Journal of Teaching and Learning for Graduate Employability

The Journal of Teaching and Learning for Graduate Employability

ISSN: 1838-3815 (online) Journal Homepage: https://ojs.deakin.edu.au/index.php/jtlge/

Competent and employed: STEM alumni perspectives on undergraduate research and NACE career-readiness competencies

MiKayla J. Newell[1] and Paul N. Ulrich [2]

Corresponding author: Paul N. Ulrich (pulrich@gsu.edu)
[1] Department of Learning Sciences, Georgia State University
[2] Department of Biology, Georgia State University

Abstract

There have been large increases in the number of STEM graduates in the United States, but majority of the career opportunities are limited to computer specialists and engineering. Thus, two challenges await STEM students upon graduation: strong competition and employer concerns that applicants lack general competencies and contextual work experience. Universities have responded to employer concerns with initiatives to enhance career readiness by embedding sets of competencies throughout curricula. However, these competencies have not been situated in STEM contexts and are derived largely from surveys of representatives from large companies who are unfamiliar with the job requirements specific to STEM positions. The current study uses a mixed methods approach to investigate the National Association of Colleges and Employers Career-Readiness Competencies in STEM. We found that STEM alumni ranked critical thinking as the most important competency for their current employment. Additional findings demonstrate that undergraduate research experiences (UREs) provide a fertile ground for the integration of career related competencies into undergraduate curricula as alumni discussed the development of various academic, personal, professional, and competency gains after participating in UREs. Lastly, implications regarding how institutions can simultaneously situate skill development in STEM and provide meaningful, work-like experience through UREs that align with the expectations of STEM employers are discussed.

Keywords

STEM, career readiness, NACE competencies, alumni, undergraduate research experiences, employment

Introduction

Projected STEM workforce growth has stimulated extensive investment in STEM programs by governmental agencies and higher education. Forecasts of STEM workforce growth in the United States (U.S.) have ranged around 20% per decade (Carnevale et al., 2013; Noonan, 2017). One particularly influential report projected that 2.7 million STEM graduates would be necessary to meet needs in the U.S. (President's Council of Advisors on Science and Technology (PCAST), 2012). Increased growth (+54%) in the number of bachelor's degrees earned in natural sciences, mathematics, computer sciences, and engineering from 2010 to 2018 coincides with the urgent call for STEM qualified workers (U.S. Department of Education, National Center for Education Statistics, 2019). Students appear to be responding to employment expectations by increasingly choosing STEM majors, and this trend is particularly pronounced in the numbers of biology degrees conferred (Liu et al., 2019). Troubling and often overlooked, however, is that demand for STEM workers varies widely across disciplines (Xue & Larson, 2015). For instance, the PCAST report noted nearly 75% of job growth in the U.S. is constrained to computer specialists and engineers. Similar heterogeneity in opportunity has also been noted in Australia (see Lin-Stephens et al., 2018; Labour Market Information Portal, 2021). Thus, STEM graduates face a two-fold problem: limited job openings and competition against a growing pool of graduates.

STEM employers globally report that they are unable to fill positions due to 'skills gaps' (Kramer et al., 2015; Prinsley & Baranyai, 2015), which further complicates students' employment prospects. Descriptions of the gaps in STEM skills are frequently undefined in the literature and elusive due to variation in employer expectations (Alic, 2018). Employer reports clearly communicate that applicants have deficits in broader, employability skills such as time management, teamwork, and communication (Prinsley & Baranyai, 2015; Confederation of British Industry, 2011). Debate continues around the question of whether employer complaints about skill gaps accurately represent workforce realities (Capelli, 2015; Bessen, 2014), although employers and academics agree that generic skills such as teamwork are 'must haves' for every graduate (Capelli, 2015).

Consequently, the higher education sector has focused on equipping students for careers by emphasizing general competencies (Nodine, 2016). However, we point out two challenges institutions must address to make their graduates compete effectively for limited employment opportunities in STEM industries. Firstly, generic skills alone are insufficient to acquire STEM employment. The value of general competencies to an employer varies depending on the situational context (Finegold & Notobartolo 2010, p. 20). While STEM skills are interdisciplinary and overlap with generic cognitive and social skills (Siekman & Korbel 2016), generic skills should be framed within STEM and augmented with occupation-specific skills. Secondly, STEM employers expect that strong applications are accompanied with at least twelve weeks of work experience (Prinsley & Baranyai, 2015).

We propose that institutions can simultaneously situate skill development in STEM and provide meaningful, work-like experience through undergraduate research experiences (UREs). Though UREs are not generally recognized as work-integrated learning (WIL), UREs have been suggested as a form of WIL (Golding et al., 2019). UREs are high-impact practices (Kuh et al., 2017) with well-established impact on student self-perceptions and career decisions (Lopatto, 2004; Russell et al., 2007; Seymour, 2004). In UREs, close interaction with STEM professionals and mentoring help participants frame generic skills within the STEM domain. These experiences range from one to many semesters working in research contexts and can serve as a proxy for the work experience desired by STEM employers.

The current study assesses the value of a set of generic competencies within STEM from the perspective of graduates who had participated in UREs. Many higher education institutions in the U.S have strategically adopted the Career Readiness Competencies defined by the National Association of Colleges and Employers (NACE). However, several limitations and concerns should_be noted about these competencies. The generic competencies presented by NACE were derived from Casner-Lotto and Barrington (2006) and a 2014 NACE survey of employer representatives. The survey design, coding process, and analyses used by NACE are not available. NACE indicates that the respondent pool comprised 606 employers (49% for-profit, private organizations; 21% for profit, public companies; 15% governmental agencies; and 15% non-profits). Nearly 25% of respondents represented companies with 101-1000 employees, and 42% of companies represented employ 1001–10,000+ people. Casner-Lotto and Barrington (2006), the primary resource for defining the NACE competencies, report that the large majority of their respondents (81%) held director, vice president, or higher positions. Therefore, it is possible that employer representatives may be unfamiliar with work-level requirements for specific positions. An extensive study of STEM employers in Australia was similarly weighted toward responses from executives but is notable because smaller businesses (<200 employees) are better represented (Deloitte Access Economics, 2014). Jang (2016, p. 285) noted that 'frameworks of 21st century skills are still seldom empirically examined from a STEM job incumbent's perspective,' and we note that this remains the case. Assessing competencies via investigation of STEM employees is an important step in refining competency training models (Akdere et al, 2019). To address this gap, we asked STEM graduates who had participated in UREs to rank the importance of the NACE competencies based on their current employment. Additionally, qualitative analysis demonstrates how UREs provide opportunities to situate competencies in STEM and prepare students for careers.

Current Study

This exploratory study was performed at an institution in the U.S. that adopted a career preparation initiative for undergraduates. A central element of the initiative includes embedding_NACE career competencies throughout curricula to increase student awareness of competencies, understanding connections between competencies and classwork, and demonstration of proficiency. This study employed a mixed method approach, designed to explore the following questions about relationships among learning experiences of STEM alumni, career-readiness competencies, and employment:

> RQ 1: *How do STEM professionals rank NACE competencies compared to non-STEM professionals?*
>
> RQ 2: *What competencies do STEM alumni feel they learned via UREs?*
>
> RQ 3: *What are perceived impacts of URE on alumni's professional and personal career readiness?*

Quantitative surveys were created to evaluate alumni rankings of NACE competencies and identify competencies embedded within UREs. An open-ended prompt was used to explore participants' perceived impact of UREs on their career readiness. Responses focused on clarifying mechanisms for benefits associated with UREs.

Methods

Participants

A survey was emailed to STEM graduates of a large urban university in the south-eastern U.S. Eligible participants were identified through institutional data. All participants graduated and had previously enrolled in a URE. Forty-two percent identified as female, and 39% identified as male. Participant age ranged from 20 to 49 (M = 27.52, SD = 5.03). Fifty-six percent of participants (n = 121) were identified as STEM employed and 41% (n = 89) as non-STEM employed. Classification into STEM and non-STEM employment utilized responses about job responsibilities and lists of STEM-jobs developed by the U.S. Bureau of Labor (Standard Occupation Policy Committee, 2019). Responses with insufficient information on roles and responsibilities when complemented with alternative data sources were not included (n = 6, 3%). It is important to note that STEM occupational codes in the U.S. classify healthcare technicians as STEM occupations but healthcare providers (e.g., physicians and nurses) as non-STEM.

Survey

The survey comprised 23 items including questions about employment, research experience, and demographic information. Participants who indicated that they were employed were asked additional questions including their place of work, how long they have worked there, and the nature of their roles and responsibilities in the workplace. In regard to research experience, participants were asked to describe the impact undergraduate research had on their 'personal and professional, career readiness' and to select the career-readiness competencies that they felt their URE taught them. In addition, participants were asked to rank the importance of NACE career-readiness competencies (Appendix A) indicating the most important to the least important competency. Those employed in non-STEM jobs, were asked to rank competencies they felt were necessary for their current occupation.

Procedures

A total of 1,923 STEM alumni were emailed and invited to participate. Approximately two weeks later, a reminder was emailed to alumni who had not returned the survey. Completed responses were received from 354 participants. An introduction to the survey and an informed consent form were the first documents participants viewed. Participants who indicated consent were able to access the survey, while those who did not consent were unable to complete the survey. Participants were not compensated for their participation in the study. Research protocols were approved by the Institutional Review Board (IRB #H19671).

Results

Study 1: STEM Competencies (Quantitative)

Participants were asked to rank a total of eight, career-readiness competencies where 1 was considered most important and 8 considered least important to their current employment. A Mann-Whitney U-test was performed to assess differential means on competency rankings between those employed in STEM compared to those employed in non-STEM jobs. As expected, critical thinking ranked as significantly more important for participants employed in STEM (M = 1.79, SD=1.34) compared to non-STEM (M = 2.45, SD=1.73), U = 4209.5, $p < 0.05$. non-STEM participants (M = 2.83, SD = 1.71) ranked oral/written communication as significantly more important than STEM participants (M = 3.52, SD = 1.75), U = 4057.0, $p < 0.05$ (RQ1, Figure 1). No other significant differences were identified.

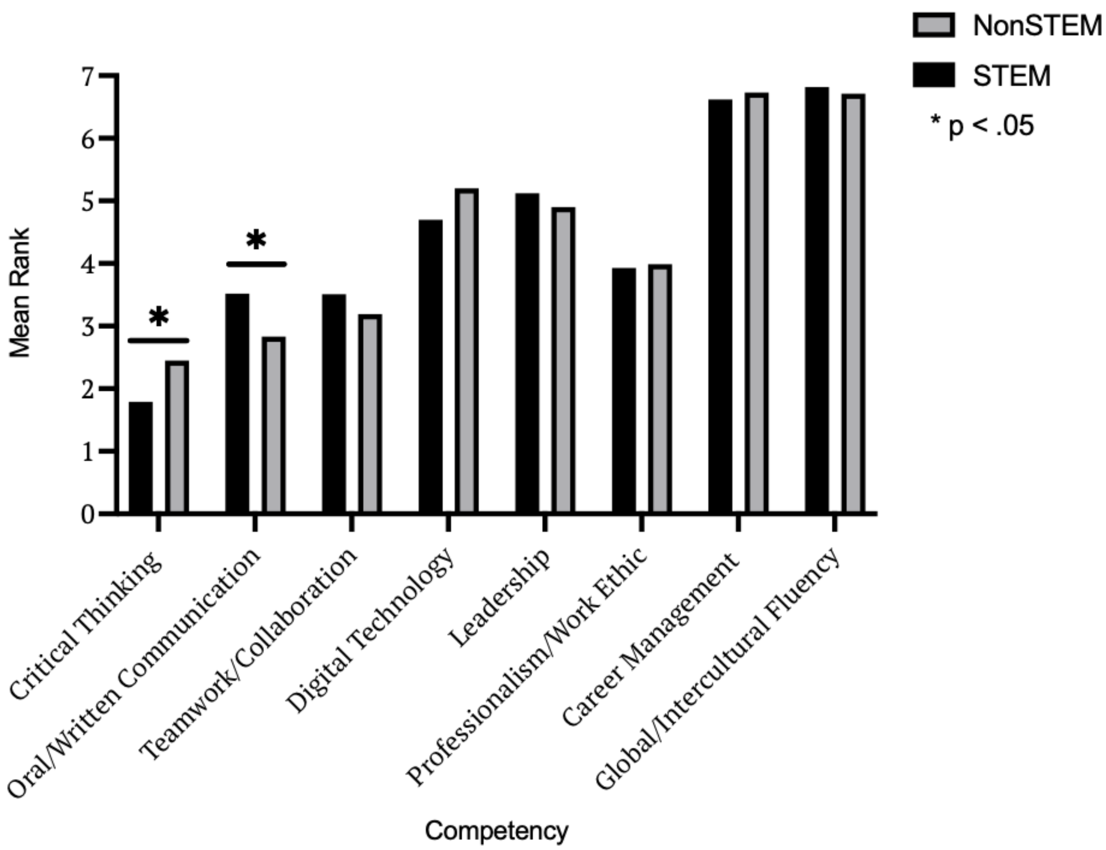

Figure 1. STEM Alumni Rankings of Career Readiness Competencies

To assess the degree to which general, NACE competencies were already embedded in UREs, alumni were asked to select competencies taught in their UREs (RQ2, Figure 2). The top four competencies identified by participants correspond with four competencies that emerged in qualitative analysis. Critical thinking was most frequently selected (>70%) followed by oral/written communication, work ethic/professionalism, and teamwork/collaboration. These formed a group distinctly more frequent than the other career-readiness competencies.

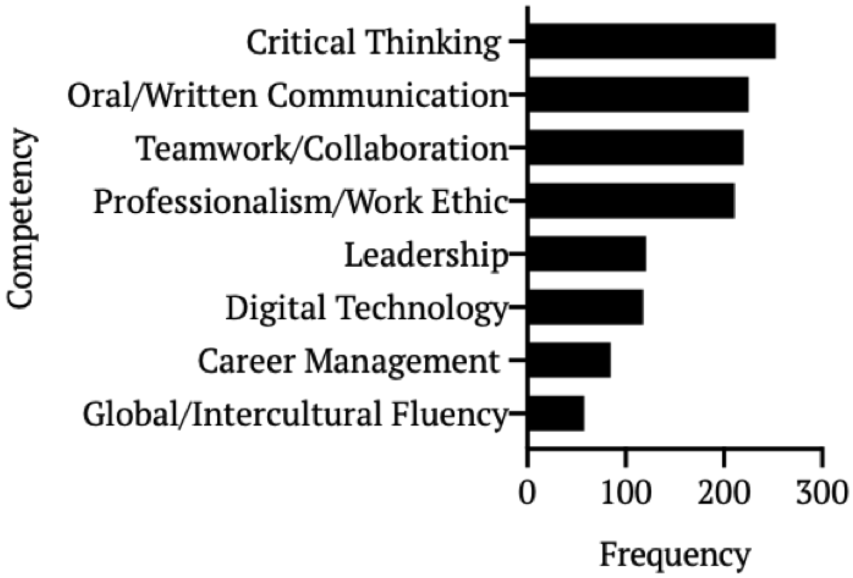

Figure 2. Frequency of Career-Readiness Competencies Taught in UREs

Results

Study 2: Impact of Undergraduate Research Experience on Personal and Professional Career Readiness (Qualitative) Data Collection

In addition to the survey, participants were prompted to reflect on their URE and describe how UREs impacted their personal and professional career readiness. Responses were coded using inductive thematic coding.

Research Subjectivity and Data Analyses

Qualitative researchers are aware and concerned with how personal expectations and assumptions can influence the research process (Levitt et al., 2018). Consequently, qualitative traditions have been employed to ensure transparency in reporting. To avoid potential biases the research team communicated their perspectives and expectations throughout the coding process. Inductive, thematic coding was used to analyze and interpret participants' responses to the open-ended prompt. The team separately evaluated 283 qualitative responses while documenting initial themes. Once the initial themes were discussed they were reconciled (100%) and represented 15 second-level codes. These second-level codes were then categorized into seven central themes: academic gains, competencies, early career success, personal development, mentorship, insights from exposure, and positive responses (Table 1). Data were analysed in NVivo 12.

Table 1. Coding Themes

First Level Codes	Second Level Codes	Themes
Science/Content Knowledge	Knowledge gains	Academic Gains
Technical skills Analyze science research Research skills Statistical skills	Science practice	Academic Gains
Working in lab teams	Teamwork/Collaboration	Competency
Problem solving	Critical thinking	Competency
	*Time management	Competency
Oral/written communication	Communication	Competency
	*Work ethic	Competency
Requirement for higher ed CV/resume building Preparation for workforce	Career	Early Career Success
Networking	*Confidence	Personal Development
	*Leadership	Personal Development
Independent projects	Independence	Personal Development
Career guidance	Mentorship	Mentorship
Career trajectory/Clarity Ideas of higher education Options of STEM careers	Exposure to UREs	Insights from Exposure
Interest, Passion, Excitement	Affective response	Positive Affective Response

Note. Second-level codes denoted with asterisks do not have corresponding first-level codes.

We identified seven central themes from the open-ended responses: (1) academic gains, (2) competencies, (3) early career success, (4) personal development, (5) mentorship, (6) insights from exposure, and (7) positive responses. The first theme (academic gains) explores learning outcomes that students gained through UREs. Students gained content knowledge during didactic lectures and had the opportunity to apply those concepts in a research lab. The second theme identifies competencies that students gained, while the third theme (career) explores how UREs impacted students' career trajectory. Similarly, the fourth theme (personal development) reviews personal gains students felt they developed. Alumni expressed an increase in confidence as UREs provided opportunities to conduct research without a blueprint. As a result, they learned to persevere through failed experiments. The fifth theme (mentorship) reviews the impact mentors had on students' career plans and development as scientists. The sixth theme (insights from exposure) encompasses insights associated with being exposed to UREs and the final theme (positive affective responses) outlines students' positive responses about their research experience.

Theme 1: Academic Gains

Students discussed the various academic gains they experienced within their UREs. Respondents referenced research as an opportunity to apply what they previously learned in didactic courses to a 'real-world environment', stating that 'undergraduate research allowed [them] to put [their] course-based knowledge into action, through hands on learning' (Respondent #68). Application seemed particularly important as respondents compared UREs to lecture and general lab components of curricula. Participants felt UREs provided opportunities to develop and exercise skills and procedures that 'would not have known by just taking the required lab courses' (Respondent #275). Within this theme knowledge gains and science practice were classified as subthemes. Knowledge gains focus on content, while science practice refers to knowledge about lab techniques and other research related activities (e.g., analysing journal articles, experimental design).

Knowledge Gains

Participants asserted they were able to 'expand[..] [their] knowledge in microbiology' (Respondent #26) and more specifically were able 'to grasp the impact of various conditions of proteins' (Respondent #128). In contrast to traditional lab courses, UREs permit a deeper understanding by introducing an investigative environment where students can directly apply what they have learned in prior courses. For example, one graduate stated that, 'undergraduate research allowed me to compile the knowledge and experience I gained through my previous classes and extracurricular activities in a situation that emulated a real-world environment as a career in a laboratory or as a researcher' (Respondent #83). In addition, one participant related how content knowledge can impact future career-related activities by stating that, 'knowing why procedures are performed will help a medical student while they are interpreting lab results in clinic and answering multiple choice questions on board examinations' (Respondent #49). The deeper content knowledge participants referred to is allied with but distinct from science practices acquired via UREs.

Science Practice

An overwhelming proportion of responses referred to science practice including technical skills, critical interpretation of literature, extension of scientific findings to other contexts, design and operational aspects of experimental processes, record keeping, and data analysis. Familiarity with instrumentation and techniques was illustrated by responses such as 'undergraduate research gave me a solid, technical foundation with lab techniques' (Respondent #36) and 'I was ready to enter the workforce as having already interacted with equipment used in the typical laboratory' (Respondent #37). In some cases, respondents explicitly linked development of science practice to career gains or perspectives of career relevance: 'undergraduate research gave me topics I could discuss with employers to discuss my competence. For example, my work building Geiger counters easily led to discussing my ability to work in a job testing hardware for spaceflight' (Respondent #71). In addition, UREs taught students how to carefully document experiments as they were required to 'maintain lab records, which are necessary for research, or any regulatory agency' and 'helped to provide me with a professional and stringent standard for reporting' (Respondent #209). These are interesting comments because credibility of the scientific community science relies on accurate reports of findings, a necessity to minimize impact of retractions of published research (Cho et al., 2020).

Respondents also referred to learning to use the scientific method from experimental conceptualization to implementation and analysis. For instance, participants reported they were 'able to learn the importance of using different aspects of the scientific method and consistently work on improving the methodology necessary to conduct experiments' (Respondent #43).

Theme 2: Competencies

Teamwork and Collaboration

Students in UREs work collaboratively in shared spaces. While participants developed 'interpersonal skills by collaborating with like-minded individuals' (Respondent #20), they also mentioned working with 'students from other backgrounds' and learning 'how important it is to work as a team and get things done independent of each other's individual or group conflicts' (Respondent #7). One participant commented on being prepared to work with 'both peers and superiors.' Participants stated that 'working as a team was the most valuable thing that [they] took away from it' (Respondent #42). Sharing resources and spaces, solving problems, and interpreting results requires effective communication.

Communication

Undergraduate research experiences provide avenues to present results within teams or at conferences. These opportunities allowed a participant to 'jump out of [their] comfort zone to improve on certain skills needed for a workplace environment such as oral and written communication' (Respondent #7). Alumni mentioned becoming 'comfortable communicating ideas and plans to colleagues in both a relaxed and more structured setting' (Respondent #10) and 'gained more confidence in talking in front of an audience' because the 'course had a lot of speaking opportunities' (Respondent #24). Presentations allowed participants 'to practice communication in this setting and receive constructive criticism from others without feeling judged/overwhelmed' (Respondent #90), which may increase comfort and confidence. Interactions that undergraduates had with graduate students provided support as a participant noted graduate students gave them 'an avenue to ask questions [they] would otherwise be too nervous to ask faculty' (Respondent #90). Furthermore, alumni claim UREs gave them 'the tools to learn how to deliver the results to the target audience' (Respondent #168). Similarly, one participant specified that research taught them 'how to present work and speak with other scientists in related/unrelated fields' (Respondent #36). Interestingly, participants recalled realizing that simply talking through what they know 'is more rewarding than staying silent for fear that [they] might not say the right thing.'

Critical Thinking

Alumni expressed UREs increased their critical thinking and problem solving, two integral elements of the research process. Research allowed participants 'to ask a new question and deal with the myriad of problems that arise when attempting to answer the question' (Respondent #54). Learning to think critically in response to obstacles may be particularly important in sustaining students through periods of discouragement. Similarly, participants gained 'knowledge about how to confirm/reject hypothesis' (Respondent #50) because they were required to 'think critically on the spot to answer tough questions' (Respondent #2). Participants felt that they personally developed 'with regards to being able to adapt easily and think on [their] feet for problem solving' (Respondent #62). The independent nature of conducting research taught participants 'how to assess a situation [themselves] before finding help and make sure that [they] think critically through all possible options' (Respondent #230).

Leadership

Because UREs typically occur in research groups comprised of individuals at different developmental stages, these experiences can present opportunities to develop leadership skills. One participant specifically mentioned being in a group during a transition period without PhD students or postdoctoral lab members. As the senior lab member, the respondent was 'tasked with ordering supplies, cleaning, running [their] own experiments, and teaching four new undergraduate students' (Respondent #121).' Participants spoke of learning 'to delegate' (Respondent #34) and 'how to lead and organise a group of people in developing further research ideas' (Respondent #10). Importantly, students playing these roles learned 'how to better motivate others to work toward a common goal with a positive attitude' (Respondent #243). Thus, undergraduates who stay in a single laboratory for multiple semesters gain seniority and can serve as a repository of knowledge for newer members of the research group.

Time-management

Participating in UREs requires students to manage multiple responsibilities and can result in effective time-management skills. Some alumni acknowledged pre-existing weakness in this area by stating research helped them 'sharpen duller attributes such as time-management' (Respondent #261). In addition, participants talked about juggling responsibilities by managing 'a research project while being a full-time student and maintaining [their] GPA' (Respondent #11). Along with school responsibilities, students also face personal, non-academic responsibilities. One participant spoke about being resilient in their URE and not dropping it even though they 'had other matters in life [such as] 'work, marriage, total of 18 credit course hours, and being a senior in college' (Respondent #217). As a result, participants felt they became 'more organized and able to better plan out daily activities due to having to balance work, schoolwork and studies with making time to do bench work and meet deadlines on a regular basis' (Respondent #239).

Work ethic and professionalism

Enhanced work ethic and professional behavior were discussed as well. Alumni noted working 'for long hours,' (Respondent #132) which 'strengthened [their] work ethic' (Respondent #43) and contributed to increased stamina. Participants noted research taught them 'how to work hard in order to achieve a goal' (Respondent #55). Specifically, alumni claimed maturation in 'self-advocacy and professionalism' [which] 'have been invaluable' to their careers (Respondent #90). Interacting with STEM professionals and working closely with other students helped them to 'learn the work ethic and dedication required to successfully contribute to the STEM fields' (Respondent #90). Regular exposure to norms of behavior modelled by professionals may be important in transferring this to undergraduate participants.

Theme 3: Early Career Success

Respondents correlated their participation to preparation for and acceptance to graduate school. One stated, 'research directly impacted my acceptance rate into the program that I applied to' (Respondent # 102). They were able to 'get acclimated faster to the environment' (Respondent # 58) once accepted into their program because UREs eased the 'transition in a Masters program into a career as an engineer' (Respondent #9). Furthermore, participants emphasized the importance of UREs stating, 'I don't think I would have been accepted into graduate school without having done a significant amount of undergraduate research' (Respondent #4), and others saw it as a 'soft requirement' (Respondent #63). UREs not only prepared students for graduate careers but also prepared them for the workforce right out of college. Participants felt UREs provided an opportunity to develop skills that made them 'qualified to start in the field immediately out of college and was able to land a position working with the CDC' (Respondent #253), and another was able to 'earn a Lead Research Specialist position' (Respondent #171).

Research experiences create environments where students work closely with faculty, giving participants the 'opportunity to network with those in the industry and land possible job offers after graduation through references from those who have seen you fully immersed in that type of environment' (Respondent #7). UREs contributed to career readiness by 'equipping [them] with the necessary skills to maintain competitiveness in the STEM job market' (Respondent #151). Students were able to 'build' and 'bolster' their resumes which made them 'very attractive to companies' (Respondent #180). Finally, respondents felt UREs equipped them to discuss competencies during interviews. For example, one participant reflected that 'undergraduate research gave me topics I could discuss with employers to show my competence' (Respondent #71).

Theme 4: Personal Development

Alumni responses indicate that UREs created opportunities for students to personally develop independence, confidence, and perseverance. Within UREs students participated in research activities and gained confidence in their ability to execute research related actions. Alumni discussed how they were not provided with a blueprint and were challenged to think critically as they encountered problems. Thus, alumni were able to develop a sense of independence and confidence. In addition, exposure to the nature of the research process taught students' perseverance and diligence when conducting research.

Independence

While students worked collaboratively, they were also given opportunities to work independently. Participants referenced 'being thrown into a truly independent setting,' which contributed to them becoming 'more independent with [their] workload' (Respondent #177; Respondent #191). A participant reported increased confidence since they were 'able to keep [their] projects moving forward' and ended up 'accomplishing more than expected' (Respondent #24). In UREs, students were not provided with a 'blueprint,' which provided 'a lot of liberty' in how they 'wanted to conduct [their] research experiment' (Respondent #108).

Confidence

UREs foster independence by allowing students to take on more responsibilities. One participant noted that 'research really boosted [their] confidence in roles requiring more responsibility' (Respondent #95). An increase in confidence allowed a participant 'to embark and to take on different explorations, whether personal or professional' (Respondent #140). Specifically, research allowed a respondent to 'achieve the level of confidence and motivation necessary to apply and get accepted into the Masters Biology program' (Respondent #202). Interestingly, one particular respondent discussed how research increased their 'confidence/self-esteem as a woman in science' (Respondent #141).

Perseverance

Alumni specifically mentioned being situated in a unique environment where they 'were allowed to fail and learn' from mistakes (Respondent #99). Failures typical of research taught one participant 'how to display grit and to continue to go forward regardless of what the current outcome of the project is' (Respondent #230). Alumni reported becoming comfortable with 'being wrong and learning how to fix whatever issue was at hand' (Respondent #282) as research cultivated 'resilience to keep pushing' (Respondent #158). Research fostered patience and understanding that 'doing things in haste will only make it worse' (Respondent #13). Thus, failure was embraced 'as an opportunity to grow' (Respondent #65). It is possible that early exposure to research in college may influence student persistence as they have the opportunity to develop a better understanding of how science works.

Theme 5: Mentorship

Respondents repeatedly emphasized the high-quality mentorship they received in UREs. Throughout responses, participants expressed gratitude for their mentors and attributed becoming a 'better scientist and student'(Respondent #25) to mentors who pushed and moulded them. Mentors opened doors to career goals by providing support. One participant mentioned how their mentor was a 'proponent of applying to and attending graduate school' (Respondent #185). Also, specific qualities of mentors were described. One participant stated that their mentor was 'great to talk to and was non-judgmental and understood what students from other backgrounds go through' (Respondent

#18) and contrasted this to poor mentorship experience later in graduate school. Another mentor was described as honest and 'always very open regarding responsibilities and the leadership choices' (Respondent #253) that the mentor made. This was important as it provided training the student can 'rely on when working through difficult procurement solutions with customers' (Respondent #253).

Theme 6: Insights from Exposure

A prevalent theme that emerged was personal insight from being exposed to research. Research provided 'insight of what it is like to work in a laboratory setting' (Respondent #22) and opened their eyes to reality of the research process. One respondent expressed that research 'experiences as an undergraduate disabused me of the idyllic fantasy of lab work' (Respondent #64), and others noted that they learned that research is 'not always glamorous or particularly exciting' (Respondent #67). Exposure also provided clarity for students' career goals. These experiences 'helped form future goals' (Respondent #271) and provided freedom to 'explore scientific interests' (Respondent #139). Some indicated that 'research taught [them] that research was not the field for [them]' (Respondent #3) and '[their] greatest realization in all of this was that research was not in [their] future' (Respondent #261) while others expressed that research 'sparked an interest in laboratory sciences' (Respondent #192) and they 'felt more inclined to pursue research' (Respondent #56). UREs helped participants 'narrow down career choices' (Respondent #196) or transition from a conventional, pre-medical track 'to continuing with research for a Ph.D' (Respondent #106). One participant noted that research encouraged curiosity and helped 'make the decision to pursue graduate degrees in chemistry' (Respondent #57). These experiences gave students insight to graduate programs and academic careers. For instance, one respondent reported that research, 'definitely helped prepare me for graduate school both in terms of what to expect and what was expected of me' (Respondent #69) and 'gave me a close look into what life would be like as a graduate student as well as an academic Ph.D. and professor' (Respondent #72).

Theme 7: Positive Affective Responses

Most alumni exhibited positive affect when reflecting about their experiences. UREs helped participants to discover 'passion for working in a lab' (Respondent #14) and 'doing science' (Respondent #32). Interestingly, participants felt they were 'able to discover a new world' (Respondent #92) through participating and expressed enjoyment in engaging in science practice and designing their own experiments. Respondents appreciated the challenging environment because they were 'able to learn more than [they] ever could in a classroom setting' (Respondent #99). Research provided 'eye opening and meaningful experiences' (Respondent #76) for students to grow in their 'profession and discover true passions within neuroscience' (Respondent #65) One claimed that, 'I would not be where I am today without my undergraduate research experience' (Respondent #139).

Discussion

Higher education institutions increasingly emphasize employment outcomes as a measure of success. To academically support these outcomes, institutions are broadly infusing curricula with generic competencies, skills, or abilities considered important for 21st century workplaces. However, we argue that it is unlikely that the importance of any given competency is equivalent across all careers (Finegold & Notobartolo, 2010), and a one-size-fits-all model overshadows the importance of situating competencies in specific domains (Bakhshi et al, 2017). Mismatched priorities between STEM training programs and employer expectations may negatively affect graduate employability. The NACE Career Readiness Competencies is one of the most widely adopted sets of generic competencies, but no study has directly investigated the relative value of NACE competencies to STEM careers. Our knowledge of competencies employers desire in STEM domains is drawn primarily from studies of upper management and human resource managers from large corporations (McGunagle & Zizka, 2018;

Deloitte Access Economics, 2014), and questions of 'skills gaps' are compromised by concerns of reliability and validity (Capelli, 2014). Far less is understood from the perspectives of those familiar with specific work level requirements. The current study contributes to the literature by assessing the importance of generic competencies from the perceptions of those directly employed in STEM careers. Furthermore, we demonstrate the utility of UREs as a mechanism that allows for the development of competencies valued by STEM employers.

In this study, we sought to (1) explore NACE competencies STEM alumni felt were critical for a career in STEM, (2) identify NACE competencies taught in UREs, and (3) understand the impact of UREs on students' personal and professional career readiness. Alumni ranked critical thinking as significantly more important for STEM employment than non-STEM employees. In contrast, non-STEM employees ranked oral and written communication significantly more important. While critical thinking and communication were highly ranked for both STEM and non-STEM employees, the differences indicate that curricular emphases should be adjusted among programs such that graduates are more competitive in their specific domains. We are not suggesting exclusion of certain competencies from STEM curricula. Rather, we emphasize the implementation of generic competencies in STEM in ways that acknowledge their relative importance. For instance, STEM courses could be intentionally designed in ways where all competencies reinforce growth in critical thinking. This would ensure that students are well-rounded in various competencies and graduate with a strong skillset in the area that employers value most.

Employers have historically noted difficulty in recruitment due to deficiencies in general employability skills such as teamwork (Confederation of British Industry, 2011). Thus, we felt it was important to identify competencies that STEM alumni learned in UREs and demonstrate how UREs can advance students' competency development within STEM. Alumni selected critical thinking, oral/written communication, work ethic/professionalism, and teamwork/collaboration as the most frequently taught competencies that they learned while participating in UREs. These results were also reflected in alumni responses for how UREs impacted their personal and professional career readiness. We found that UREs equip graduates with these competencies and express how these directly relate to their activities in STEM careers. Undergraduate research experiences thus touch on primary complaint of employers about regarding 'skills gaps.'

Existing literature reports the benefits associated with participation in UREs (Lopatto, 2004; Russell et al., 2007; Seymour, 2004), and our work extends the literature by framing these benefits within the broader context of career competencies. Qualitative analysis revealed seven, central themes associated with UREs. Participants reported specific academic gains in content knowledge and science practice (theme 1). Alumni noted UREs enabled them to form deep understanding of concepts, the research process, and science techniques. Similarly, UREs allowed students to develop and refine competencies (theme 2) important to their own personal and professional development. These findings suggest that UREs are aligned with skills and abilities necessary for occupational demands arising in the coming decade (Bakhshi et al., 2017). Additionally, UREs provided an environment where students were able to exercise freedom when conducting experiments and enabled them to develop a sense of independence, confidence, and perseverance (theme 4). Undergraduate research experiences can help close the large gap in 'soft skill' requirements for jobs and the preparedness of recent graduates (Hart Research Associates, 2018). While UREs created environments that facilitated academic, personal, and professional growth, our findings suggest that mentorship affected student's development across the central themes. For example, close relationships with faculty influenced early career success (theme 3) because faculty actively encouraged students to become better scientists and modelled how to be a scientist. The ability of faculty to model how to be a scientist and the research process provided students with insights (theme 6) to the requirements of a research career. These relationships provided support for career decisions through workforce-related advice and letters of recommendation. A recent meta-analysis of youth, workplace, and academic contexts revealed positive effects of mentorship on perceived socialization and career outcomes of mentees

(Eby et al., 2017). These same patterns emerged from responses by URE participants in the current study. Socialization is particularly important for groups that have been historically under-represented in STEM (Estrada et al., 2018), and mentoring support by faculty has significant impacts on intention to pursue STEM careers (Hernandez et al., 2020).

The current study begins to bridge the gap between students' competency development and employer expectations in a field with restricted job opportunities. We feel that evaluating the relative importance of competencies by referring to those familiar with work level requirements and situating these competencies specifically within STEM should reflect positively in graduate employability. Based on the benefits of UREs highlighted in previous literature and the findings in this study, we recommend expansion of UREs because UREs offer a competitive advantage to graduates in two respects: (1) UREs equip graduates with the competencies that employers seek and (2) UREs serve as a proxy for the work experience that employers expect of applicants (Prinsley & Baranyai, 2015).

Limitations

One limitation of this study includes the manner in which participants ranked NACE competencies. Ordinal ranking may limit participant ability to communicate perceptions of equivalent value as one respondent noted that it was difficult to rank the competencies as 'they are all important.' Furthermore, our study cohort comprised only alumni who had participated in UREs. While these findings may be applicable across STEM students and employment additional studies are necessary to determine if URE participants employed in STEM have different perceptions of competencies valued by employers than students who did not participate in UREs.

Conclusions

In an era of job uncertainty characterized by a global pandemic and strong competition for careers in some STEM disciplines, higher education rightly focuses on graduate employability, and UREs have considerable potential promise for meeting this goal. However, rapid adoption of career-readiness competencies by institutions is troublesome as foundational questions remain unanswered: How can career competencies be defined inclusively and reliably? Are career outcomes for graduates contingent on general competencies or domain-specific competencies? Do studies of STEM workers and their direct supervisors reveal more about requisite competencies than studies weighted toward upper management and executives? How do STEM workers' views of competencies change as they gain seniority in their fields? Further research is necessary to address these questions.

Although our study helps identify NACE competencies relevant to STEM employment, it is only the first step. Closing skills gaps that employers persistently observe in STEM graduates is a formidable challenge given the variety of STEM career paths and gaps between academics and employers. Strategic implementation of career readiness competencies should account for different priorities of stakeholders including employers, administrators, faculty, and students. If institutions intend to generate work-ready graduates, future studies of STEM competencies must focus recruitment strategies to individuals directly familiar with work-level requirements. Results from this study indicate that STEM employees prioritize general competencies for their careers differently than their non-STEM counterparts. We encourage ongoing reassessment of competencies (Akdere et al, 2019) because priorities will change over time (Rayner & Papakonstantinou, 2015). For instance, the COVID-19 pandemic has normalized remote work in STEM, and communication is increasingly important. Furthermore, we found that UREs endowed STEM students with opportunities to learn the career-competencies that alumni reported as important for STEM jobs. Thus, undergraduate research programs should be accordingly prioritized and expanded by institutions as a means of equipping students for successful careers. Increasing access to these transformative experiences is a winning strategy for students and institutions as they redefine themselves in a post-pandemic world.

References

Akdere, M., Hickman, L., & Kirchner, M. (2019). Developing leadership competencies for STEM fields: The case of Purdue Polytechnic Leadership Academy. *Advances in Developing Human Resources*, *21*(1), 49-71. https://doi.org/10.1177/1523422318814546

Alic, J. A. (2018). 'What we mean when we talk about workforce skills.' *Issues in Science and Technology* 34(3): 30-36. https://www.jstor.org/stable/26594262

Bakhshi, H., Downing, J. M., Osborne, M. A., & Schneider, P. (2017). The future of skills: Employment in 2030. Pearson. https://futureskills.pearson.com/research/assets/pdfs/technical-report.pdf

Bessen, J. (2014). Employers aren't just whining–the "skills gap" is real. *Harvard Business Review, 25*. https://hbr.org/2014/08/employers-arent-just-whining-the-skills-gap-is-real

Cappelli, P. (2015). Skill gaps, skill shortages, and skill mismatches: Evidence and arguments for the United States. *ILR review, 68*(2), 251-290. https://doi.org/10.1177/0019793914564961

Carnevale, A. P., Smith, N., & Strohl, J. (2013). Recovery: Job growth and education requirements through 2020. Georgetown University Center on Education and the Workforce. https://cew.georgetown.edu/cew-reports/recovery-job-growth-and-education-requirements-through-2020/

Casner-Lotto, J., & Barrington, L. (2006). *Are they really ready to work? Employers' perspectives on the basic knowledge and applied skills of new entrants to the 21st century US workforce*. Partnership for 21st Century Skills. https://files.eric.ed.gov/fulltext/ED519465.pdf

Cho, I., Jia, Z.-J., & Arnold, F. H. (2020). Retraction. *Science*, 367(6474), 155-156. https://doi.org/10.1126/science.aba6100

Confederation of British Industry (CBI). (2011). Building for growth: Business priorities for education and skills – Education and skills survey 2011, CBI London. http://hdl.voced.edu.au/10707/3232

Deloitte Access Economics. (2014). *Australia's STEM workforce: A survey of employers*. http://www2.deloitte.com/au/en/pages/economics/articles/australias-stem-workforce-survey.html

Eby, L. T. D. T., Allen, T. D., Hoffman, B. J., Baranik, L. E., Sauer, J. B., Baldwin, S., ... & Evans, S. C. (2013). An interdisciplinary meta-analysis of the potential antecedents, correlates, and consequences of protégé perceptions of mentoring. *Psychological bulletin*, *139*(2), 441. https://doi.org/10.1037/a0029279

Estrada, M., Hernandez, P. R., & Schultz, P. W. (2018). A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers. *CBE—Life Sciences Education*, 17(1). https://doi.org/10.1187/cbe.17-04-0066

Finegold, D., & Notabartolo, A. S. (2010). 21st century competencies and their impact: An interdisciplinary literature review. Transforming the US workforce development system, 19. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.800.532&rep=rep1&type=pdf

Golding, R. M., Breen, L. J., Krause, A. E., & Allen, P. J. (2019). The summer undergraduate research experience as a work-integrated learning opportunity and potential pathway to publication in psychology. *Frontiers in psychology*, *10*, 541. https://doi.org/10.3389/fpsyg.2019.00541

Hart Research Associates. (2018). Fulfilling the American Dream: Liberal Education and the Future of Work: Selected Findings from Online Surveys of Business Executives and Hiring Managers. https://www.aacu.org/research/2018-future-of-work

Hernandez, P. R., Agocha, V. B., Carney, L. M., Estrada, M., Lee, S. Y., Loomis, D., ... & Park, C. L. (2020). Testing models of reciprocal relations between social influence and integration in STEM across the college years. *PloS one*,*15*(9), e0238250. https://doi.org/10.1371/journal.pone.0238250

Jang, H. (2016). Identifying 21st Century STEM Competencies Using Workplace Data. *Journal of science education and technology, 25*(2), 284-301. https://doi:10.1007/s10956-015-9593-1

Kramer, M., Tallant, K., Goldberger, A., & Lund, F. (2015). The global STEM paradox. New York: New York Academy of Sciences. https://www.nyas.org/media/15805/global_stem_paradox.pdf

Kuh, G., O'Donnell, K., & Schneider, C. G. (2017). HIPs at Ten. *Change: The Magazine of Higher Learning*,*49*(5), 8-16. https://doi.org/10.1080/00091383.2017.1366805

Labour Market Information Data Portal. Welcome to the Labour Market Information Portal. (n.d.). https://lmip.gov.au/default.aspx?LMIP%2FGainInsights%2FSpecialTopicReports

Levitt, H. M., Bamberg, M., Creswell, J. W., Frost, D. M., Josselson, R., & Suárez-Orozco, C. (2018). Journal article reporting standards for qualitative primary, qualitative meta-analytic, and mixed methods research in psychology: The APA Publications and Communications Board task force report. *American Psychologist*, 73(1), 26–46. https://doi.org/10.1037/amp0000151

Lin-Stephens, S., Manuguerra, M., & Uesi, J. (2018). Comparing STEM Students' and Employers' Emphases on Career Information Literacy-A Study on Undergraduate Capstone Units. *International Journal of*

Innovation in Science and Mathematics Education, 26(7). https://openjournals.library.sydney.edu.au/index.php/CAL/article/view/12646

Liu, S., Sun, W., & Winters, J. V. (2019). Up in STEM, down in business: Changing college major decisions with the Great Recession. *Contemporary Economic Policy*, 37(3), 476-491. https://doi.org/10.1111/coep.12396

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. *Cell Biology Education*, 3(4), 270-277. https://doi.org/10.1187/cbe.04-07-0045

McGunagle, D., & Zizka, L. (2018). Meeting real world demands of the global economy: an employer's perspective. *Journal of Aviation/Aerospace Education & Research*, *27*(2), 59-76. https://doi.org/10.1108/HESWBL-10-2019-0148

National Association of Colleges and Employers. (2014). Career Readiness Competencies: Employer Survey Results Methods. https://www.naceweb.org/career-readiness/competencies/career-readiness-competencies-employer-survey-results/

Nodine, T. R. (2016). How did we get here? A brief history of competency-based higher education in the United States. *The Journal of Competency-Based Education*, 1(1), 5-11. https://doi.org/10.1002/cbe2.1004

Noonan, R. (2017). STEM Jobs: 2017 Update. ESA Issue Brief# 02-17. US Department of Commerce. https://eric.ed.gov/?id=ED594354

Rayner, G. & Papakonstantinou, T. (2015). Employer perspectives of the current and future value of STEM graduate skills and attributes: An Australian study. *Journal of Teaching and Learning for Graduate Employability, 6* (1), 100–115. https://doi.org/10.3316/informit.174714129523604

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. *Science*, 316(5824), 548-549. https://doi.org/10.1126/science.1140384

President's Council of Advisors on Science and Technology. (2012). Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. http://files.eric.ed.gov/fulltext/ED541511.pdf

Prinsley, R., & Baranyai, K. (2015). *STEM skills in the workforce: what do employers want?* Occasional Papers Series, issue 9, March. Office of the Chief Scientist. https://www.chiefscientist.gov.au/sites/default/files/OPS09_02Mar2015_Web.pdf

Seymour, E., Hunter, A. B., Laursen, S. L., & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Science Education*, 88(4), 493-534. https://doi.org/10.1002/sce.10131

Siekmann, G., & Korbel, P. (2016). Defining 'STEM' skills: review and synthesis of the literature. *Support document*, *1*. https://www.ncver.edu.au/__data/assets/word_doc/0015/61341/Support-doc-1-Defining-STEM-skills_review-and-synthesis-of-the-literature.docx

Standard Occupation Policy Committee. (2019, June). SOC occupations included in STEM. https://www.bls.gov/soc/Attachment_C_STEM_2018.pdf

U.S. Department of Education, National Center for Education Statistics (2019). Table 318.20. Bachelor's, master's, and doctor's degrees conferred by postsecondary institutions, by field of study: Selected years, 1970-71 through 2017-18. U.S. Department of Education, National Center for Education Statistics (Ed.), *Digest of Education Statistics* (2019 ed.). https://nces.ed.gov/programs/digest/d19/tables/dt19_318.20.asp

Xue, Y., & Larson, R. C. (2015). STEM crisis or STEM surplus? Yes and yes. *Monthly Labor Review*, 2015. https://doi.org/10.21916/mlr.2015.14