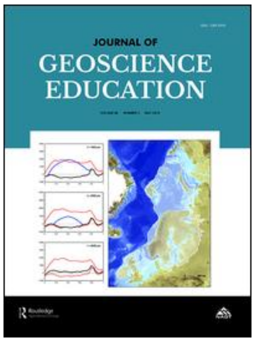

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Macrosystem Analysis of Programs and Strategies to Increase Underrepresented Populations in the Geosciences

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ABSTRACT

Meeting the future demand for a qualified geoscience workforce will require efforts to increase recruitment, retention, and graduation of an increasingly diverse student body. Doing this successfully requires renewed attention to the needs and characteristics of underrepresented students, which include ethnic and cultural minorities, women, and students with disabilities. We synthesize the current literature on successful science, technology, engineering, and mathematics (STEM) diversity programs and programs in the geosciences specifically through the lens of educational macrosystems. Macrosystems are an element of an approach to analysis of educational systems and institutions that adopts a social–ecological model. Interacting subsystems of microsystems, mesosystems, macrosystems, and exosystems operate together to contribute to student success. STEM fields in general and geoscience in particular have benefited from recent research into microsystems, the student-centric, intrinsic aspects of success. The synthesis we present here is intended to add a new dimension to this body of literature, highlighting reports from successful STEM and geoscience-specific programs that have worked to strengthen macrosystems, which are extrinsic factors that surround students. These include peer support and faculty mentoring networks, institutional bridge programs, systemic pedagogy reforms, and purposeful work to improve campus climate, culture, and accountability for diversity. This synthesis is not comprehensive but rather aims to highlight and illustrate elements of selected successful programs. We conclude with general recommendations and observations intended to be helpful to the geosciences education community in directing future work to optimize macrosystems in support of diversifying the geosciences. © *2017 National Association of Geoscience Teachers*. [DOI: 10.5408/17-256.1]

Key words: geoscience, diversity, broadening participation, macrosystems

INTRODUCTION

Despite widely publicized recent downturns in the petroleum and mining industries in recent years and significant accompanying layoffs of geoscientists, the geosciences as a group of allied professions are still projected to encounter a significant employment shortfall over the next 10–20 y (Wilson, 2014) as growth in extractive industries rebounds, combined with steady sustained growth in environmental, geotechnical, and hydrological professions. Compounding the tightening of the overall geoscience labor supply from strong employment demand, large numbers of geoscientists either recently have retired or are projected to retire in the next 10 y. In 2012, there were approximately 340,000 geoscientists employed in the US, and over the next decade, 48% of the workforce will be at or near retirement, resulting in a predicted shortage of approximately 150,000 geoscientists (Wilson, 2014). However, there remains a significant shortfall of students entering the geosciences, staying in the field, and entering the workforce, particularly students from underrepresented populations. In this paper, we use an inclusive definition of underrepresented populations and students, generally including ethnic and cultural minorities, women, and students with disabilities. The more inclusive definition is useful in approaching the synthesis of literature on factors external to students within institutional educational systems that provide supports or present barriers.

In general, a significant gap also exists in science and mathematics fields for both Black or African American and Hispanic students as compared to White and Asian students (National Science Board, 2014). Even more discouraging, the geosciences lag behind all other sciences in terms of minority and first-generation college-student participation (Wilson, 2014). Broadening participation in and completion of geoscience degrees by individuals from underrepresented groups is critical to building a diverse and informed future geoscience workforce. To improve the overall diversity of the geosciences, a greater understanding of factors that lead to successful completion of degrees in the geosciences is needed.

If the goals are to expand the number of geoscience graduates, grow the geoscience workforce, and facilitate greater numbers of underrepresented students to continue on to pursue geoscience graduate degrees, it is critical to identify factors that are associated with baccalaureate degree attainment and intended postbaccalaureate graduate degree pursuit. By studying the factors that increase underrepresented populations in the geosciences, recommendations for educational policies and practices may open the door wider for successful completion of undergraduate and graduate degrees in the geosciences by underrepresented groups.

Recent syntheses (i.e., the *Journal of Geoscience Education* [JGE] 2007 special edition, Riggs and Alexander, 2007). and much of the literature focusing on efforts to broaden participation in the geosciences have been focused on individual programs, curricular innovations, or recruitment and retention strategies that are institution specific. While

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these are valuable and are rooted in theories of diversity that are seated in the individual learner and in curriculum structure, there are several programs in North America that have shown notable success in attracting underrepresented populations, including women, to the geosciences (e.g., Houser et al., 2015; Carrick et al., 2016). Within these institutions, there typically exist arrays of interacting programs and strategies that connect networks of individual institutions at a variety of educational levels and institution types (high schools, two-year colleges [2YCs], research universities, agencies, etc.) and that enjoy internal, institutional political and financial support. These networks and institutional programs generally have not sprung up quickly or fully formed and are the product of sustained effort and iteration by a team of engaged individuals (Carrick et al., 2016). As sustained projects, they appear to leverage funding opportunities well and maximize the efforts of faculty and administrators for synergistic benefit (Houser et al., 2015). These networks and institutional-scale programs also typically reach outside of the geosciences, often leveraging support from allied science, technology, engineering, and mathematics (STEM) fields or relevant social sciences and humanities, and leveraging the efforts of professional and scientific societies in related fields (Tsui, 2007). Because these programs leverage all of the resources in and around a university, an analysis of successful programs needs to look at much more than just recruitment and retention, but also the entire educational ecosystem that retains and supports students through a program and beyond.

Macrosystems in STEM Education

A primary goal of this contribution is to provide a balance between a comprehensive overview of progress in diversity efforts in the geosciences and an analysis of how this literature can inform the community in planning future programmatic and research efforts moving forward. We find that the *macrosystems* construct and framework as presented by Rice and Alfred (2014) can be useful in this regard. We summarize this approach next and the seminal literature that gave rise to it, and then we move into an analysis of the published literature in diversity and inclusion in the geosciences in this context. Our aim is for this summary to provide a perspective on student success that stretches beyond the traditional focus on departments and in-house curricula to include personal, cultural, and institutional factors that reach well beyond departmental boundaries, but that nonetheless have a powerful influence on student success in geoscience programs. Our hope is that through this analysis, geoscience departments and individual faculty will see the collective impact of external factors on students and therefore see more clearly the impact and potential of their own actions. Many of these advances, both in understanding student attraction and success in STEM, as well as in the understanding of geoscience-focused diversity programs, have advanced since the 2007 synthesis and have become more sophisticated as intellectual frameworks; therefore, so should the actions of geoscience departments become more purposeful.

An analysis of educational systems as ecosystems is not new, but the application to STEM education and career pathways is relatively recent. Rice and Alfred (2014) provided a model we find particularly applicable to a systems-scale analysis of geoscience programs that have been successful in attracting underrepresented groups and fostering their success. Their analysis was focused on the total educational life cycle of African American female engineers from early interest and family supports through university education into successful careers. They adapted a model presented by Cook et al. (2002, 2005) that applied the model presented originally by Bronfenbrenner (1977), which characterizes human interaction in a social environment as being composed of a macrosystem, exosystem, mesosystem, and microsystem. This ecological approach to social systems was adapted by Cook et al. (2002, 2005) to educational systems and minority students, within which they concluded that macrosystem and microsystem analysis is the most useful for understanding the forces acting upon the educational and career pathways of underrepresented students. Rice and Alfred (2014) carried this model forward to STEM education, and this analysis provides useful analogs to extend their model to geoscience. We adapted this theoretical frame for the programmatic-scale analysis of published geoscience programs in this review because of this ecological focus on systems extrinsic to individual students, and because it provides a context for action within the sphere of influence of individual programs and departments.

Working within the framework of Rice and Alfred (2014), *microsystems* are defined as those factors related to student-centric factors, specifically self-image, identity, self-efficacy, and related affective domain constructs. Factors also grouped in microsystems are personal qualities of determination and persistence. Microsystems in their model are those elements a student personally brings to their educational experience, so it would be a reasonable extension to include a student's personal cultural identity, lived experience, and worldview in this category. Microsystems are shown as the inner circle related to the Individual in Fig. 1.

Macrosystems, on the other hand, focus on structural and institutional cultural systems in place around students, rather than within them. These include family, friend, and peer support networks, professional mentorship by professors or advisors, precollege programs, university resources (financial and structural), and broader minority networks. Macrosystems also extend into the workplace in Rice and Alfred's (2014) analysis. The fine-scale details of workplace mentorship and career-advancement structures are generally beyond the scope of this university-centric review, except to the extent that career pathways and future employers are explicitly and deliberately involved in the structure of curriculum, internship, and career placement activities within a university context. Macrosystems are shown as the outer circle related to the System in Fig. 1.

Our focus is on those systems that exist around students within university environments and their pre-university environments. We examined the elements and characteristics of published accounts of programs in broader STEM education and then specifically in the geosciences that have been successful at leveraging and enhancing macrosystems for the recruitment, retention, degree completion, and graduation of underrepresented students. Here, we highlight elements of selected successful programs and conclude with general recommendations and observations that we hope will be helpful to the geosciences education community in future work to optimize macrosystems in support of

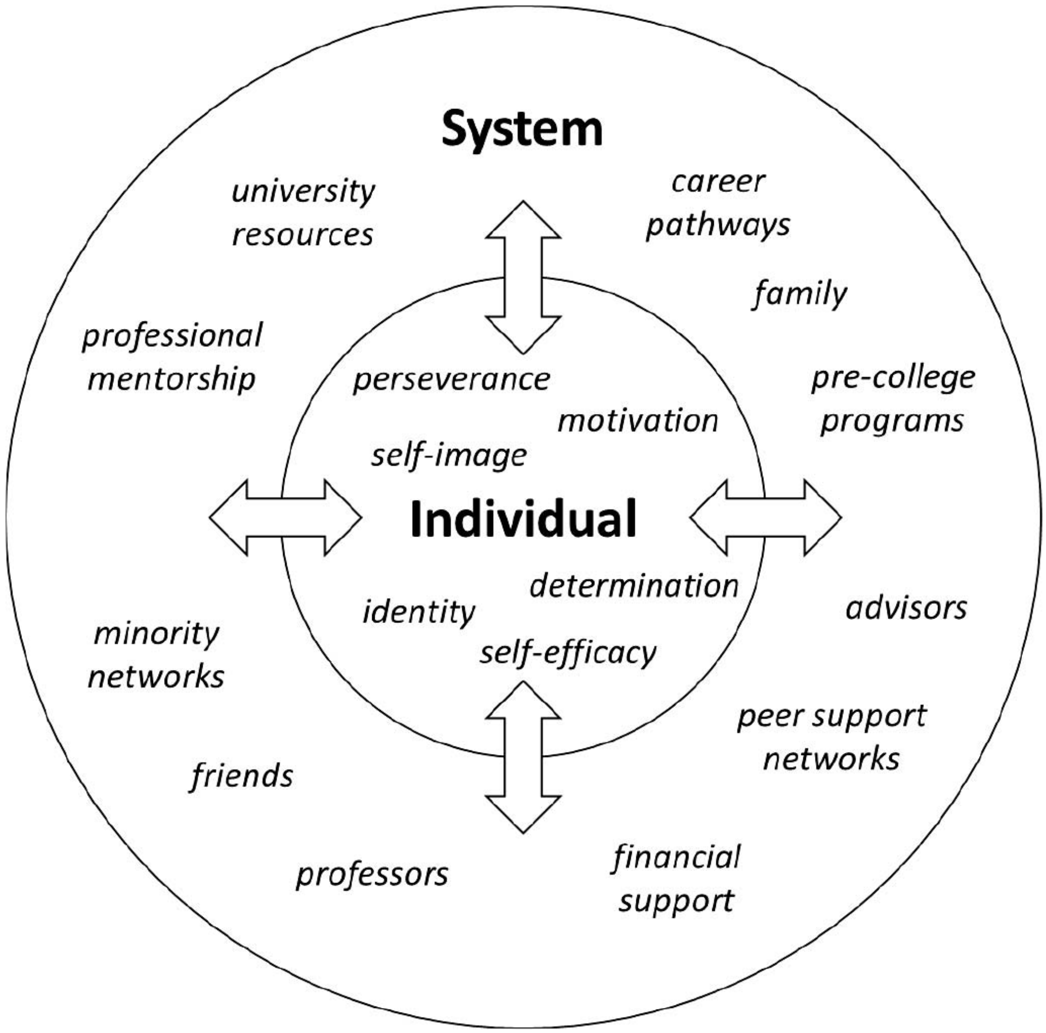

FIGURE 1: Ecological model adapted from Rice and Alfred (2014) showing the relationship between the microsystem (inner circle) and the macrosystem (outer circle).

diversifying the geosciences student body and workforce moving forward.

An ecosystems-based approach to thinking about programs and curricula also informs the scope and scale of interventions. Programs can be built to maximize the connection from individual factors such as identity to macrosystem features like culture and community that support that identity. Understanding the placement within university systems can further help geoscientists build programs and curricula that are deliberately supportive and informed by all other aspects of a student's academic world. This opens research directions and assessment/evaluation efforts that are focused on the supports and barriers that are internal to a program or curriculum or major, as well as those that arise at institutional and community interactions and touch points. The macrosystems framework encourages analysis of the whole student experience, from the perspective of the student as the focus outward into the systems they navigate, rather than having the curriculum or major being the focus, looking inward, with students being the "water" that passes through a standing wave in a river. By changing the focus, this systems approach fosters more student-centered recruitment, programming, assessment, and measures of success.

METHODS

This paper seeks to provide a synthesis of recent existing research on programmatic and institutional approaches observed to advance underrepresented population participation in the geosciences. While many syntheses exist focusing on approaches to recruit diverse populations into STEM as a whole (e.g., Tsui, 2007; Hurtado et al., 2010; Ong et al., 2011; Olson and Riordan, 2012; Whittaker and Montgomery, 2012), fewer have examined those specific to the geosciences (e.g., Huntoon and Lane, 2007; National Research Council, 2013). In an effort to identify the strides made by geoscience-specific programs in this area since the JGE 2007 issue, the intent of this summary is to be comprehensive, rather than a full critical review of the literature, to capture the fullest range of efforts in the community and yield valuable insights for geoscience education, policy, and practice.

The publications included in this paper were identified by conducting searches on education-related databases, such as ProQuest, JSTOR, Education Resources Information Center (ERIC), Google Scholar, and OmniFile full text select. Grounded in the macrosystem framework and incorporating the recommendations of Huntoon and Lane (2007) for components of effective programs, searches were conducted using keywords pertaining to diversity, minorities, higher education, STEM, geoscience, retention, mentoring, pedagogy, active learning, undergraduate research, bridge program, and field trip. In order to expand the search, citations appearing in relevant retrieved articles were also considered.

The papers included herein are not all-inclusive but represent elements of example macrosystems-focused efforts that have reported effectiveness in increasing women and minority recruitment, retention, and completion in STEM disciplines and the geosciences in particular. Although effort was made to examine the literature since the JGE 2007 special edition for more recent macrosystem examples, especially those that relate to the geosciences, we did not preclude earlier published research where relevant. Fifty-one papers were coded into programmatic themes encompassing the macrosystems of mentorship, peer support networks, precollege or bridge programs, and university resources in the form of pedagogical and research experience support, as well as institutional climate and culture. Of the 51 total papers, 26 describe geoscience-specific programs. Many cut across multiple themes; however, for clarity of discussion, they were placed into a predominant theme. In themes with fewer geoscience-related programs reported in the literature, research from other science disciplines that reported on impacts to larger populations of underrepresented students or demonstrated broader student impact was considered and included. Several themes (mentoring, peer support networks, and institutional climate and culture) align with the National Academy of Sciences' publication *Preparing the Next Generation of Earth Scientists* (National Research Council, 2013) based on best practices for National Science Foundation Opportunities for Enhancing Diversity in the Geosciences.

APPROACHES TO ADVANCE PARTICIPATION OF UNDERREPRESENTED POPULATIONS IN THE GEOSCIENCES

Mentoring

Often, underrepresented students in STEM majors struggle to overcome discriminatory practices, feelings of isolation, and low expectations from peers and faculty (Griffin et al., 2010). A critical support system helping students feel welcomed and supported includes strong faculty–student relationships (Rice and Alfred, 2014). These mentoring activities can develop a strong professional bond between faculty and students, in turn increasing retention and postsecondary degree pursuit in STEM disciplines (Barlow and Villarejo, 2004; Villarejo et al., 2008; Carter et al., 2009). Berk et al. (2005, 67) defined a mentoring relationship as "one that may vary along a continuum from informal/short-term to formal/long-term in which faculty with useful experience, knowledge, skills, and/or wisdom offers advice, information, guidance, support, or opportunity to another faculty member or student for that individual's professional development. (Note: This is a voluntary relationship initiated by the mentee.)" Mentoring focuses both on student learning and development, often a key component embedded in specific research opportunities (Baber et al., 2010; Houser et al., 2013; White et al., 2013) or professional development activities (Pyrtle and Williamson-Whitney, 2008).

Multiple positive student gains from mentoring relationships have been demonstrated in the literature. These include appreciation of what is required to be a scientist (White et al., 2013) and opportunities to network with professionals (Lopatto, 2004; Seymour et al., 2004; Thiry et al., 2011). Research has also shown meaningful relationships with faculty can help students prepare for careers (Packard, 2004; Doerschuk et al., 2016), grow professional networks (Pyrtle and Williamson-Whitney, 2008), and explore research opportunities (Griffin et al., 2010), as well as increase student self-efficacy (Baber et al., 2010; Thiry et al., 2011; Wilson et al., 2012).

In mentorship of underrepresented students, interactions of minority students with their research mentor can result in increased likelihood of graduate school pursuit and in choosing a career in scientific research (Thiry et al., 2011). More importantly, a faculty member's commitment to fostering the student's academic success results in positive mentor relationship outcomes regardless of the racial similarity between mentor and mentee (Griffin et al., 2010). However, it should be noted that some students identify interactions with mentors as difficult, resulting in less positive outcomes, such as students feeling more like assistants or experiencing a lack of relatability with faculty (Houser et al., 2013). Certainly, the style of mentorship plays an important role. For example, Thiry et al. (2011) found that when research mentors are accessible, friendly, and treat students as legitimate members of the research team, students feel comfortable taking the intellectual risks that contribute to their development as scientists. Others (Judge et al., 2012) have reported mentored research experiences are most successful when the relationship is one of trusted collaboration. Generally, the characteristics of good mentoring include expertise, professional integrity, honesty, accessibility, approachability, motivation, respect by peers in field, and supportiveness and encouragement (Berk et al., 2005), in addition to balancing the dual goals of helping students nurture scientific understanding and serving as a guide in the development of their identity as a scientist (Linn et al., 2015). It is important to recognize that positive outcomes of mentoring are not one-directional; White et al. (2013) reported that mentoring provides the opportunity for the mentor to gain an appreciation for the difficulties faced by aspiring minority scientists.

Papers illustrating examples of successful mentoring programs are listed in Table I. As it pertains to the geosciences in particular, positive student outcomes of mentoring have been demonstrated in geoscience-specific programs (e.g., Johnson et al., 2016). For example, Baber et al. (2010) found that underrepresented students interested in geoscience reported that faculty members introduced students to academic programs; gave them opportunities to conduct research and present findings with them; gave them advice about their academic and professional interests; provided support regarding their personal lives; demonstrated what a scholar and a researcher does; and discussed what students should do in order to achieve success in their careers. White et al. (2013) reported that mentoring activities embedded in the Jackson State University Meteorology

TABLE I: Example studies reporting on mentoring in STEM disciplines.

References	Ref Pub	R/E[1]	*n*	% Minority	Methods of Program Evaluation
Windham et al. (2004)[2]	Y	E	85	93	Questionnaire
Pyrtle and Williamson-Whitney (2008)[2]	Y	E	25	100	Survey
Fries-Britt et al. (2010)	Y	R	110	100	Interviews
Thiry et al. (2011)	Y	R	73	36	Interviews
Wilson et al. (2012)	Y	E	100	56	Retention data
Houser et al. (2013)[2]	Y	R	25	12	Focus group interviews; surveys
White et al. (2013)[2]	Y	E	60	92	Retention data
Fifolt et al. (2014)	Y	R	92	66 identify as Black	GRE[3] scores; focus group interviews
Doerschuk et al. (2016)	Y	R	96	72	Retention data; GPA[3] and drop rate; surveys; exit interview

[1]R = research study; E = program evaluation and description.
[2]Geoscience specific.
[3]GRE = Graduate Record Examinations; GPA = grade point average.

Program provided a level of community where mentor and mentee could form a professional partnership and students could gain an appreciation of what is required to be a scientist. Similarly, Houser et al. (2013) found the relationship between the student and faculty mentor appears to influence the decision of the students to conduct future research and attend graduate school. Moreover, they concluded that reflection by students on their relationship with the faculty mentor could help them to identify the preferred characteristics and style of mentoring important to their success in a graduate program.

Peer Support Networks and Community Building

Alongside mentoring, macrosystem perspectives of peer support networks and community building efforts play an important role in fostering student engagement and retention in STEM majors and positive student outcomes (Table II lists example programs). Programs fostering peer-to-peer interaction and community building are often intentionally structured so that participants live together in residential communities and/or partake in shared curriculum with the goal of building a sense of community with meaningful peer relationships and support networks (Kendricks and Arment, 2011; Soldner et al., 2012). For example, Blake et al. (2013, 405) described a component of their undergraduate research experiences (URE) program, "Student Support and Safety Nets," as a "structured and holistic learning environment that supports the undergraduates in becoming successful researchers and scholars." They described this component as a combination of networking sessions, brown bag meetings, social events, graduate school workshops, and counseling services. These activities encouraged students, provided positive peer-group motivation, and socialized students to the institutional and department culture and expectations (Toven-Lindsey et al., 2015). Additionally, these social supports had positive effects on major choice, STEM-related interests, grades, and perceived STEM preparation (Kendricks and Arment, 2011; Soldner et al., 2012).

It has been argued that institutions should ensure inclusion of all students in learning communities (Graham et al., 2013). For example, Dagley et al. (2016), in describing a learning community model composed of both residential and curricular components, reported overall higher retention of students in a STEM major and, in particular, higher retention and graduation rates of women, Blacks, and Hispanics in the program. Similarly, improved student performance in science courses, higher grade point average, and student persistence in science majors were reported outcomes of the Program for Excellence in Education and Research in the Sciences (PEERS) at the University of California–Los Angeles, which aimed to help increase the success of underrepresented students in life and physical sciences majors (Toven-Lindsey et al., 2015). Inkelas (2011) reported that women in STEM majors who were involved with women-only STEM-focused living–learning programs or coeducational STEM living–learning programs were more likely to report a smooth transition to college than women in STEM majors who did not participate. Others have argued that underrepresented minority students may be unaware of the academic and social benefits of learning communities or peer support networks and encounter both intentional and

TABLE II: Example studies of peer-support networks and community building.

References	Ref Pub	R/E[1]	*n*	% Minority	Methods of Program Evaluation
Kendricks and Arment (2011)	Y	R	20	100	Postprogram survey
Soldner et al. (2012)	Y	R	5,240	10	National study and data set, structural equation modeling
Toven-Lindsey et al. (2015)	Y	R	147	78	Matched comparison group
Dagley et al. (2016)	Y	R	1,351	31	Graduation/retention rate

[1]R = research study; E = program evaluation and description.

unintentional biases by faculty and peers that may make it challenging to break into established peer groups or cliques (Ong et al., 2011; Johnson, 2012; Graham et al., 2013).

Peer cohort and community building efforts have been applied in geosciences programs aimed at recruiting underrepresented populations and are often embedded within larger program frameworks (e.g., Houser et al., 2015). For example, a joint program between Pennsylvania State University and Howard University (Fuentes et al., 2012) was designed to recruit and retain underrepresented students in geosciences through a combination of research and mentoring opportunities, creating what they termed "clusters of learners," with each cluster serving as a community of faculty, graduate students, and undergraduate students who worked on common research objectives. Riggs et al. (2007) described an example of geoscience student community building involving recruitment of Native American students in the geosciences. Their program involved development of a Science Explorer's club that provided after-school field activities and summer activities focused on natural science and the environment. Also included in the program was a cooperation with the Young Native Scholars program and associated Summer Program built on a foundation of mutual respect, cooperation, and peer mentoring.

Bridge Programs

Many macrosystem support programs have focused on growing and strengthening STEM recruitment pipeline strategies, starting at the primary and secondary school level. These programs are meant to serve as a "bridge" between the secondary and postsecondary education pathways, between the 2YC and receiving four-year institutions, or between the baccalaureate institution and graduate school. Although bridge programs vary, they typically entail intensive academic enrichment and other strategies designed to facilitate students' transitions and adjustment to college (Tsui, 2007). This includes academic support such as writing, mathematics, and reading, as well as expectations for college work (Kezar, 2000). Often, such programs are targeted at first-generation and underrepresented populations in an effort to increase awareness of STEM degrees and to strengthen the academic preparation of students for the rigor of college (e.g., Wechsler et al., 2005; Hanks et al., 2007; Miller et al., 2007; Thiry and Hunter, 2008; Carrick et al., 2016). Additionally, many bridge programs focus on career counseling and developing relationships with faculty and professional mentors (Kezar, 2000).

Bridge programs have also become a common macrosystem support within higher education to help recruit, retain, and graduate underrepresented students in STEM disciplines (Tsui, 2007), and a number of bridge programs aimed at recruiting and aiding student transition within the geosciences can be found in the literature (see Table III). Many positive student outcomes are associated with these programs, including increased interest in the geosciences (Wechsler et al., 2005; Miller et al., 2007; Baber et al., 2010; Adetunji et al., 2012; Carrick et al., 2016), relationship building between student and faculty members (Wechsler et al., 2005; Thiry and Hunter, 2008; Baber et al., 2010), development of research skills (Thiry and Hunter, 2008; Baber et al., 2010), knowledge gained regarding careers in STEM and the geosciences (Wechsler et al., 2005; Winkleby et al., 2009; Baber et al., 2010), knowledge gained about the college application process (Baber et al., 2010), and increased self-efficacy (Thiry and Hunter, 2008; Baber et al., 2010; Carrick et al., 2016). For example, Bruno et al. (2016) demonstrated that after participation in an oceanography-focused summer bridge program aimed at 2YC students in Hawaii, students reported greater awareness of ocean science majors, degrees, and careers, as well as greater confidence in their skills and abilities required to major in the geosciences.

Pedagogies

Allocation and application of macrosystem support through university resources in the form of transforming undergraduate STEM curriculum and education can positively affect the performance and success of all students in STEM disciplines (Freeman et al., 2014). Movement beyond traditional lecture to encompass pedagogies of inquiry, engaged, or active learning has demonstrated positive student learning and retention outcomes (Freeman et al., 2007, 2014; Preszler, 2009) and has been advocated as an alternative to increasing persistence and retention of underrepresented students (Graham et al., 2013).

A wealth of literature exists regarding thinking and learning in the geosciences (e.g., Manduca and Mogk, 2006; Kastens and Manduca, 2012), and a complete discussion of such literature is well beyond the scope of this review. Instead, we focus on three pedagogical approaches as they pertain to benefiting underrepresented students in STEM: inquiry and active learning, place-based learning, and field-based learning. It should be noted that an analysis of pedagogy as a macrosystem risks blurring the line between micro- and macrosystem analysis, depending on the scale of the pedagogical innovation or application. In this synthesis, we focus on those pedagogical reforms that reach beyond a single course or classroom implementation, involving instead many courses and instructors, sometimes entire departmental curricula, or suites of educational experiences that reach beyond a single topic or instructor. Table IV provides examples of curricular programs illustrating inquiry, active, and place-based learning and the methods of evaluation employed by each study.

Inquiry and Active Learning

Attrition rates, particularly for underrepresented students, in STEM majors have long been of concern, and many have advocated reform of pedagogical methods to include active and inquiry-based learning activities as a solution (Tsui, 2007; Graham et al., 2013). The effectiveness of active learning in improved student learning is clear. In their comprehensive meta-analysis of 225 studies of undergraduate STEM education, Freeman et al. (2014) empirically validated that active learning teaching practices increase student performance across the STEM disciplines. Others have shown a highly structured course design, or one with substantial active learning activities combined with frequent formative assessment, leads to an increase in overall performance by all students, compared with a lecture-intensive course with no required active learning (Freeman et al., 2011; Haak et al., 2011). When active-learning exercises are required in the curriculum, Freeman et al. (2007) found increased performance by all students com-

TABLE III: Example studies reporting on bridge programs.

References	Ref Pub	R/E[1]	Duration	*n*	% Minority	Methods of Program Evaluation
Wechsler et al. (2005)[2]	Y	E	Summer	29	100	Pre- and postprogram focus groups
Gilligan et al. (2007)[2]	Y	E	Nine weeks	106	95	Evaluation survey
Hanks et al. (2007)[2]	Y	R	Six weeks	1,180	90	Demographic and retention data
Miller et al. (2007)[2]	Y	E	Two weeks	71	79	Pre- and postprogram surveys
Thiry and Hunter (2008)	N	E	Summer	23	48	Survey
Winkleby et al. (2009)	Y	R	Five weeks	476	Not reported	Surveys
Baber et al. (2010)[2]	Y	E	Six weeks	62	90	Questionnaire
Adetunji et al. (2012)[2]	Y	E	Seminars, embedded course activities	85	88	Pre- and postprogram surveys
Strawn and Livelybrooks (2012)	Y	R	Ten weeks	Not reported		Focus group interviews with faculty members
Hirst et al. (2014)	Y	R	Summer	28	22	Transfer and retention data; surveys
Houser et al. (2015)[2]	Y	R	One week	59	48	Survey
McCoy and Winkle-Wagner (2015)	Y	R	Four weeks	16	63	Qualitative case study
Bruno et al. (2016)[2]	Y	R	One week	64	1/3 are Native Hawaiian	Survey
Carrick et al. (2016)[2]	Y	R	Two weeks	245	>80	Surveys
Tomasko et al. (2016)	Y	R	Not reported	188	61	Surveys

[1]R = research study; E = program evaluation and description.
[2]Geoscience specific.

TABLE IV: Example studies reporting on pedagogies of inquiry, active learning, and place-based learning strategies.

References	Ref Pub	Learning Strategy	*n*	% Minority	Methods of Program Evaluation
Freeman et al. (2007)	Y	Active learning	3,338	7	Grades
Preszler (2009)	Y	Peer-led instruction	2,909	56.6	Grades
Haak et al. (2011)	Y	Active learning	111,227	~17 in EOP[1]	Grades
Fuentes et al. (2012)[2]	Y	Experiential learning	15	Not reported	Graduate school enrollment
Hammersley et al. (2012)[2]	Y	Place-based	69	95	Grades; course evaluations
Meyer et al. (2012)[2]	Y	Inquiry	21 elementary students	100	Observation
Unsworth et al. (2012)[2]	Y	Cultural relevance; place-based	16 high school students	100	Surveys
Boger et al. (2014)[2]	Y	Place-based	51	Unknown	Surveys
Dalbotten et al. (2014)[2]	Y	Place-based	56	100	Observations, interviews, surveys
DeFelice et al. (2014)[2]	Y	Place-based	22	77	Surveys
Freeman et al. (2014)	Y	Active learning	225 studies	Unknown	Meta-analysis
Oyana et al. (2015)[2]	Y	Place-based, inquiry, civic engagement	20 high school students	46	Case study; surveys

[1]University of Washington Educational Opportunity Program (EOP) are individuals from educationally or economically disadvantaged backgrounds, 76.5% of whom are underrepresented minorities in the EOP category (Haak et al., 2011).
[2]Geoscience specific.

TABLE V: Example studies reporting on undergraduate research experiences in STEM disciplines.

References	Ref Pub	Duration/Type	n	% Minority	Methods of Program Evaluation
Chigbu et al. (2007)[1]	Y	Four-week short course followed by four- to eight-week internship	41	90	Questionnaire
Hurtado et al. (2009)	Y	Various, three MSI,[2] one large selective institution	65	89	Focus groups, interviews
Baber et al. (2010)[1]	Y	Eight weeks	4	100	Interviews
Hallar et al. (2010)[1]	Y	Six months	4 females	75	Interviews and pre- and postprogram surveys
Espinosa (2011)	Y	Various nationwide	1,250 students at 96 different 4YCs[3]	100	Hierarchical generalized linear modeling
Blake et al. (2013)	Y	Year-round	47	83	Retention data; testimonials
Eagan et al. (2013)	Y	Various nationwide	4,152 students at 219 different 4YCs[3]	Not reported	Multinomial generalized hierarchical linear modeling
Hopper et al. (2013)[1]	Y	Semester	95	18	Surveys
Blake et al. (2015b)[1]	Y	Three weeks	89	73	Pre- and postprogram surveys
Jackson-Smith (2015)	Y	Summer	6	100	Qualitative interviews
Leggett-Robinson et al. (2015)	Y	Three-week introduction in undergraduate research @2YC followed by eight-week undergraduate research at 4YC[3]	12	Not reported	Surveys; focus group interviews
Kortz and van der Hoeven Kraft (2016)[1]	Y	Semester course-based	54	28	Questionnaire assignment

[1]Geoscience specific.
[2]MSI = minority serving institution.
[3]4YC = four-year college; 2YC = two-year college.

pared with performance in lecture-intensive courses where active-learning exercises were absent or optional.

Within the literature, research on the effectiveness of active learning in the geosciences is limited and generally focuses on nonmajors and students enrolled in introductory geoscience courses. Notwithstanding this situation, several benefits of active learning in geoscience courses have been demonstrated. These include improved student retention (McConnell et al., 2003;, 2005), higher grades (McConnell et al., 2003), increased logical thinking skills (McConnell et al., 2003;, 2005), increased information recall and quantitative reasoning (Yuretich et al., 2001), increased interest in science (Yuretich et al., 2001), and satisfaction with their class experiences (McConnell et al., 2006).

Although research in the geosciences is somewhat lacking on the impact of active learning on underrepresented student learning, similar research in other STEM disciplines has shown active learning to be effective in improving overall underrepresented student performance and grades (Haak et al., 2011; Graham et al., 2013; Freeman et al., 2014). For example, Preszler (2009) reported that replacement of one weekly lecture with a weekly peer-led workshop, where students worked in small cooperative groups as they solved challenging problems, evaluated case studies, and participated in activities designed to improve their general learning skills, resulted in a higher increase in the proportion of underrepresented minority students earning "A's" or "B's," than nonminority students (Preszler, 2009).

Place-Based Learning

Underrepresented students often leave STEM degrees due to the perceived lack of social value or relevance to improving conditions for their communities (Bonous-Hammarth, 2000). Certainly, the relevance of science coursework to students' lives has a significant impact on academic and social adjustment for underrepresented students in the sciences (Hurtado et al., 2010). To this end, many in the geosciences have turned to the pedagogical approach of place-based learning, which places curriculum content in local environments and communities through the use of local features, phenomena, and issues as context and scaffolding for content (Gruenewald, 2003). Semken (2005, 151) defined place-based teaching as "the physical attributes and the cultural, historic, and socioeconomic meanings of places (i.e., sense of place) [that] define and infuse content and pedagogy, and in which students regularly work in the local outdoor environment or in the community....". He further described five essential characteristics of place-based geoscience education: (1) course content focused explicitly on the geological and other natural attributes of a place; (2) content integrating the diverse meanings that place holds for the instructor, the students, and the community; (3) course content taught by using authentic experiences in that place, or in an environment that strongly evokes that place; (4) content that promotes and supports ecologically and culturally sustainable living in that place; and (5) course content that enriches the sense of place of students and instructor.

An example incorporating a place-based geoscience curriculum was detailed by Hammersley et al. (2012) in their description of an introductory geology course organized around the geology of Mexico. They reported that the course was successful in increasing Hispanic enrollment as compared to the ethnicity of students in the traditional physical geology course. More importantly, Hammersley et al. (2012) noted that students in the place-based course reported significant and more positive attitudes towards geoscience. Similarly, Boger et al. (2014) redesigned two foundational Earth and Environmental Science courses using the rationale that place-based education in an urban context allows students at an urban college with a significant underrepresented student population to form connections with natural science and the social, political, and cultural aspects of environmental issues. In another urban place-based example, DeFelice et al. (2014) found students reported increased interest in learning science outdoors and enhanced science identities.

Likewise, Riggs (2005) discussed incorporation of indigenous Earth systems knowledge into Earth Science education to make curricula relevant and useful to indigenous learners. Indigenous knowledge is primarily "concerned with the balance of humans and human activities within the interwoven functions of the natural environment and natural surroundings" (Riggs, 2005, 307). Others have likewise reported positive student outcomes, specific to Native American students, in the geosciences utilizing a place-based model integrating indigenous knowledge (Palmer et al., 2009; Dalbotten et al., 2014; Ricci, 2014).

Field-Based Learning

The pedagogy of field-based learning is a common component of undergraduate geoscience student learning, is incorporated into the geoscience curriculum (e.g., Knapp et al., 2006), and is often a component of geoscience bachelor degrees (Drummond and Markin, 2008). Many bridge programs include a field-based component (e.g., Houser et al., 2015; Carrick et al., 2016) as well as many pedagogical practices (e.g., place-based learning). The literature on the effectiveness of field-based courses and improved student learning is well-established (e.g., Boyle et al., 2007; Elkins and Elkins, 2007; Mogk and Goodwin, 2012). It has been shown that field study courses can have positive effects on students' values, interest, and attitudes (Boyle et al., 2007; Stokes and Boyle, 2009). Field-based learning and field study courses are often included in geoscience curriculum at 2YC (Wolfe and Martin, 2013) and four-year institutions (Knapp et al., 2006; LaSage et al., 2006; Elkins and Elkins, 2007), particularly for upper-level students majoring in science disciplines (Boyle et al., 2007; Stokes and Boyle, 2009; Feig, 2010). Nearly all geoscience graduates report having had at least one field experience or one research experience, and most participated in at least one of both types (Wilson, 2016).

Field studies, field trips, and field-based activities provide learning experiences that positively affect student motivation, attitudes, and perceptions (Boyle et al., 2007; Stokes and Boyle, 2009; Mogk and Goodwin, 2012; Wolfe and Martin, 2013), build confidence and increase student value in the content they are learning (Gonzales and Semken, 2006; Hemler and Repine, 2006; Tedesco and Salazar, 2006), and provide opportunities for students to see themselves as geoscientists (Hemler and Repine, 2006). Field-based learning can provide a learning environment where strong social and peer community networks can be fostered as well as student to faculty relationships (Boyle et al., 2007; Mogk and Goodwin, 2012; Wolfe and Martin, 2013). Importantly, field trip and field activities targeted at underrepresented middle and high school students can serve to generate interest in the geosciences early in a student's formative years and serve as a recruiting tool for students to choose to pursue a geoscience major (Serpa et al., 2007). Similarly, Wolfe (2016) reported that students in introductory physical science courses at 2YCs who participated in field experiences significantly increased their intent to transfer to a four-year college or university and pursue a geoscience-related degree. It has also been argued that field studies designed to be accessible and inclusive can broaden participation in the geosciences for students with disabilities (Gilley et al., 2015).

Currently, field-based and outdoor learning is a significant component of the geoscience-related degree pathway, and students will likely encounter such learning activities during their academic career. However, it is important to recognize that underrepresented minority students have reported little outdoor appeal, and it is likely that underrepresented minorities may find geoscience's emphasis on fieldwork and the outdoors a deterrent to majoring in the discipline (O'Connell and Holmes, 2011). In their study, Whitney et al. (2005) found Caucasians are more likely than other ethnic groups to report enjoyment of outdoor activities and are more likely than African-Americans to go hiking and/or camping. Similarly, Sherman-Morris and McNeal (2016) found that outdoor-related factors are not as positively viewed by underrepresented students and may not be an effective tool for recruiting these populations to the geosciences. These differences are likely attributable to both opportunity and actual experience in these activities (Whitney et al., 2005). O'Connell and Holmes (2011) recommended that greater focus should instead be on raising awareness of the diversity of geoscience-related careers, particularly those that provide opportunities to work indoors. Likewise, Sherman-Morris and McNeal (2016) recommended spending equal time in recruitment efforts on the laboratory and technological skills included in the geosciences.

Undergraduate Research Experiences (UREs)

A common programmatic approach to the macrosystem of university support structures cutting across the multiple domains of mentoring, peer support and community building, and student professional development is that of UREs. The Council on Undergraduate Research and National Conference for Undergraduate Research (2005) defined six principles of undergraduate research: (1) Undergraduate research combines teaching and research; (2) it serves as a collaborative investigative model done with a mentor or jointly by students and teachers; (3) it is focused on collective and collaborative work; (4) research motivates students to learn by doing; (5) the experience promotes both new research and a student's analytical and communicative skills; and (6) it creates internal networks to support collaborative learning. UREs expose students to new ideas and ways of thinking and actively engage students in exploring and discovering new knowledge (Boyer Commission on Educating Undergraduates in the Research University, 1998; Council on Undergraduate Research and National Conference for Undergraduate Research, 2005).

The literature is rich with demonstrated URE student outcomes (e.g., Linn et al., 2015). Research has shown students significantly increase their chances of pursuing not only a science major, but also a graduate degree or a science career by participating in UREs (Barlow and Villarejo, 2004; Lopatto, 2004; Villarejo et al., 2008). Students engaged in UREs report greater self-confidence (Lopatto, 2004; Seymour et al., 2004; Hunter et al., 2007), gains in "thinking like a scientist" (Hunter et al., 2007), or 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 (Thiry et al., 2011). Students with UREs report gains in their ability to apply critical thinking skills and gain a greater understanding of the scientific research process, including data collection and interpretation (Bauer and Bennett, 2003; Lopatto, 2004; Thiry et al., 2011), as well as in their ability to explain, present, discuss, and defend their work to peers, advisors, and other faculty (Bauer and Bennett, 2003; Lopatto, 2004; Hunter et al., 2007; Thiry et al., 2011).

Others have found that students value URE opportunities in terms of personal gains to perceived professional value, specifically serving as "resume builders" (Lopatto, 2004, 2006) or as useful preparation for careers and/or the job market, because they offered "real-world work experience," enhancing resumes (Seymour et al., 2004; Thiry et al., 2011). Undergraduate UREs help in shaping career plans (Seymour et al., 2004). Specific to the geosciences, participation by underrepresented minorities in UREs can raise awareness of and interest in the geosciences (Hopper et al., 2013; Blake et al., 2015a, 2015b).

Several studies have focused on the specific educational and professional gains from UREs reported by underrepresented students (Lopatto, 2004; Hurtado et al., 2009; Hallar et al., 2010; Jones et al., 2010; see Table IV for selected example URE programs). Participation in UREs helps to prepare underrepresented students for graduate education and careers in the sciences (Villarejo et al., 2008; Jones et al., 2010), and UREs have particular benefits for first-generation and low-income college students (Nagda et al., 1998; Ishiyama, 2002). For example, Nnadozie et al. (2001) suggested that early and continuous exposure to the process of conducting research better prepares minority students for graduate school. Hathaway et al. (2002) found that underrepresented students who participated in an URE were significantly more likely to pursue graduate education than were underrepresented students who did not participate in UREs. In addition, underrepresented students engaged in UREs reported a much higher use of a faculty member for a job recommendation (Hathaway et al., 2002). Campbell and Skoog (2004) found women engaged in UREs increased skills, confidence, and motivation to seek a science career. Their study reported that a URE was an important factor in facilitating women's entrance to and success in graduate and professional studies in science and research-related positions. Similarly, Espinosa (2011) found female minority students who participated in research programs were more likely to persist in STEM.

Course-Based Undergraduate Research Experiences

Course-based undergraduate research experiences (CUREs) are adapted to involve larger numbers of students in research and are designed to be embedded within a specific course curriculum or learning unit. A key benefit of CUREs is their ability to engage all students who enroll in a course and can reach students that are unaware of traditional UREs (Auchincloss et al., 2014; Bangera and Brownell, 2014). Bangera and Brownell (2014, 604), in particular, advocated CUREs to "help reduce the factors that contribute to inequities and give *all* [emphasis theirs] students the opportunity to engage in authentic research.". Others have noted that students who engage in research early in their academic career are more likely to persist in STEM majors (Nagda et al., 1998; Rodenbusch et al., 2016), persist in semester-to-semester retention (Kerr and Yan, 2016), and persist to graduation (Rodenbusch et al., 2016). Students in courses in which CUREs are incorporated report increased confidence in their technical skills (Jordan et al., 2014; Kerr and Yan, 2016), research skills (Shaffer et al., 2010; Harrison et al., 2011), and content knowledge (Shaffer et al., 2010; Jordan et al., 2014), and greater STEM career knowledge (Harrison et al., 2011; Shaffer et al., 2014).

The effectiveness of CUREs has been demonstrated in chemistry (Kerr and Yan, 2016) and biology (Shaffer et al., 2010; Harrison et al., 2011), but the reporting of their use in the geosciences is more limited. A specific geoscience example of a CURE designed for an undergraduate introductory geology course consisting of primarily non-majors was described by Kortz and van der Hoeven Kraft (2016). In their study, students who participated in a CURE project reported increased content knowledge, a greater ability to think like a scientist, more effective communication skills, and increased general interest in and positive affective response to science. Other examples of UREs can be found in the National Association of Geoscience Teachers publication *In the Trenches* (April 2015 issue, Kraft, 2015) and the Council for Undergraduate Research Web site (http://www.cur.org), including their geoscience-affiliated subdivision (http://geocur.org).

Institutional Climate and Culture

Campus and department climate and culture as a macrosystem of university support are often demonstrated by the campus and department commitment (including financial commitment) to elements of student support. These are manifested in the existence and persistence of friendly institutional structures, rich mentoring, and strong peer networks. While the individual interactions between students and members of the university community are one realization of campus climate, they also operate mostly at the microsystems level. The factors related to successful support of macrosystems all involve broad-based, institutional commitment to diversity and inclusion and action to advance accountability at all levels.

While mentoring networks and formation of strong and supportive social groups are key aspects of macrosystems, the literature shows these efforts need to extend beyond just immediate, nearest-neighbor peers. This is valuable, but the establishment and sustainment of broad peer engagement across broader groups of students, ideally across all STEM fields on campus, have been shown to be associated with higher diversity and graduation rates for diverse students

(Fox et al., 2009). Similarly, university-scale organization and advancement of cultural and social capital for underrepresented students through organized undergraduate research programs and purposeful socialization into the academic community of practice beyond just academics or extracurricular activities are also effective and critical (Ovink and Veazey, 2011).

A central factor in all of these efforts is the broad and sustained engagement of faculty. This is clearly a macrosystems component, but building an environment where these interactions persist and reach large communities of students requires institutional action. Broad engagement of faculty and actions taken by institutions to shape and sustain those interactions have been shown to be significant differentiators for institutions that have a particularly successful track record with underrepresented students (Hurtado et al., 2011). Most of these actions are also coupled with institutional, college, departmental, and faculty accountability. Faculty accountability manifests in terms of reward structure and metrics toward tenure, promotion, and merit. Faculty activities can be designed to involve students in research or involve faculty in community-formation events, cross-college or department-wide activities, or in specific curricular, cocurricular, or outreach/recruitment activities. Several institutions also require reporting of faculty activity to advance diversity in performance evaluations, and statements of diversity philosophy included in applications for tenure-track positions (Whittaker and Montgomery, 2014).

These are all examples of institutional and structural actions working to support macrosystems that advance underrepresented students through improvement of the operational environment for students in terms of inclusivity, and the removal of community and institutional barriers and optimization of supports.

Specific Geoscience Education Programs

Research suggests that macrosystem support for underrepresented students in STEM works best if employed in an integrated approach (Tsui, 2007). Numerous examples of geoscience-specific integrated macrosystem support programs exist in the literature. The following discussion is not intended to be a comprehensive listing of successful institutions, but rather a purposeful sample presented to show the synergistic and cross-institutional links and factors that commonly appear in recognized successful programs. As such, the intent is not to provide generalizable findings that can be simply applied in any other context, but rather to highlight those types and classes of macrosystem interactions and supports that tend to lead to greater success, as well as demonstrate systemized approaches that are sustainable over longer time periods. Not all of these will fit for all institutional contexts, but based on preliminary analysis of notable programs familiar to us, and with insights presented here, they can provide useful guidance and policy to departmental and college-level leaders in the geosciences as they seek to broaden participation in and strengthen their own programs.

Pathways to the Geosciences (Pathways)

Carrick et al. (2016) provided a comprehensive discussion of the Pathways program in the Department of Geological Sciences at University of Texas–El Paso. Pathways, first started in June 2002 and lasting 10 y, was designed to enhance awareness of the geosciences among local high school students. The program goals were designed to give participants an introduction to geoscience-related disciplines and career opportunities in the geosciences, and to show them how to prepare for the college application process. Thirty students were selected for one of two 2 week sessions of the program and received a small stipend at the conclusion of the program as an incentive to complete the program. Program activities included field-based and hands-on activities and projects that promoted critical thinking and inquiry-based learning. The program was also designed to provide interactions with faculty members, graduate students, and undergraduate students with diverse backgrounds. On the last day of the program, participates attended a college preparatory activity to raise awareness of four-year and two-year college options and the college application process. Through the lifetime of the Pathways program, 245 high school students, half female and three-quarters Hispanic, were introduced to the geosciences. Longitudinal survey results of 86 participants revealed that 55% were in a STEM major, and 20% had become geoscience majors.

GeoFORCE

GeoFORCE (2014), operated out of the University of Texas–Austin, is similarly designed to increase the number and diversity of students from Texas high schools pursuing STEM degree programs, especially geology and engineering. The program operates in both inner-city Houston and rural southwest Texas, and around 600 high school students participate annually. Participants, beginning in 9th grade and continuing each summer through 12th grade, travel on week-long geologic field trips to gain field experience and knowledge of the energy industry. University faculty, research scientists, and professional geologists provide mentorship to participants, which continues through high school and college. In addition, the program offers Scholastic Aptitude Test (SAT) and Preliminary SAT (PSAT) preparation, help with college and financial aid applications, and scholarships and internship opportunities. In 2014, the program reported more than 1,500 students had participated in the GeoFORCE program, 80% of whom were underrepresented students. The program reported in 2014 that 62% of GeoFORCE program graduates were declared STEM majors.

Significant Opportunities in Atmospheric Research and Science

The University Corporation for Atmospheric Research (UCAR) Significant Opportunities in Atmospheric Research and Science (SOARS) program is dedicated to broadening participation in the geosciences, specifically, atmospheric and related sciences (Windham et al., 2004; Pandya et al., 2007). The SOARS program recruits underrepresented students from a broad range of STEM disciplines for a 10 week summer program incorporating research, mentoring, and community. Participants (called protégés) can spend up to four summers doing research in atmospheric and related sciences at university research laboratories, federal research programs, and federal science laboratories. The program also offers a mentoring program, writing workshop, and leadership training, funding for graduate school, and funding for conference attendance by participants. Participants work 40 hours a week and earn a competitive wage. Since 1996, 185 students have participated in SOARS; 157 having earned undergraduate degrees in science or engineering (UCAR/SOARS, 2016).

Geosciences Exploration Summer Program (GeoX)

Houser et al. (2015) provided a comprehensive description of the effectiveness of the integrated GeoX program housed in the College of Geosciences at Texas A&M University. They described the purpose of this 1 week summer outreach program, which was to (1) increase awareness of the geosciences by high school students from underrepresented group; (2) highlight geoscience career opportunities; (3) expose students to the college campus experience at Texas A&M; (4) facilitate interactions and networking with faculty, staff, students, and companies; and (5) provide information about the college admission process. Specific goals of the program were to introduce students to the rewards of geoscience careers, to allow participants to experience the collegiate and professional experiences of geoscience students, and to create a community of learners in the geosciences. Participants in the program were targeted from diverse high schools in Houston, Dallas, San Antonio, and Austin, Texas, as well as traditional feeder regions for Texas A&M. Program activities for the 1 week program included field and laboratory hands-on learning experiences. Faculty and graduate students discussed with participants the opportunities and strategies for success in transitioning to the rigor of college. Participants were also shown how to navigate the college application and financial aid process and made aware of resources available to support student success. A sense of community and peer networking was fostered, with participants staying in the same dormitory and attending evening social activities. Between 2011 and 2013, 59 students participated in the program, nearly 50% either Hispanic or Black. At the end of the program, 56% identified the geosciences as their primary career goal. Of those students who applied to an undergraduate program at Texas A&M, most identified the geosciences as their preferred major, while the remaining identified other STEM-related degrees.

Areas of Future Study

The synthesis presented here reveals a number of research gaps regarding macrosystem support outcomes within the geosciences. Nearly all geoscience-specific program examples identified during the literature review relied on student self-reported data for assessment, were institution specific, or included study sample sizes of relatively small-scale impact. It is also clear geoscience education research lags behind other science disciplines in research on macrosystem support mechanisms and underrepresented student outcomes. It stands to reason that the geoscience community needs to be more proactive in documenting and disseminating effective programs to the broader research community. This could include deeper assessment of program effectiveness, research on geoscience student outcomes, and the development of models of successful program structure. This ideally would also include longitudinal studies that follow students through their geoscience academic pathway to graduation and postgraduate pursuits. Additionally, the need to ramp up existing institutional models to larger scales exists. This includes understanding the effect of scaling on the effectiveness and focus of programs. For instance, the issue of scale may need to take into account regional variations of demographic populations and geography. This could include not only ethnic/racial and gender demographics, but also include urban and rural student populations, economic issues, and pathway dependencies such as 2YC transfer, nontraditional/adult learner students, and veterans.

Several specific macrosystem support areas are noticeably weak in the geoscience literature. The first is the limited presence of research on the effectiveness of peer- and cohort-support networks. Although many existing programs implicitly incorporate elements of peer support into overarching program activities, and elements of community building are a component in many of the programs identified in this review, few have reported outcomes focused specifically on the impacts of peer-support networks. Moving forward, researchers need to be more explicit in documenting the effectiveness of peer-support and community-building structures on underrepresented student outcomes.

Similarly, reporting of the use of CUREs within geoscience courses is under documented. Certainly, the use of CUREs in geoscience curriculum is emerging, and only more recently have CUREs begun to occur with greater frequency (Kortz and van der Hoeven Kraft, 2016). As the numbers of CURE opportunities increase for students, it would be meaningful for future studies to reexamine the effect of CUREs on recruitment and retention in geoscience majors, particularly for underrepresented populations. This includes incorporating design models of Corwin et al. (2015) for the CURE community and instruments that are ready to use in CURE assessment.

Future research should also examine the relationship of student engagement outside the classroom, including cocurricular and nonacademic engagement, on underrepresented student recruitment and pursuit of geoscience degrees. This includes the influence, if any, of nonacademic factors common to underrepresented and minority students, such as part-time versus full-time enrollment, working while attending school, and outside family commitments and responsibilities.

CONCLUDING OBSERVATIONS: WHAT CAN GEOSCIENTISTS DO?

This summary of macrosystems is meant to introduce geosciences faculty, staff, and administrators to the array of systems that serve to recruit and retain underrepresented groups. The challenge, however, for our community remains in extending lessons from other fields to the geosciences and effectively engaging these broader systems to benefit our own students. In our summary tables and synthesis, we have attempted to highlight programs that are already doing a number of things well and that provide useful examples. However, geoscience departments are typically small and, with notable exceptions, are usually embedded in much larger colleges, and they are not always in colleges that have an exclusive STEM focus. In this setting, what can individual faculty, administrators, or even entire departments do to enhance macrosystem support for underrepresented students?

The review we present here provides many concrete suggestions, but the first necessary step for any person wishing to act on these larger systems is to understand their local situation well. What are the institutional supports and barriers? What programs already exist? What else is going on in the academic and nonacademic lives of their students? Faculty and department heads/chairs can take many steps to institutionalize student support networks across entire departments and to reward faculty for effort in making these networks thrive. Students can be supported to build and sustain these networks, especially if departments have a mix of graduate and undergraduate students. Department heads/chairs can work with their colleagues in allied STEM departments in common cause to mutually support each other's students. Many of the highlighted programs in this synthesis are quite resource intensive, either in terms of faculty time, finances, or both. It is not coincidental that many of these programs rely on sustained industry and philanthropic support. However, not all programs need be expensive to be sustained or effective, and many macrosystems in universities can be effectively engaged without being costly. Part of understanding where to act to engage these systems is first understanding the local availability of human and financial resources.

Deans, vice presidents, and associate provosts can encourage this kind of interaction and also advance a culture of measurement (qualitative and quantitative), accountability, and reward, and importantly allow time for results to appear. Fully developed, supportive macrosystems do not spring into existence overnight, and individual faculty and academic units must be rewarded for efforts that fail to produce insights just as much as those that are a runaway success. The literature as well as the lived professional experience of the authors, both working in roles responsible for these activities at our respective institutions, show that annual reporting and low stakes but strongly symbolic reward and recognition, coupled with institution-wide support, do generate results over time.

Individual geoscientists and individual departments/programs can do a lot, and the key is to work with the support structures offered by the institution, adapted to suit our needs as a scientific community. We must do this for the good of our students and the communities they represent and will serve, as well as for the future vitality of our discipline. All STEM fields are in this together and have similar goals. A macrosystems awareness and approach can help geoscientists be positive change agents and innovators moving forward.

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