critically	3.85	197
Mentor	My intern is good at thinking critically	3.80	218
Intern	I am good at time management skills	3.56*	197
Mentor	My intern is good at time management skills	3.83	216
Intern	I am good at creating and innovating	3.65	196
Mentor	My intern is good at creating and innovating	3.72	217
Intern	I am good at demonstrating professional behavior	3.86*	196
Mentor	My intern is good at demonstrating professional behavior	3.94	221
Intern	I am good at exercising judgment and making sound decisions	3.81	198
Mentor	My intern is good at exercising judgment and making sound decisions	3.85	219

*Indicates significance at or below the .05 level for comparison of the mean scores between mentors and interns.

with others, and working as part of a team. Computer skills and flexibility and adaptability were also highly rated. These capabilities represent key areas needed by business/industry, as reported in studies by the Society for Human Resource Management (Casner-Lotto et al., 2006; NACE, 2010). Of some concern, however, were the lower ratings from mentors on interns' creativity/innovation, technical skills, critical thinking, and analytical thinking. Although mentors agreed that their interns demonstrated appropriate skill sets in these areas, the ratings for these areas were lower than for other skill sets. These general skill sets are qualities that go beyond basic knowledge in one's area of expertise and reflect important skills if we expect students to be able to identify and define problems clearly, understand arguments/reasoning on all sides of an issue, identify as many plausible solutions as possible, and exercise good judgment in choosing the best of the alternatives (Bok, 2006). These general skill sets could be addressed more systematically at the college level to help ensure students are given opportunities to develop these skills (Crouch & Mazur, 2001; Treisman, 1992).

A lack of appropriate responsibility/self-regulation has been cited as a major concern by business and industry regarding new college hires (Casner-Lotto et al., 2006). However, 97% of the mentors agreed that their interns exhibited the ability to self-regulate at the end of their internship. Work-related experiences can be highly beneficial in helping students learn these skills, but much can also be done at the college/university level to reinforce self-regulation (Bok, 2006).

When asked to rate the internship experience overall, both student interns and mentors responded positively. However, one item from the student interns stood out as discouraging. Forty-two percent of the interns reported either a weak or no connection between the knowledge they had gained in the classroom and the knowledge they had applied during the internship. This disconnect is not atypical (Garvin, 2003; Mazur, 1996).

Limitations

Certain limitations of this study should be noted. The study focuses on a particular cohort of student interns in a specialized setting. Therefore, generalizations should be made with caution. The survey statements in Table 1 are stated differently for the mentors and interns, limiting comparisons beyond descriptive information. The mentors' ratings represent a direct assessment of students' knowledge, skills, and abilities. However, the students' responses reflect their perceptions. This indirect assessment limits the ability to compare and contrast outcomes. (Since completion of this study, the survey has been modified for mentors and students to allow for a direct comparison.) The information in the current study does not address potential differences with respect to gender and minority status.

Additional Research

Additional research is needed into the benefits of internships for student retention in the STEM fields. More than one half of the students entering higher education with engineering as a declared major persist in engineering in the first eight semesters (Ohland et al., 2008). Are students who participate in an internship during their undergraduate experience more likely to be retained in comparison to students who do not? This question is especially important for women and minorities. Research outside of STEM fields supports the use of co-op and internship experiences in terms of gender and race (Weisenfield & Robinson-Backmon, 2001). Further research is also needed in linking classroom learning to the work experience for STEM majors in general and engineering majors in particular.

A study by the American Association of University Women (Corbett & Hill, 2012) reported that 39% of women who graduate as engineers enter the engineering workforce—compared to 57% of male engineering grads. In a longitudinal study of more than 3,700 women graduating with an engineering degree from more than 30 colleges/universities, Fouad and Singh (2011) found that 15% of these women chose not to enter the workforce. Four out of five, however, were working in fields outside of engineering. Of those who initially entered the workforce in engineering, one out of five left the field after a short time. Overall, roughly 40% of women with degrees in engineering had left the field within the first five years. The majority of these women are still pursuing careers but not in their original field of study. For women, leaving the organization where they are employed as engineers is often tied to leaving the profession. Would participation in an internship or internships during the academic career be helpful in stemming this exodus from the field?

Plouff &Barott (2012) found that a three-semester, mandatory co-op experience was beneficial in helping students transition from academia to the workforce. One of the benefits of the experience was helping students understand what to expect in certain work environments and to develop strategies and tactics as warranted with support from fellow students and the university. Whereas a co-op typically spans an extended period of time, would a well-constructed internship serve a similar purpose? More research is needed into the potential benefits of an internship experience for women and minorities in relation to academic and career retention.

Summative Assessment

A longitudinal study of the LARSS program is underway to help assess the quality and effectiveness of the program over time. This study focuses on the experiences before, during, and after the internship that have influenced interns in their pursuit of a STEM degree and, ideally, a STEM career. The study addresses key issues relating to the potential influence of the LARSS summer internship program on academic retention and career persistence of STEM majors, focusing on student interns who participated in the summer session programs from 1986-2011. Evaluative elements of the study include:

- determining the impact of the LARSS internship on workforce development;
- looking at the educational progression and career trajectories of interns following their LARSS experience;
- gauging the influence of the LARSS internship on career choices, and persistence in STEM fields; and
- tracking the influence of various people and experiences that led LARSS interns to develop an interest in a STEM field.

Beyond the assessment goals for the LARSS program are a set of goals that apply more broadly to NASA's efforts, namely, to ensure that LARSS is meeting the objectives of the NASA 2011 Workforce Plan. Has the LARSS internship program been effective in training and developing talent, recruiting and employing a diverse workforce, sustaining a high-performing workforce, and enabling efficient human resource services through the adequate provision of support and information? The population for the longitudinal study of the LARSS program included 1,757 LARSS interns who were STEM majors during the years 1986-2011. Non-STEM majors were excluded as were students who had completed more than one rotation in the LARSS internship program. Findings will be used to assess the long-term effects of the LARSS program in support of the STEM workforce pipeline as well as persistence in the field.

Concluding Remarks

The internship experience provides many benefits to students, colleges/universities, and business/industry. In our view the internship experience plays a key role in knowledge acquisition for students and a chance for participants to "try out" their chosen fields. It provides a means to offer feedback to institutions of higher learning on the skill sets their students bring to the workplace; and it gives business/industry an opportunity to engage with future employees. Internships also make a difference in starting salaries and offers of full-time employment prior to graduation (Schuurman et al, 2008). NACE (2010) notes that roughly 75% of potential employers prefer to hire recent graduates who also have prior work experience; 53% of these potential employers indicate a preference for internship/co-op experiences. Potential employers note that they perceive internships/co-ops as more reflective of relevant job experiences than other types of work experience. Collaborative work experiences among universities, students, and business/industry create a win-win for everyone involved.

Editor's note: This article is updated from a conference paper presented at the 2012 ASQ Advancing the STEM Agenda Conference presented at the University of Wisconsin, Menomonie, WI.

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