Nurturing Diversity in STEM Fields through Geography: the Past, the Present, and the Future

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Abstract

To date, there has been a wealth of research on participation in science, technology, engineering, and mathematics (STEM) fields, but most research focuses on the implementation of programs and whether these programs work. Such research can be expanded and enhanced by considering geographic perspectives on participation in the STEM fields and by examining the factors that prevent participation in these fields. In this paper, we seek to examine geographic perspectives to broadening participation in the STEM fields in two ways. We first conduct a literature review on the geographical understanding of barriers and facilitators of higher education that encompasses underrepresented populations in STEM fields. Second, we present a case study that catalyzes geography and seeks to broaden participation in the STEM fields. Both the literature review and case study show the significance and the role played by place-based factors and approaches, spatial thinking and inquiry-based learning, and environmental education and civic engagement work in helping advance the science of broadening participation in STEM fields.

Key words: place-based factors; inquiry-based pedagogy; service learning; spatial behavior; geography; STEM Fields; broadening participation

Introduction

In Pursuit of a Diverse and Expanded STEM Workforce

The demand for individuals with an educational background in science, technology, engineering, and mathematics (STEM) fields has been rapidly growing in the career market (Rogers and Molina, 2006; Peckham, et al., 2007; Moss-Rascusin, Dovidio, Brescoll, Graham, and Handelsman 2012). For instance, according to the US Bureau of Labor Statistics the projected employment growth from 2010 to 2020 of geoscientists is 21 percent, environmental engineers is 22 percent, and computer systems analysts is 22 percent (U.S. Department of Labor, 2012). Yet, only about 300,000 students graduate with a bachelor or associate degree in a STEM field annually (President's Council of Advisors on Science and Technology, 2012). According to the U.S. Department of Labor (2012) the demand in the labor market for STEM careers is growing at a rate twice that for all occupations. They projected the growth rate for all occupations in the U.S. at only 11%. Most studies have also indicated that heterogeneity in the workforce is of growing importance due to the economic benefits it can provide (Rogers and Molina, 2006; Peckham, et al., 2007). Increasing diversity within work groups is said to promote creativity and effectiveness when solving problems and ultimately generating pertinent solutions for society as a whole since different perspectives are presented during development (Rogers and Molina, 2006; Peckham, et al., 2007). To increase workforce heterogeneity it is also beneficial to increase educational participation in STEM fields using effective strategies to not only recruit underrepresented groups but retain them as well (Rogers and Molina, 2006; Peckham, et al., 2007; Estaville, Akiwumi, and Montalvo, 2008; Moss-Rascusin et al., 2012).

Unfortunately, there has not been an increase in the production of STEM degrees to match this growing demand (Strayhorn, 2009a). In fact, the President's Council of Advisors on Science and Technology Report (2012) suggests a deficit of 1,000,000 workers over the next decade in the US workforce. Also, of the individuals who do obtain STEM degrees and careers within their educational field, women and minorities are highly underrepresented in these disciplines (Tsui, 2007; Estaville, Akiwumi, and Montalvo, 2008; Hoffman, Gneezy, and List 2009). According to Villarejo, Barlow, Kogan, Veazey, and Sweeney, (2008) women and minorities only represented 4.2 percent of the doctoral-level biomedical workforce in 2007. Hoffman, Gneezy, and List (2011) argue that women make up only 8.3 percent of math professors, 12.1 percent of chemistry professors, 6.6 percent of physics professors, and 6.7 percent of mechanical engineering professors. They further observe that women make up only 19 percent of the science, engineering, and technology workforce. Additionally, according to Strayhorn (2009b) African American men make up only 4 percent of all undergraduate students, and 3 percent of all graduate students in STEM. This problem is further compounded by a poor conceptualization of STEM fields. The "Science" in STEM has narrowly included only the physical and environmental sciences such as chemistry, geology, and physics. However, science is an interdisciplinary field that can include subjects that combine social science and geography. Geography as a discipline enjoys the advantage of providing interdisciplinary discourse because it offers both human and physical geographic perspectives. Moreover, it can be used as an alternative vehicle for catalyzing STEM fields. More specifically, the interdisciplinary foundation of geography can be used to help draw students from underrepresented communities into STEM fields.

Over the past thirty years, many reports have been published on geographic perspectives to broaden participation in fields such as geography and STEM through inquiry-based pedagogical approaches (Dick and Van De Walt 1996; Golledge and Stimson 1997; Laurian 2004; Smith, Edwards, and Raschke, 2006; The Darden AAG Task 2006 Task Force; Spronken-Smith, Bullard, Ray, Roberts, and Keiffer 2008; Harris and Tweed, 2010; Kinniburgh, 2010; Zhao, et al., 2010; Favier and Schee, 2011; Scanlon, et al., 2011; Levy and Petrulis 2012; Adams, Solis, and McKendry 2014). Based on these publications there is a general agreement on what works to attract and retain underrepresented individuals. Three geographic perspectives, prevalent throughout the literature, offer promise for enhancing participation in the discipline: (1) place-based factors, (2) environmental education and civic engagement, and (3) spatial behavior and inquiry-based learning. Earlier research suggests that there is a strong correlation between student success and factors such as pre-college preparation, recruitment programs, financial assistance, individual perception of the program, and intervention programs (May and Chubin, 2003; Tsui, 2007; Peckham, et al., 2007; Villarejo, et al., 2008; Machina and Gokhale, 2010; Gates, 2010; Moss-Rascusin et al., 2012). Frequently overlooked is the fact that targeted interventions can be quite effective in reducing race/ethnic disparities and gender gaps in STEM fields.

In two of the most authoritative sources on science and mathematics education, Laws (1999) noted the existence of more than 500 reports on this subject alone since 1983, while Tsui (2007) presented strong research evidence for ten of the most effective strategies adopted by programmatic efforts to increase diversity in STEM fields. Indeed, the state of scientific knowledge on this topic together with specific geographic perspectives could help in catalyzing the participation of underrepresented groups in STEM fields. The existing knowledge has a great potential to guide various program developments that will promote diversity, retention, and outreach to underrepresented individuals.

In this paper, we seek to examine geographic perspectives to broadening participation in the STEM fields in two ways. We first conduct a literature review on the geographical understanding of barriers and facilitators at individual, rural vs. urban settings, community, regional or national level of higher education that encompasses underrepresented populations in STEM fields. Second, we present a case study that catalyzes geography and seeks to broaden participation in the STEM fields. This paper makes the following contributions:

- a literature review on the geographic perspectives on STEM fields, which may guide research and policy development, especially among underrepresented populations;
- highlights the principal role and distinct lenses of spatial-based perspectives to broadening participation in the STEM fields;
- preliminary empirical evidence showing STEM as a preferred program for spatial-based outlooks to broadening participation in the STEM fields.

A Review of Geographic Perspectives on STEM Fields

Three core concepts that inspire geographic perspectives on STEM fields include (1) place-based factors, (2) spatial behavior and inquiry-based learning, and (3) environmental education and civic engagement. Although best practices in increasing diversity are well-documented, the goal of this review is to understand the state of geographic knowledge that will enable new creative paths. In reviewing these geographic perspectives, we seek to advance and clarify the critical role they play in the science of broadening participation.

Place-Based Factors and Approaches

Four major themes appear to contribute to the challenges of underrepresented individuals. The first is economic factors or the background characteristics of the student such as race, gender, socioeconomic status, high school performance, pipeline and catchments, and occupational objectives (Villarejo, et al., 2008; Strayhorn, 2009a). Second is the individual student's experience during college, such as their interaction and dependence on family, and their peers and faculty to provide encouragement and support (Villarejo, et al., 2008; Strayhorn, 2009a; Moss-Rascusin et al., 2012). Third is the students' participation in supplementary educational or advisory activities (Villarejo, et al., 2008). Lastly, is the geographic location of the university or individual and their interaction with that environment. These are known as place-based factors (Villarejo, et al., 2008; Semken and Butler Freeman 2008; Gibbons and Vignoles, 2012).

To attract and retain prospective students, institutions operate at different scales (i.e., individual, community, neighborhood, regional, national, and global) to resolve challenges and create facilitators for higher education. Such factors include exposure, accessibility, resources (physical and online), cultural, social, and economic support infrastructures, as well as courage and belief in one's self. However, as earlier mentioned, despite previous research on whether or not intervention programs for STEM fields are successful in general, few studies examine the academic experiences of the underrepresented population (i.e., racial/ethnic minorities, women, persons with disabilities, non-traditional students, and the economically disadvantaged) who are likely to face different social challenges in higher education than those of their white male peers.

An individual's life path is the decisions one makes on a daily basis and their physical and emotional association with people or places that influence those decisions. For instance, students whose parents are in a STEM career are more likely to obtain a STEM degree or if an individual's home is relatively close to a university that offers science related degrees such as Massachusetts Institute of Technology (MIT) (Tsui, 2007; Strayhorn, 2009b), that individual is more likely to attend that university. The advice or guidance from family, friends, and the community can create a sense of place – emotional meanings and attachments – which could ultimately persuade the individual's decision to attend a university closer to home rather than going farther away even if that means giving up a better education (Semken and Butler Freeman, 2008; Strayhorn, 2009a; Strayhorn, 2009b). For example, Strayhorn (2009b) discovered that nearly half of African American men considered advice from the community when choosing a university to attend; where 9 percent considered advice from parents, 4 percent considered advice from siblings, and 39 percent considered advice from other graduate students.

Another factor that is considered when choosing a university or degree among underrepresented minorities is the geographic location (Massey et al. 1991; Ellen and Turner 1997) in which the individual lives (i.e., the neighborhood can be located in an urban, suburban, or rural area). It has been noted that a person living in an urban community (Fadigan and Hammrich 2004; Basu and Barton 2007) is more likely to come into contact with STEM on a daily basis since they might have a parent that is in a STEM field, or there are several universities in the area that offer STEM degrees, whereas a person living in a rural community is less likely to come into contact with STEM on a daily basis since their parents are more likely in the agriculture workforce, or the closest university may be several miles away from home. More specifically, individuals whose parents work in agriculture are more likely to remain in agriculture rather than seek a degree in a STEM field.

The physical location of the university is another factor that is highly considered among underrepresented minorities when deciding on a university and career field. The decision on the location of a university may result from multiple universities within one area (more to choose from) or based on geographic location relative to their home and family. Research has also indicated that investment and consumption motives can be deciding factors such as financial assistance to attend a particular university, higher future wages or employability, or better local amenities (Sá, Florax and Rietveld, 2004). Nonetheless, when considering a university to attend, regardless of the quality of the university or majors offered, proximity to home is most frequently considered by underrepresented minorities (Sá, Florax and Rietveld, 2004; Strayhorn, 2009b; Gibbons and Vignoles, 2012). According to Gibbons and Vignoles (2012, p. 98), the "geographical distance between parental home and college poses a potential barrier to higher education entry, and could be a deciding factor when choosing between institutions." Furthermore, influences such as religious, cultural, or financial reasons can generate pressure to stay close to home (Gibbons and Vignoles, 2012).

One facilitator to counteract these challenges is place-based pedagogy in the sciences to improve the attraction and retention of underrepresented students to science fields. Such place-based pedagogies may be particularly attractive to underrepresented students who are "members of indigenous or historically inhabited communities (e.g., American Indian, Alaska Native, Native Hawaiian, Mexican American) who possess rich culturally rooted senses of the places studied" (Semken and Butler Freeman, 2008). Place-based science education immerses students in the topic due to the course's field-based teaching approach – i.e., hands-on experience outdoors rather than in a classroom. Furthermore, Semken and Butler Freeman (2008) state that it is not only experiential but also transdisciplinary (i.e., research that bridges between two or more disciplines).

Spatial Thinking, Spatial Behavior, and Inquiry-Based Learning

Spatial thinking, spatial behavior, and inquiry-based learning approaches are currently utilized in developing skills required to advance STEM fields. How individuals perceive and negotiate the areas in which they play, work, and live is instilled in them from childhood. To geographers this comportment is known as spatial thinking and behavior which fuels involvement in STEM fields (Golledge and Stimson, 1997). For instance, many children play with Legos as they grow up. Cognitive learning skills increase as the child develops different ways in which they can build objects and fill space with the Legos. Essentially they are learning and acting out which decisions to make about their natural and artificial environment and what they can contribute to it (Golledge and Stimson, 1997). Later in life this child may grow to be an engineer, which will require STEM education.

Spatial thinking, according to Wakanayashia and Ishikawa (2011), is a thinking process that is highly interdisciplinary and spans across various STEM subjects; however, there is yet to be a consensus definition of the term. Spatial thinking is often associated with the psychological theory of Spatial Intelligence developed by Howard Gardner (1985) as one of the nine theories of multiple intelligences. Spatial Intelligence is normally measured through various standardized aptitude tests, such as the military's ASVAB or IQ tests, using image manipulation, spatial reasoning, online gaming tests, or mental imagery. According to Gardner, Spatial Intelligence is an individual's capacity to accurately perceive the world both visually and spatially (i.e., thinking in two and three dimensions). Therefore, an individual who has the ability to think spatially exhibits the research abilities of spatial reasoning, spatial concepts, and spatial representation (Kinniburgh, 2010; Hoffman, Gneezy, and List, 2011; Wakanayashia and Ishikawa, 2011). According to the National Research Council (NRC) (2006; see also Kinniburgh, 2010; pp. 78–79), there are three elements to spatial thinking:

> (i) Concepts of space, for example, the relationships between units of measurement, proximity between features, etc.; (ii) tools of representation, for example, maps, multidimensional scaling models; and (iii) processes of reasoning, for example, estimating the slope of a hill from a contour map, deciding to take an alternative detour during heavy traffic. (p. 78-79)

Spatial behavior, according to Downs and Stea (2011), is a human's behavior dependent upon their individual cognition of their spatial environment. Recent examples in spatial behavior are based on understanding consumer choices, social media networks, individual mobility, way finding, real estate markets, video games, and online entertainment systems. It is therefore prudent to assess their influence in relation to educational success, performance, and retention in STEM fields. Do these examples play a critical role among children's social space and networks? If so, in what ways do they catalyze technologically-savvy children towards STEM fields? Is there sufficient empirical evidence that suggests that they promote science education among underrepresented populations? Knowing this information will help in further strengthening spatial intelligence in children. Thus, designing children's activities that involve, for example, playing with toys of different shapes and colors, creating or seeing models of how things work etc., will improve their understanding and imagination in science subjects.

Inquiry-based learning (IBL) aims to increase an individual's intellectual engagement, deepen their understanding, and enhance the research and knowledge base. This can be accomplished in the STEM fields using a hands-on and minds-on approach and actively engaging students in STEM discipline research. More specifically, IBL targets the individuals' inquiry skills and self-regulated learning. This aids students in developing their own knowledge set by performing self-guided STEM research rather than acquiring the solutions from their professors (Smith, Edwards and Raschke, 2006; Spronken-Smith, et al., 2008; Harris and Tweed, 2010; Kinniburgh, 2010; Zhao, et al., 2010; Favier and Schee, 2011; Hawthorne, 2011; Kim, 2011; Scanlon, et al., 2011; Levy and Petrulis, 2012). For instance, in their study on inquiry-based geography education with geographic information systems, Favier and Schee (2011) state that:

> The world around us is characterized by the presence of natural and human phenomena in space and time, and by the relationships between these phenomena. Engaging in geographic inquiry may stimulate progression in one's knowledge, skills, and motivation, but knowledge, skills, and motivation are also a precondition for engaging in geographic inquiry. (p.666)

In another study by Kinniburgh (2010; pp.76), the inquiry-based method of learning is reviewed through the use of GIS in the classroom. He states,

> No other techniques, however, have been as influential to the development of spatial analysis in geography as GIS. When applied effectively, this technology has the potential to facilitate research-based investigations integrating the major traditions of geography, including the spatial and temporal distribution of phenomena, processes and features, as well as the interaction of humans and their environment. (Kinniburgh, 2010, p. 76)

Through the spatial behavior and inquiry-based learning perspectives, we can spatially analyze individual or neighborhood behavior and activities in terms of how individuals make choices and decisions. Or how groups or neighborhoods make choices and decisions, which typically will have a strong bearing on whether this individual or group will pursue a STEM field. Spatial science can also play a key role in terms of providing the tools, models, and methods to map and analyze individual or group choices. The knowledge gained from spatial sciences can help us to better understand whether residence proximity to STEM-based institutions or activities influence individual or group choices; why some neighborhoods or schools that are located in close proximity to STEM-based institutions or activities excel in STEM fields; and most importantly, whether individuals or groups are drawn into STEM due to their past experiences and interactions.

Environmental Education and Civic Engagement Work

Environmental education and civic engagement is a way of learning STEM through real-world problems and experiences; this can also be considered "Informal Science Education" (Friedman and Mappen, 2011). Informal Science Education (ISE), according to Friedman and Mappen (2011), "provides opportunities for people to become fascinated with something they experience, and to then find themselves learning and becoming even more interested in whatever it was that caught their imagination." According to the Center for Advancement of Informal Science Education (CAISE) "informal science education supports people of all ages and all walks of life in exploring science, technology, engineering and mathematics" (CAISE, 2009; Friedman and Mappen, 2011).

In her research on "environmental education: a geographical perspective," McKeown-Ice (1994) states:

> Geography is an ideal disciplinary vehicle for environmental education; however, non-geographers are rarely aware of the vast geographic interest, research, and literature related to the environment. Geographers study the environment in four major ways: 1) the natural environment using scientific methods and techniques; 2) the impact of human behavior on the environment; 3) environmental influences on human behavior; and 4) the different cultural perceptions of the environment and how these perceptions are expressed in the surrounding landscape. (p.40)

The importance of environmental education and civic engagement, or ISE, in the decision process of an individual's STEM field education not only influences geographers but non-geographers as well. This is due to their daily interactions with various STEM factors such as zoos, museums, recycling, farms, environmental hazards, water, weather, food, and public health (McKeown-Ice, 1994). The goals of science learning in informal environments is discussed by Bell, Lewenstein, Shouse, and Feder (2009) in their 2009 NRC report "Learning Science in Informal Environments: People, Places, and Pursuits." According to Bell et al. (2009)

> Learning science in informal environments is a diverse enterprise and serves a broad range of intended outcomes. These include inspiring emotional reaction, reframing ideas, introducing new concepts, communicating the social and personal value of science, promoting deep experiences of natural phenomena, and showcasing cutting-edge scientific developments. (p.41)

Early exposure to science and technology concepts may influence the choices children make later on in their lives. For instance, when an individual encounters an environmental hazard that devastates their community they may become inquisitive as to why certain types of natural disasters happen in one area but not in others. When a child goes to the zoo with his or her parents, this may trigger their potential interests and they may want to learn what kind of environment the animals naturally grow and live in. Or, while in high school the individual goes camping with their friends, falls in love with the forest and wants to know all there is about the different types of plants and trees that grow. All of these scenarios allow for environmental education, service learning, and civic engagement. The knowledge and insights gained from earlier childhood experiences may assist individuals later on in their lives if they happen to pursue a degree in STEM fields such as geography, zoology, or environmental/natural resources and policy.

Documented Strategies to Increase Participation in STEM Fields

Within the past thirty years, there has been a growing collection of research on how to increase participation in STEM fields (Anderson, 1990; Culotta, 1992; Laws, 1999; Benbow and Arjmand, 2003; The Darden AAG Task 2006 Task Force; Tsui, 2007; Moss-Rascusin et al., 2012; Adams et al. 2014). According to Tsui (2007) there are ten major intervention strategies commonly adopted to increase diversity in programs to date. However, based on current literature the most effective programs are peer-to-peer knowledge transfer, bridge programs, or classes like National Aeronautics and Space Administration's (NASA) "Workshop without Walls" to broaden access to all people no matter where they are located (Semken and Butler Freeman, 2008; Doerschuk, Liu, and Mann, 2008; Doerschuk, Liu, and Mann, 2009; Doerschuk, Liu, and Mann, 2010; Arslan, et al., 2011; Newton and Apple, 2011). Many STEM universities and businesses are beginning to expand access and communication abilities for their classes and workshops to everyone, regardless of travel capabilities. According to Arslan, et al. (2011), to increase access is to allow participation from various technological devices (i.e., phone, videoconference system, home computer/laptop, tablet, cellular phone) and location (i.e., local school room, home, office, even the park). One such example includes two "Workshops Without Walls' hosted in 2010 by the NASA Astrobiology Institute (NAI). The virtual scientific workshops allowed the exchange of information on the latest developments between scientists worldwide without the requirement of traveling (Arslan, et al., 2011).

Peer-to-peer knowledge transfer is another way in which to increase participation in STEM fields. It is a practice that involves engaging teams of students (both undergraduate and graduate) on how to conduct research in a STEM field and serve as peer teachers and mentors (Doerschuk, Liu, and Mann, 2008; Doerschuk, Liu, and Mann, 2009; Doerschuk, Liu, and Mann, 2010; Newton and Apple, 2011). This strategy not only helps attract and retain other underrepresented students but it also allows the mentors to gain teaching experience while new students learn research techniques in a relaxed and personal setting (Doerschuk, Liu, and Mann, 2008; Doerschuk, Liu, and Mann, 2009; Doerschuk, Liu, and Mann, 2010; Newton and Apple, 2011). Building effective peer mentoring programs and a relevant support infrastructure to enable broad participation in STEM fields not only increases diversity, but also cultivates positive mentoring relationships. A strong support infrastructure should be able to address the major concern raised in the 2012 President's Council of Advisors on Science and Technology report. This report alludes to the fact that most members of underrepresented groups in STEM fields cite an unwelcoming atmosphere from faculty in STEM courses as a reason for their departure (President's Council of Advisors on Science and Technology, 2012).

In the past, strong mentoring programs have been developed by several universities in the Puget Sound region, such as the National Science Foundation's Science and Technology Center for Coastal Margin Observation and Prediction, the University of Washington College of the Environment, the Northwest Indian College to enable Native American tribes in the Pacific Northwest to participate in ocean studies, especially given the fact that they have strong cultural ties to the sea for thousands of years, a pertinent factor for sustainability (Newton and Apple, 2011). Where, according to Newton and Apple (2011, p. 2), Native American students make up only 1% of the student population, and nation-wide only 10 out of 960 ocean sciences graduate students were Native American. In an effort to increase enrollment of Native Americans in ocean sciences these universities have begun to implement peer-to-peer knowledge transfer and claim that it is successful because

> Native American students and their communities are attracted to this work because the data are ecosystem inclusive (water to whales), the content is place-based (near the Northwest Indian College and traditional tribal lands/waters), and the learning environment focuses on an experiential, student-led, inquiry-based approach – all of which resonate with the Native culture.

Finally, bridge programs are another way to increase participation in STEM fields. Currently there are two forms of bridge programs, a STEM bridge from high schools and community colleges into universities, and a STEM bridge that is interdepartmental within the university. Reaching out to high schools and community colleges has been widely practiced throughout universities over the past 30 years in an effort to increase enrollment in STEM courses. However, a consensus has emerged among universities that worry that there will be an unsuccessful transfer and/or completion of a four-year STEM degree. This issue could be caused by several factors, such as students not understanding the potential value of a STEM degree, or an inconsistent or limited education in science and math. (Lenaburg, et al. 2012). Because of this and a declining interest among incoming college students in STEM fields many departments are attempting to broaden participation by reaching out to other departments on their campuses (Barr, Liew, and Salter; 2010). For instance, Barr, Liew, and Salter (2010) suggested that one tactic for computer science departments is to "encourage interdisciplinary work that has computing as a significant component."

Although a recent report suggests that the gender gap in STEM fields is smaller than in the past (National Science Board, 2012), there is still a strong need to cultivate new paths for women and other underrepresented groups in STEM fields. Collectively, the effective peer-to-peer knowledge transfer and bridge programs along with the three geographical perspectives (place-based factors, spatial behavior, and environmental education and civic engagement work) can create new paths for women and minorities into STEM fields. From this review of past literature, we can empathetically suggest that geographic perspectives offer creative ideas through which we can effectively reach and attract traditionally underrepresented populations into STEM fields. Moreover, specific topics in community geography, spatial science, fieldwork, etc. can help advance experiential learning in ways that offer relevant experiences and enhance interest in a STEM career.

Geographic Case Study to Broaden Participation in STEM

The second part of this research considers a case study that provides some empirical evidence of geographic perspectives to broadening participation of underrepresented groups through inquiry-based pedagogical approaches. This case study was a pre-college inquiry-based summer program conducted at a large Southwestern University in the summer of 2011 and holds potential to contribute to the science of broadening participation. Our expectation in presenting the results of this qualitative study is not only to motivate the science of broadening participation discussion, but also to call on other researchers to generate additional empirical data. In beginning this discussion, the principal aim of our case study was to restructure the participants' relative understanding of various STEM fields, help recruit participants into STEM studies, and provide awareness of the value of spatial information and technology. Furthermore, the case study was initiated with assessment tools that consisted of content knowledge surveys and oral interviews.

Case Study | Summer Science Exploration Program

Assessment Tools

A content knowledge pre-survey assessment for the Southwestern University was designed to help identify students' past perceptions and experiences regarding STEM fields, their knowledge of different study areas within STEM fields, and if they were planning on pursuing a STEM degree in college. The program was organized by the College of Geosciences in the spring of 2011 and the surveys were conducted during the subsequent Summer Science Exploration Program. Students were also asked to answer ten questions to the best of their knowledge to determine their level of comprehension for one concept of STEM program variety. The first five questions were used to establish the students' pre-program awareness of the diversity of study areas within five different STEM fields. These fields included atmospheric science, geography, geology and geophysics, oceanography, and environmental geoscience. The last five questions addressed the students' pre-program awareness of the diversity of career areas within the aforementioned STEM fields.

Similarly, the post-survey served as a follow up on participants' experiences after attending the summer program. The post-survey reflects discussed topics, including assessing whether the new knowledge gained about STEM fields gave them a better career perspective, and gauged whether they would enroll in a STEM field. Additionally, students were asked to answer 12 questions to the best of their knowledge to determine their level of comprehension for the STEM programs. The first five questions were used to establish the students' post-program awareness of the diversity of study areas within five different STEM fields. These fields included atmospheric science, geography, geology and geophysics, oceanography, and environmental geoscience. The next five questions addressed the students' post-program awareness of the diversity of career areas within the same aforementioned STEM fields. The last two questions addressed what the students found most interesting about the program and gave them an opportunity to share their experiences about the summer program. Both survey responses were compiled, analyzed, and compared to determine if there were any changes in participants' constructs. The results returned a 100% response rate, which was likely due to the fact that students were still on campus when the surveys were administered.

Demographic Characteristics of Participants

Twenty pre-college (high-school) participants attended the Southwestern University's Summer Science Exploration Program. All of the participants were either sophomores or juniors between the ages of 16 and 17 and maintained an average high school class rank of 6.47%. Additionally, the demographic characteristics for this study were richly diverse in females (i.e., 13) and ethnic minority groups mainly African Americans and Hispanics (i.e., 10); who are typically widely underrepresented in STEM fields. In our sample, all the students participating in the summer program had taken Algebra I and II, and geometry. Only six of them had taken trigonometry, while 11 had taken a pre-calculus course. None of the participants had taken a calculus course before.

The students who attended this workshop came from various places, with the majority from urban areas. A proximity analysis between the university and participants' place of residence showed that 95% (19 participants) lived within a distance ranging from 68 km to 456 km from the university. Only one participant came from California, which was about 2,585 km from the university. Fifty percent of the participants lived within 176 km from the university. The average distance for 95% of the participants was 218 km ± 130 km (standard deviation). Sixty percent of the participants' lived within a city or where 20 km away from the city, 25% of them were from a small town, and only 15% of them came from the rural area. Demographically, there were about 9.7 million people living in the places from which the participants were drawn, and 51% of these were of the female gender. The race/ethnicity makeup of the study area comprised 54.3% White, 30.8% Hispanics, 12.9% Black or African-American and 2% other. The demographic data suggests a richly, ethnically-diverse community in gender, class, socioeconomic status, age, economic activities, and minority populations. However, some counties tend to attract specific racial/ethnic groups as shown by the presence of mild and extreme outliers (symbolized by a dot and asterisk, respectively) in Figure 1.

Pre-Survey Results

Generally, all the participants who attended the summer program had some prior experience in STEM-related fields. When asked about their previous science course work experience, 100% of them had at least taken one course in biology, chemistry, or physics. However, 85% of them had not taken any courses in geosciences. Also, all the participants had taken math courses in Algebra (I and II) and geometry, while only 55% had taken pre-calculus and 3% trigonometry. Furthermore, all participants strongly agreed that they had a genuine interest in science and intended to pursue a STEM degree.

In other responses, when the participants were asked to write down, "What can they study in the following programs?" (1) atmospheric science, (2) geography, (3) geology and geophysics, (4) oceanography, and (5) environmental geosciences; their responses were varied and showed different levels of knowledge. Overall, the participants had a basic understanding of each program and were able to relate weather to atmospheric science and ocean currents to oceanography. Besides, many of these participants knew more in-depth studies within each field. For instance, one participant

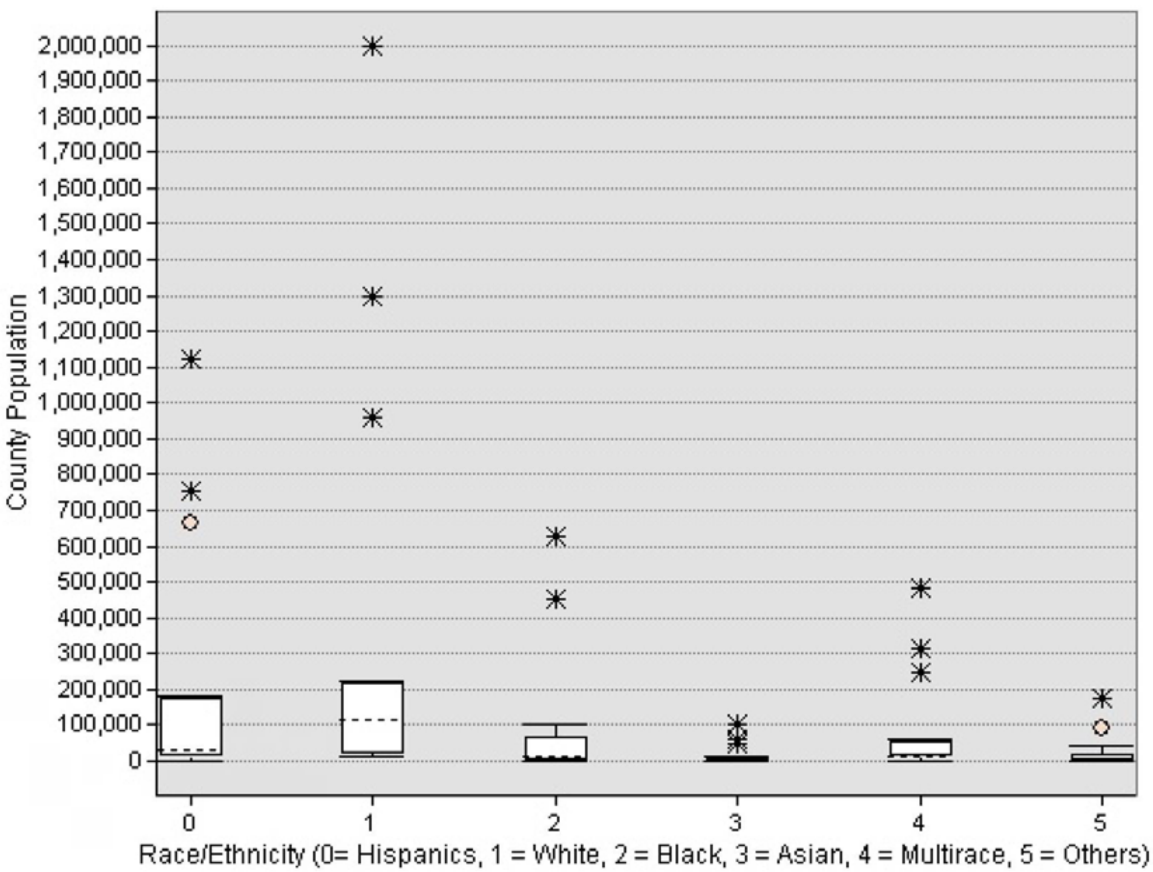

FIGURE 1. Provides the distribution of different race/ethnic groups where the participants' were drawn from (Compiled using US Census Data). Mild and extreme outliers are symbolized by a dot and asterisk, respectively.

noted this about the study of geology and geophysics, "Argon-potassium dating specialists for paleoanthropology, rocks, types of rocks" while another participant explained that geography involved the study of "human geography, study of culture, landscape, and how it affected people groups, mapping."

Additionally, referring to the same five aforementioned fields, the participants were asked, "What kind of job can you get with a degree from the following programs?" Generally, the most common job in each field was referenced; for instance, a weather forecaster with a degree in atmospheric sciences, a cartographer with a degree in geography, and a job in the oil industry with a degree in geology and geophysics. For the programs of geography, oceanography, and environmental geosciences, most of the participants offered a wide range of occupations suggesting they were unsure of specific response.

Post-Survey Results

The responses from the post-survey assessment indicated that knowledge of different study areas within various STEM fields increased in all the participants and there was increased interest in pursuing a STEM degree. For instance, one of the participants reported this: "I came to this camp not knowing anything about Geosciences and what it had to offer. After attending … [the Summer Science Exploration Program], I have changed by mind about my dream major and am in the process of deciding to switch from pre-vet to environmental science."

One student discovered that they could even apply geoscience to various fields:

> I learned that there are many job opportunities for geosciences and that there's something out there for every interest. I like a little bit of everything, so I will most likely major in environmental geosciences. I also learned that I could still become a pediatrician and improve the earth and discover helpful things.

Another participant mentioned how she was able to connect program learning to real-world, community problem solving:

> In the field of geoscience, there are many opportunities to help in communities. These can include anything from helping someone building a house to have a solid foundation (geology) to informing people of the hazards of an impending hurricane (meteorology). I hope to benefit the communities that I visit throughout my career as much as possible.

The students were asked, "What were the most interesting demonstrations during the training?" Although there was a varied interest in all of the fields that were showcased, there was a considerable interest among 55% of the participants who took core samples at the Integrated Ocean Drilling Program. This was followed by 50% of participants showing interest in fieldwork at Wolf Pen Creek. Ranking last was the visit to British Petroleum, where 45% of the participants showed considerable interest.

The participants were again asked, "What can you study in the following programs?" The available areas of study in the programs were (1) atmospheric science, (2) geography, (3) geology and geophysics, (4) oceanography, and (5) environmental geoscience. Overall, many of the participants showed a deeper appreciation of each field than before. For instance, one of the participants listed these fields of study in geology and geophysics, "Petroleum geology, oceanographic geology, seismology, Earth structures, stratigraphic plate tectonics, environmental geology". While another participant explained that atmospheric science was concerned with the study of "weather, meteorology, radar, clouds, thunderstorms, hurricanes, cold fronts, tornadoes, and movements of other storms."

Finally, referring to the same five aforementioned fields, the participants were again asked, "What kind of job can you get with a degree from the following programs?" Generally, rather than the most common job in each field, the participants were able to provide a more particular title for the field than before; for instance, a meteorologist with a degree in atmospheric sciences, a surveyor with a degree in geography, and a job in the oil industry with a degree in geology and geophysics. Importantly, participants also learned about the breadth of geosciences as noted by one participant:

> … [The Summer Science Exploration Program] helped me discover the different types of geosciences. I used to think that looking at rocks was the only type of geoscience. Going to … [the Summer Science Exploration Program] introduced me to meteorology, hydrology, oceanography, and other fields in geosciences. I also further realized my desire to major in geology. In addition, the friendly professors and environment that I was exposed to motivated me to attend … [this university].

In summary, the pre- and post-survey assessment data can provide a basis for the understanding of the science of broadening participation. Though this anecdotal evidence, we notice an increase among the high school student participation, especially those of ethnic minority backgrounds, who developed a stronger interest after the summer program in geosciences. Furthermore, the summer training program achieved its planned learning outcomes and was also effective in getting participants to take a critical look at geosciences as a viable alternative field in STEM. Additionally, as demonstrated above, these results indicate that the implementation of service learning/inquiry-based programs are effective recruitment tools that bring participants into STEM studies, and that geographers can play an important role in the science of broadening participation in STEM disciplines.

Conclusion and Future Work

This research finds that having communities of underrepresented STEM students near universities involved in (and excited about) university research and education programs provides a variety of benefits. First, a community's knowledge base and skillsets can be enhanced by collaborative research with university faculty and students. Second, university faculty and students can reveal local knowledge that can better inform community-based research agendas and lead to stronger analyses and conclusions. Third, by including underrepresented groups near a university in research and education outreach plans through community geography and citizen science, and it also increases the enthusiasm of these groups to enter into educational STEM fields and careers. Fourth, participation in programs similar to the Summer Science Exploration Program case study mentioned in this article can restructure participants' relative understanding of STEM and lead to a higher likelihood of participation in STEM fields. Finally, geography-focused programs can provide awareness of the value of spatial information and technology that can help potential STEM students from underrepresented groups see connections across their course work and in their everyday lives.

Moreover, this research suggests multiple ways for geographers to contribute to the science of broadening participation. First, in thinking about place-based factors, universities and STEM educators might find some success in targeting their recruitment efforts in economically challenged and/or predominantly minority neighborhoods near a university. Geographers with GIS and mapping analysis can play an important role in this as they overlay socio-demographic data, secondary school district boundaries, and a university's recruitment catchment areas. Second, STEM educators from other disciplines could look toward community geography and citizen science as valuable opportunities to enhance the connections between classroom theory and real-world experiences through service learning, civic engagement, and community-based research.

Consequently, as researchers attempt to broaden participation in STEM, it is imperative that geography is not only recognized as a key STEM field but also as a field that offers place-based perspectives that can lead to improved recruitment efforts across the spectrum of STEM disciplines. As demonstrated in the review of existing literature, there are three distinct lenses that inspire geographical perspectives on STEM fields. First, place-based factors comprise four principal variables that serve as facilitators/enablers or barriers of success among underrepresented individuals: (1) economical or sociocultural factors, (2) the student's academic preparation, support system, and dependencies during college, (3) student's experiences, access, and exposure to supplementary educational or advisory activities, and (4) the geographical location "place factor" of the university or individual. Second, spatial thinking, spatial behavior, and inquiry-based pedagogical approaches used in developing fundamental knowledge and skills required to advance STEM fields. Finally, environmental education and civic engagement is a way of learning STEM through real-world problems and experiences.

In the discussion of the geographic case study, many of these perspectives have been addressed; specifically indicating that placed-based factors and approaches, spatial thinking and inquiry-based learning, and environmental education and civic engagement all work in helping advance the science of broadening participation in STEM fields. For instance, the core of this case study entailed student participation in supplementary educational activities (i.e., the Summer Science Exploration Program)—which is encompassed in environmental education and civic engagement—to analyze each student's spatial thinking, spatial behavior, and inquiry-based learning capabilities. Although the study consisted mainly of students from urban areas, several students lived in rural locations as well; thus, the student's geographical location to the university for the Summer Science Exploration Program was addressed. Furthermore, the economic factors and background characteristics of the study sample included a diverse community in gender, class, socioeconomic status, age, economic activities, and minority populations. However, the student's interactions and dependencies during college were not addressed, as this was a pre-college case study.

The Summer Science Exploration Program not only addressed the participants' pre-program knowledge in various STEM fields it also developed a beyond basic understanding of several STEM fields throughout the program. Although the student's interactions and dependencies during college were not individually addressed, all three distinct lenses that inspire geographical perspectives were addressed in this case study. Therefore, this case study shows the true impact of inquiry-based pedagogical approaches and how we can catalyze the participation of underrepresented groups through these perspectives.

Looking Forward

This paper has illuminated how geography is the foundation upon which broadening participation can be built and strengthened. The paper has underscored geographic factors that fuel the growth and nurturing of a STEM career path. We are encouraged by the fact that broadening participation through geography will enable individuals to engage in purposeful ways as individuals grow in spatial thinking, imagination, and concepts. On the whole, nurturing diversity in STEM fields can be accomplished through a number of ways, for example: (1) using practical initiatives, especially through job, career, and networking like it was presented in the case study; (2) by presenting and re-presenting spatial information in ways that are meaningful to the young generation through creative and narrative stories, GIS, schematics, spatial intelligence, visual analytics, mapping, critical thinking, field studies and observations; and (3) using community geography, local civic engagement activities, and place-based science education to connect classroom theory with real-world experiences.

As we move forward, we hope this research stimulates a larger discussion of the role for geographers in the science of broadening participation. We expect to provide more case studies in future studies and solid data to move this topic forward. We also suggest that future studies will include an analysis of problem-based learning (PBL), as several recent studies have shown that students get more deeply engaged in scientific perspectives when they are exposed to advance learning procedures and practices. Additionally, from our initial discoveries, we contend that future research on the science of broadening participation focus on two major questions. Fundamentally, should geography serve as one of the paths to catalyze the participation of underrepresented groups in STEM fields? If so, then how should spatial reasoning concepts and thinking be incorporated into the K-12 curriculum? Looking forward, it is vital that we advance geographic factors that catalyze participation in STEM fields. To attain a rich and diverse workforce in the 21st century, we should aim at equipping members of underrepresented groups with a relevant set of knowledge and skills firmly rooted in place through a variety of geographically-oriented, theoretical and methodological perspectives.

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