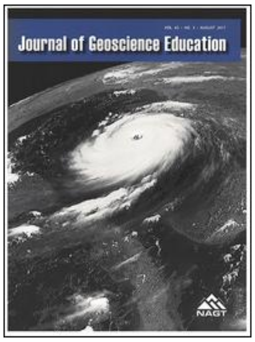


Journal of Geoscience Education

ISSN: 1089-9995 (Print) 2158-1428 (Online) Journal homepage: https://www.tandfonline.com/loi/ujge20

# The Geoscience Pipeline: A Conceptual Framework

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## ABSTRACT

In order to assess the effectiveness of projects intended to increase the participation of members of traditionally underrepresented groups in geoscience careers, short-term indicators of "success" must be identified and developed. Our first step in identifying these indicators was the creation of a model of the science, technology, engineering, and math (STEM) career pipeline, based on a literature review of factors associated with STEM career choice in minority populations. To validate the appropriateness of this model for the geosciences, as well as to identify factors specific to geoscience career choice, we conducted a critical incident study and further refined our pipeline model. We used the model to determine the potential efficacy of different approaches that are being employed by geoscience diversity projects and to show how it can be used for determining the effectiveness of these projects.

## INTRODUCTION

The Opportunities for Enhancing Diversity in the Geosciences (OEDG) program, funded by the National Science Foundation (NSF), awards grants to projects that are intended to increase participation in geoscience careers by members of groups that have been traditionally underrepresented in geoscience disciplines. In this case, underrepresented groups refer specifically to persons with disabilities, African Americans, Hispanics, Native Americans, Alaska Natives, and Native Pacific Islanders. OEDG grantee projects are implementing a variety of approaches designed to influence the attitudes, beliefs, and behaviors of underrepresented students at grade levels ranging from middle school through graduate school.

In order to determine if these projects are successful in their intentions, it would be necessary to ascertain whether project activities were responsible for members of underrepresented groups' eventual employment in the field of geosciences. Unfortunately, career-employment measures are infeasible for most projects because they would require extensive, expensive, multi-year tracking of participants. In order to assess project effectiveness in the short term, it is necessary to identify factors that are associated with an enhanced likelihood of employment in the field of geosciences.

Since there were no existing models of geoscience career choice, we chose to initiate our study by conducting a review of the literature to identify factors associated with STEM career choice by minority students. In doing so, we were making the assumption that only by being attracted to and retained within the STEM career pipeline would a student emerge as a geoscientist.

In order to verify the appropriateness and relevance of this model, as well as to try to identify factors unique to the geosciences, we conducted a small critical incident study. It is worth noting that this methodology has been used to study factors responsible for STEM major choices (and field switching) by African American and Hispanic undergraduates (Brown and Clewell, 1995; Bembry et al., 1998) and to identify barriers to STEM career pursuit and development by individuals with disabilities (Weisgerber, 1991).

We chose this qualitative methodology because of its empirical basis: Factors identified through this technique are based on the actual experiences of professional geoscientists who described actual incidents in their lives that were responsible for their geoscience career choice. In other words, each identified factor is something that was reported to be responsible for an individual's geoscience career choice. Large numbers of participants were not essential for our purpose; A single person self-reporting an event can determine both the criticality of the event and its impact, and validates the inclusion of the factor in our model.

We used this pipeline model to determine the appropriateness of the approaches being used the different OEDG projects. We developed a descriptive schema to categorize approaches and linked these approaches with components of the pipeline model, verifying their potential efficacy for achieving desired outcomes.

## METHODS

**General STEM Pipeline Model Development** - To create the pipeline model and to identify indicators of retention in the geosciences, we first conducted a review of the literature. We reviewed the general literature about science, technology, engineering, and/or mathematics (STEM) college majors or career choice by members of traditionally underrepresented groups. The indicators were divided into levels corresponding to the target audiences of different OEDG projects: middle/high school, community college, four-year college, and graduate school.

**Validation of General Pipeline for Geosciences and Identification of Geoscience Specific Factors** - In order to validate the appropriateness of our STEM model for the geosciences and to include indicators specific to a geoscience career pipeline, we conducted a critical incident (CI) study, focusing on behaviors that influenced someone to enter or leave the geosciences. This technique, developed by John Flanagan (1954), has been widely used in the industrial and organizational psychology, health, and education fields. In 2001, Fivars and Fitzpatrick published a 301-page bibliography of critical incident studies (now available on the American

| Incident #1 | |
|---|---|
| 1. What led up to the situation?<br><br>*I was a biology major and I knew I did not want to go to med school. I took intro biology and chemistry in college and hated the whole pre-med thing. It was a very unsupportive environment. I was looking at some liberal arts options.* | 2. What happened? What did you do?<br><br>*I just walked into the geology department and talked to an advisor.* |
| 3. (If not obvious) How did this influence you to choose or consider a geosciences major?<br><br>*He listened and gave me good feedback. I took his class that fall.* | |
| **Incident #2** | |
| 1. What led up to the situation?<br><br>*As a child, I was interested in rocks and fossils.* | 2. What happened? What did (you/person) do?<br><br>*My parents encouraged this interest. They bought me books about rocks and fossils and helped me collect rocks.* |
| 3. (If not obvious): How did this influence you to choose or consider a geosciences major?<br><br>*Having the books and collecting the rocks made me want to know more about rocks and fossils.* | |

**Figure 1. Sample Critical Incidents**

Psychological Association's Website: http://www.apa.org).

Critical incident interviewing is a type of open-ended interviewing. The interviewer asks questions (i.e., "Can you think of something that someone did or said that caused you to consider a geoscience career?" "Can you tell me the reasons why you chose to major in geoscience?") and probes that are designed to stimulate the provision of specific situations and events that played a critical role in the selection of a geoscience major or career (i.e., "Tell me more. Exactly what did [PERSON] do or say that led you to consider geoscience?" "What do you like about geoscience? Why do you feel that way - that is, what happened that made you feel this way?"). These events are then written up as critical incidents, each of which focuses on a specific behavior that was responsible for an individual's choice of a geoscience career or major. Negative incidents can also be collected, and are equally informative for identifying factors associated with retention in a geoscience career pathway. Sample incidents are provided as Figure 1.

In a CI study, it is not necessary to select a random sample of participants. Since the goals of the study are to identify factors that could be responsible for geoscience career choice and compare these factors with those identified from our review of the literature, it is not necessary to select a random sample of participants to produce estimates of the relative prevalence and importance of these factors. Respondents must be knowledgeable about the reasons that individuals choose geoscience careers and they must be able to report about specific behaviors or events that were responsible for these decisions.

A total of 14 interviews were conducted. Eleven were conducted with OEDG Principal Investigators (PIs), one with an OEDG project coordinator, and two with graduate students in the geosciences. Eight of the interviewees were male; six were female. Four of the

| Approach/Methodology | Elem. | Middle / High School | Community College | Under-graduate | Graduate | Total |
|---|---|---|---|---|---|---|
| **Projects Directly Serving Students** | | | | | | |
| Curriculum/material development/dissemination | 3 | 4 | 4 | 6 | 1 | 13 |
| Field trips | 2 | 24 | 10 | 11 | 1 | 34 |
| Research experience | 2 | 19 | 6 | 26 | 10 | 36 |
| Provision of resources | 0 | 9 | 5 | 22 | 14 | 30 |
| Professional development | 0 | 1 | 1 | 20 | 13 | 25 |
| GEO incorporated into other subject classes | 2 | 3 | 2 | 3 | 0 | 5 |
| Summer/afterschool program | 2 | 26 | 2 | 11 | 4 | 31 |
| Career opportunity information dissemination | 1 | 15 | 8 | 13 | 3 | 27 |
| ***Total*** | ***8*** | ***38*** | ***14*** | ***43*** | ***21*** | |
| **Projects Directly Serving Teachers** | | | | | | |
| Curriculum/material development/dissemination | 7 | 17 | 4 | 6 | 0 | 23 |
| Field trips | 0 | 17 | 4 | 3 | 1 | 18 |
| Research experience | 3 | 12 | 3 | 1 | 0 | 14 |
| Course development | 1 | 3 | 4 | 3 | 0 | 10 |
| Provision of resources | 1 | 12 | 4 | 5 | 1 | 16 |
| Professional development | 7 | 28 | 8 | 15 | 0 | 39 |
| GEO incorporated into other subject classes | 3 | 11 | 2 | 5 | 1 | 16 |
| Summer/afterschool program | 4 | 9 | 1 | 2 | 1 | 11 |
| Career opportunity information dissemination | 0 | 1 | 2 | 2 | 0 | 3 |
| ***Total*** | ***9*** | ***34*** | ***11*** | ***22*** | ***1*** | |

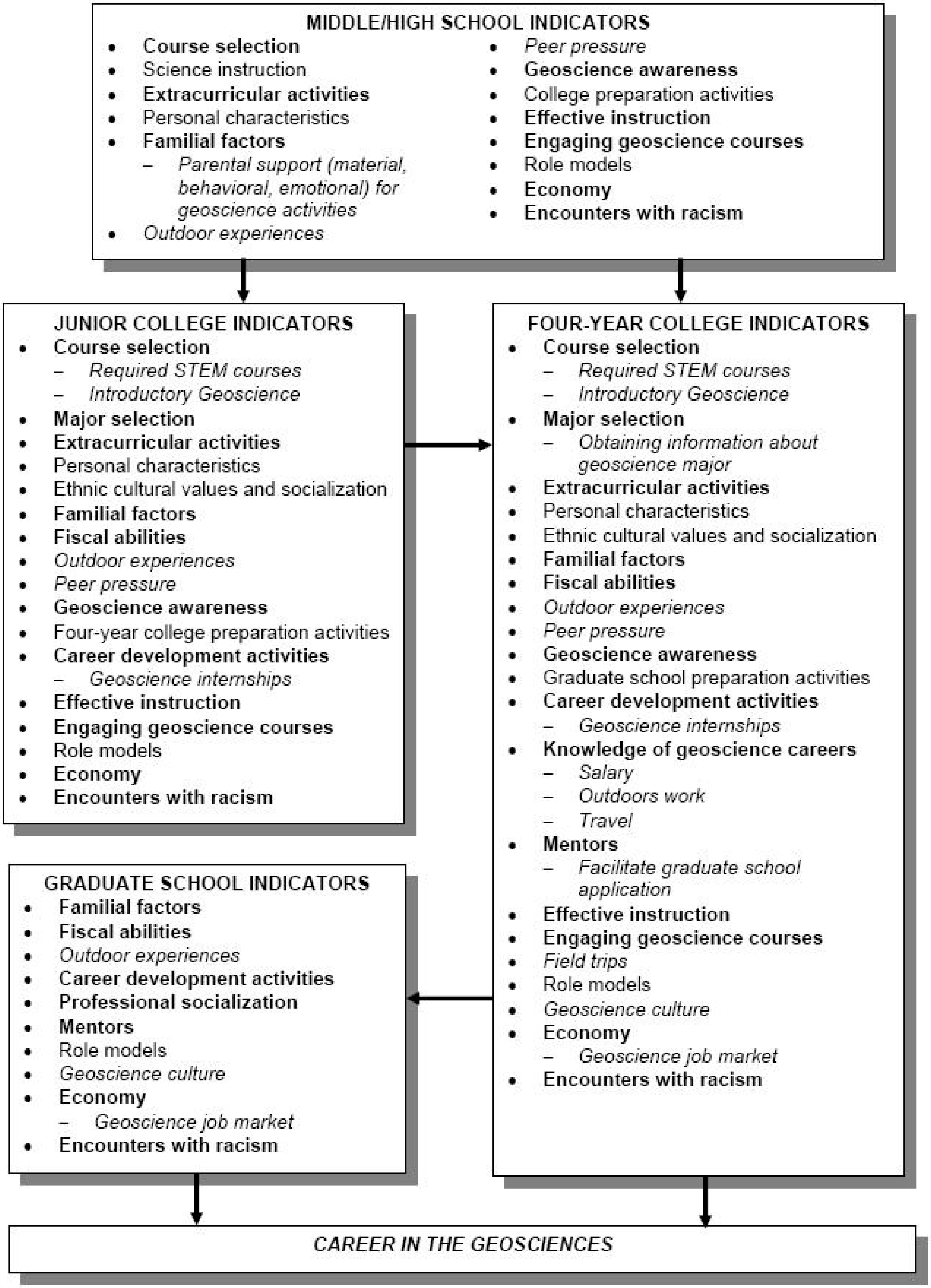
**Figure 2. Number of OEDG Projects Directly Serving Student and Teachers, by Approach/ Methodology**

respondents (29%) were from underrepresented minority groups. The interviews were conducted by the authors and another colleague, primarily by telephone, and averaged 30 minutes. A total of 141 critical incidents were produced. Of those 141 incidents, 9 were dropped because the critical behavior could not be clearly identified or linked to the outcome of selecting a major or career in the geosciences. Another nine incidents dealt with behaviors that occurred after employment as a geoscientist. Since our model is only concerned with factors related to entry into a geoscience career, these incidents were also excluded. Therefore, a total of 123 incidents were used to validate and refine the model. PIs were not asked about their projects and did not provide examples of how their projects impacted others. They were asked about specific things that happened to them (and their peers) that were responsible for their geoscience career choice.

**Categorization of Approaches Employed by OEDG-sponsored Project**s - In order to summarize the different approaches used by OEDG grantees, we developed a descriptive typology (Levine et al., 2005). This typology identified the audience(s) directly served (e.g., teachers and students) and their grade levels (e.g., elementary, middle school/high school, community college, undergraduate, and graduate). The approaches employed by 57 different projects, representing the OEDG grantees through 2005 are summarized in Figure 2. Most projects employed several approaches in their efforts to increase the numbers of underrepresented minorities in the geosciences.

## ANALYSIS AND RESULTS

The unit of analysis for this study was the critical incident and not the individual respondent. Each incident described a behavior that was responsible for an individual's consideration of (or rejection of) a geoscience career or major. Each of these behaviors was compared with the factors that comprised our original STEM pipeline model. If an incident could be matched to a factor in the model, we deemed the factor "confirmed." That is, our procedures provided evidence of construct




NOTE: Bolded text represents verification of the pipeline category from the critical incident study. *Italicized* text represents additional categories and subcategories added as a result of the critical incident study

**Figure 3. Geoscience Career Pipeline Mode**

validity by demonstrating that the factor was responsible for geoscience career choice by a geoscientist.

Since this was a small study, we did not expect to be able to verify all of the general STEM factors with only 123 incidents. Nonetheless, we were able to validate 39 of 52 STEM factors (75%) as being part of a geoscience career pipeline. These are indicated in bold in Figure 3. We were particularly interested in identifying indicators that were not part of our general STEM pipeline model. These were indicators that appear to be unique to a geoscience career pipeline and are indicated in italics in Figure 3. These unique factors include outdoor experiences (which increase a person's appreciation of nature and the outdoors), the geoscience department culture (more cooperative than other STEM courses; more social), the impact of geoscience courses, field trips (an activity that distinguishes geoscience courses from other STEM courses), the geoscience job market, various geoscience specific activities (taking introductory geoscience courses, participating in geoscience internships), and peer pressure (related to the stereotype that geosciences are for the less bright students).

**Overview of the Pipeline Model** - Our pipeline model reflects the transition of underrepresented minority students into a career in geosciences. The pipeline is divided into four levels: middle/high school, community college, four-year college, and graduate school. Although certain factors can influence career choice at any point in the pipeline, other factors appear to be more salient at specific times.

After high school, the pipeline diverges into two pathways: community college entry or entry into a four-year college. The community college pathway is of particular relevance, since greater proportions of students from underrepresented groups initially attend community colleges (NSF, 2002). These pathways merge together after community college when students transfer to a four-year college or university.

Some people enter geoscience careers immediately after college graduation. There is a "faucet" in the pipeline after college graduation to acknowledge this successful outcome. Our pipeline does not require formal declaration of a geoscience major until graduate school. This reflects our observation that many geoscience graduate students had other undergraduate majors.

## DETAILED DESCRIPTION OF FACTORS

While our pipeline model is divided by school level, below we discuss the factors by three cross-cutting groupings: student factors, teacher factors, and institutional factors.

**Student Factors - Course selection -** Course selection in high school can be an indicator of underrepresented students' retention in the pipeline. High school courses can be predictors of college attendance and of academic preparedness for college. Taking algebra is a good predictor of college attendance (Pelavin and Associates, 1990) and taking high school geometry is a major predictor of college completion, a critical component of keeping students in the pipeline.

Enrolling in high school STEM classes can prepare minority students for rigorous STEM coursework in college. An NSF report (1996) showed that only 1.2 percent of Latino students took algebra II, geometry, and trigonometry in their high school programs (and only 0.9% took calculus). Without a strong academic preparation in STEM in high school, minority students are less likely to remain in a STEM pipeline. Indeed, much of the literature on minority students in STEM stresses the importance of academic preparation of these students (Bembry et al., 1998; Chang, 2002; Committee on Equal Opportunities in Science and Engineering, 2004; Feuers, 1990; Grandy, 1998; NSF, 1994; Seymour and Hewitt, 1997; Strenta et al., 1994; Brown, 2002; Wilson, 2000).

Anderson and Kim (2006) reported that students who earned a Bachelor's degree in STEM fields were better prepared for college if they took a "highly rigorous high school curriculum." We found evidence of this in our CI study. Several incidents were collected about rigorous mathematics requirements for geoscience majors that were barriers to retention in the geosciences. Students who were unable to satisfy the mathematics requirements of geoscience majors often switched majors.

Other barriers to recruitment for the geosciences, identified in the CI study, were availability, perception, and knowledge of geoscience courses. In high school, the geosciences are not as widely taught as biology, chemistry, or physics. And, as our CI study showed, they are not considered to be a rigorous pre-college science course. According to *State Indicators of Science and Mathematics Education*, 28 percent of high school students take a high-school earth science course, while approximately 95 percent of high school students take biology (Blank and Langesen, 2005).

We found some students were recruited into the major simply by exposure to the discipline. Several incidents were collected on students who entered the geosciences after enrolling in an introductory geoscience course. Some of these incidents described students who were initially unaware of the discipline, but after enrolling in an introductory geoscience course and enjoying it, they ultimately became geoscience majors. The reasons for enrolling in an introductory geoscience course included an interesting description in the course catalogue, wanting to explore different science fields, and having a professor encourage enrollment.

**Major selection and persistence** - Selection of a STEM major in college is a straightforward indicator of minority students remaining in the pipeline. Our research showed that obtaining information from professors, advisors, and other students about a geoscience major was important in their choice of a major. Equally important is retention in a STEM major (Brown, 1994; Bembry et al., 1998; Jackson, 2002; CAWMSET 2000). According to the Center for Institutional Data Exchange and Analysis, 2000, "approximately 50 percent of students entering college with an intention to major in STEM change majors within the first two years" (Chang, 2002).

**Extracurricular activities** - Bembry et al. (1998) found that one of the most influential factors for minority students who remained in STEM majors was extracurricular exposure and experiences. These activities can provide minority students with an opportunity to learn more about STEM fields as well as create or maintain interest in these areas. The Office of Technology Assessment's (1988) list of "important factors that contribute" to students entering STEM fields included participation in early research and in an intervention program. These activities might include taking summer jobs or part-time jobs relevant to the field, entering science fairs or contests, attending summer science programs, and taking field trips (Fields, 1998). The CI study validated this factor: extracurricular research experience in the geosciences helps retain students in the field.

**Personal characteristics** - Certain personal characteristics reflect a student's ability and desire to remain in the pipeline. Setting high, long-range goals, such as earning a college degree, can indicate students' ability to remain in the pipeline. In a study of potential African American physicians, students who did not remain in the physician pipeline "frequently lacked family and school support for setting high, and hence long-range, educational goals" (Wilson-Pessano et al., 1985).

Students' perceptions of their own ability and a willingness to defer gratification can also impact underrepresented students' decisions to remain in or to leave the pipeline. STEM courses often have the "stigma" of being academically rigorous. Brown and Clewell (1995) found that the course requirements, the intense competitiveness among students in STEM courses, the restrictive curriculum of STEM majors, and the time demands of STEM courses were reasons that minority students avoided STEM majors. Although difficulty in STEM courses affected retention in STEM majors, an equally important component of STEM retention was minority students' "perceptions of their ability to be successful in a STEM major." These minority students reported they could not handle the workload for STEM majors, often leading to self-defeating behaviors. Students who believed they were well prepared from high school or accepted the challenge of the workload were less likely to switch out of STEM majors (Bembry et al., 1998). Minority students' performance in STEM courses, their willingness to devote the requisite study time required of STEM majors, and their sense of self-efficacy (with respect to performance in STEM classes) can all serve as indicators of remaining in the pipeline.

**Ethnic cultural values and socialization** - Differences in cultural values and socialization are important considerations as to why minority students are not retained in STEM (NSF, 1996; Seymour and Hewitt, 1997). Native Americans and Latinos possess strong cultural values of group and community membership that are often at odds with the levels of individualism and competition associated with the sciences (NSF, 1996; Seymour and Hewitt, 1997). Seymour and Hewitt (1997) found that an obligation to serve the community, the conflict between academic and family responsibilities, cultural restraints on self-assertiveness, and cultural variations in peer group success norms were cultural values unique to members of certain minority groups. In some cultures, the outdoor work associated with the geosciences is typically associated with laborers rather than professionals. Furthermore, cultural incongruity that may arise between minorities and the dominant culture can increase barriers to students' social and academic integration. The perceived congruity between cultural values and STEM can be an indicator of retention in the pipeline.

**Familial factors** - Parental and familial factors play a large role in education, career choice and development (Huang et al., 2000; Brown, 2002; Clark, 1999; Jordan, 2006). We found that parental support, such as collecting rocks with a child or going on camping trips, can encourage an interest in the geosciences. Knowledge of professions is strongly associated with parents and family members who are members of that profession. A substantial proportion of African American physicians have one or more parents who are also physicians (Wilson-Pessano et al., 1985). Parental attitudes about career choice clearly influence minority students' college major decisions (Bembry et al., 1998).

**Fiscal abilities** - The importance of finances for the attraction and retention of underrepresented minority students in STEM has been clearly demonstrated (CAWMSET, 2000; Georges, 2000; Fenske, Porter and DuBrock, 2000; Quimbita, 1991). In fact, many believe the major reason that minority students withdraw from (or do not enter) higher education is financial (Carter, 2006; Hu and St. John, 2001; Seidman, 2005; Hilton et al., 1988; Brazziel and Brazziel, 2001). Awareness of financial support sources and knowledge of post-secondary application processes are important for minority student to attend and remain in college (Jackson, 2002). Wilson-Pessano et al. (1985) demonstrated that many potential physicians from lower SES backgrounds lacked the understanding of how a medical education could be "accomplished and financed." The cost of a medical education deterred many potential African American physicians in their sample from pursuing a career as a doctor. Both the possession of adequate financial resources and an understanding of financing higher education are factors associated with pipeline retention.

**Outdoor experiences** - Outdoor experiences are a geoscience-specific factor identified through our research. It is not surprising that a love of the outdoors was cited as motivation to enter the geosciences. Incidents such as experiencing an extraordinary geosciences event, such as a lightning storm, or an interest in nature and rocks were mentioned as reasons for drawing some geoscientists into the field. One Latino geologist told about his experiences in the Boy Scouts. His troop leader would take the troop to interesting rock formations, rivers, and lakes to learn about geological history. This activity had a lasting impact and was cited as a behavior responsible for developing his interest in geology.

**Peer pressure** - In our CI study, one barrier to recruitment and retention in the geosciences was peer pressure. As stated by a respondent, geoscience high school courses are sometimes perceived as "something that dummies do." This perception can deter college-bound students from taking a high school geoscience course, making recruitment into the geoscience career pipeline less likely. In another incident, a student switched from a physics major to sociology, because of her friend's perception that physics was "really weird."

**Geosciences awareness** - Many students are never exposed to the geosciences or at least not early on in their academic training (Fields, 1998). Conversely, many geoscientists report that an early experience with geosciences - a chance encounter, a field trip, meeting a geoscientist - played a critical role in their career choice, pointing out the importance of knowledge of geosciences as a pipeline factor.

**College/Graduate school preparatory activities** - In order for middle and high school minority students to continue in the pipeline, they must enter and complete college. Therefore, taking the SAT or ACT (two tests that are often needed to enter college) and applying to an Institution of Higher Education (IHE) are indicators of students continuing in the pipeline. Similarly, transferring to a four-year college and activities associated with applying to graduate school (such as taking the Graduate Record Exams) are also pipeline factors.

**Career development activities** - Knowledge of STEM careers has been shown to influence minority students' career choices. In a study conducted by Brown and Clewell (1995), several students commented on their ignorance of STEM careers: Several students stated that they would have considered a STEM career if they had known more about such careers.

STEM internships can promote retention in the geoscience pipeline. Brown and Clewell also pointed out that the quality of internships is also important, since some minority students left the STEM pipeline due to negative summer internship experiences. (Most of the negative internship experiences were in engineering.) The importance of positive internship experiences in the geosciences was validated in our CI study. Numerous incidents described how internships allowed students to learn more about the field, provided them with practical experience, and built one student's confidence.

**Professional socialization** -Professional development in a career requires training in the behaviors appropriate for members of the profession. Both research experiences and attendance at professional conferences provide important socialization experiences (Summers and Hrabowski, 2006; Windham et al., 2004) and are indicators of remaining in the pipeline.

**Teacher Factors - Mentors -** Mentors can provide immense support for their mentees, profoundly influencing career choice decisions. The prototypical example is the graduate student's advisor, who, in addition to teaching technical knowledge and skills, also serves as a source of professional socialization. The literature supports the importance of mentoring in keeping minority students in STEM (Alfred et al., 2005; Armstrong and Thompson, 2003; Baker, 2000; Bembry et al., 1998; Brown, 1994; CEOSE, 2004; Koshland, 1992; NSF, 1996; Payton, 2004; Windham et al., 2004; Zappo, 1998).

In less formal ways, instructor engagement and the time post-secondary instructors spend teaching and advising students is important to student achievement and retention (Tinto, 1993; Brazziel and Brazziel, 2001; Clark, 1999; Rotberg, 1990). In addition, teacher engagement can facilitate the academic integration of students (Yslas Vélez, 2000). Similarly, positive experiences that graduate students have with geoscience faculty facilitates retention in the geosciences (Windham et al., 2004).

Geoscience faculty also assisted students in pursuing graduate degrees and finding employment. In our CI study, respondents reported that faculty encouraged and supported them in applying to graduate school. One faculty member offered to introduce a student to professors at various doctoral programs and reviewed the student's statement of purpose. Because of this professor's support, the student felt she could be successful in the field, which therefore kept her in the pipeline. Accordingly, these positive experiences, including applying to graduate school and obtaining a job in the field, are factors in our pipeline model.

**Effective instruction** - Engaging students through effective instruction is an important component in the recruitment and retention of underrepresented minorities in STEM (Armstrong and Thompson, 2003; Brown, 2002; Brown and Clewell, 1995; Clark, 1999; Seymour and Hewitt, 1997). In high school, teachers can influence students to continue taking mathematics and science courses that will keep students interested in STEM careers. Positive experiences with high school teachers, such as receiving respect, support, and encouragement are important in promoting minority students' interest in STEM careers (Brown and Clewell, 1995). For science and math instruction to be effective, teachers must have high expectations for all students and "make provisions for as much individualization as possible" using cooperative learning techniques (Clark, 1999). Low teacher expectations were cited as a "persistent deterrent" to success in geosciences among African American geoscientists and students (Fields, 1998).

The Office of Technology Assessment (1988) indicates having a well-qualified science teacher and being taught using hands-on science experiments are "important factors that contribute" to students entering STEM. Also, high school teachers' ability to connect science to real life helps keep students interested in the sciences (Brown and Clewell, 1995; Brown, 2002).

Effective instruction is important at all education levels. Seymour and Hewitt (1997) found that poor teaching by STEM college faculty was the third most significant reason why students switched to non-STEM majors. Of those students who switched to non-STEM majors, 90% complained of poor teaching.

Showing the relevance of STEM courses and their application is important for effective instruction (Collea, 1990; Brown, 1994). Several studies found that minority students choose non-STEM over STEM majors because they do not see the relevance or utility of these fields to their daily lives (Brown, 1994; Payton, 2004; Clark, 1999; Rosser, 1993). In our research, professors who brought geological examples into the classroom, encouraged class participation, and utilized textbooks with references to the local area, were cited as being responsible for geoscience career choice.

**"Engaging" geoscience course** - Closely related to effective instruction are "engaging" geoscience courses. One method to create an "engaging" geoscience course is to utilize "place-based" teaching practices that emphasize the study of local places and "the synthesis of local cultural knowledge" (Semken, 2005). The impact of place-based teaching was validated in our CI study: One respondent reported that learning about the scientific explanations for the local landscape and geography in college not only excited her about the field, but also made her more certain of her choice to major in geology.

Minority students often encounter incongruence between their knowledge and ways of knowing and science. To address these issues, faculty must utilize culturally appropriate pedagogy. Tewksbury (1995) created an introductory course on the geology and development of modern Africa to attract African Americans to the geosciences by connecting geologic topics to historical, political, and economic issues in Africa. Eleven African American students, comprising over one-sixth of her university's African American enrollment at the time, took this course. In K-12 science education, Lee and Fradd (1998) propose instructional congruence or "the process of mediating academic disciplines…with students' languages and culture to make the academic content accessible and meaningful for all students." Tuitt (2003) argues for a more inclusive pedagogy to accommodate the growing diversity and learning styles of students in college.

Native American students often find curricula and teaching styles conflict both with how they were taught to understand the world in their home cultures and how they have been taught to learn, resulting in efforts to provide more culturally appropriate pedagogy for Native American students (Semken, 2001; Baker, 2000).

**Field trips** - The prevalence and importance of field trips in geoscience education distinguishes the geosciences from other STEM fields. Geoscience research field trips often involve camping and overnight stays. These trips promote socialization, providing students an opportunity to bond with other geoscience majors and faculty. Positive field trip experiences are factors associated with recruitment and retention that appear to be geoscience-specific. For example, one critical incident respondent spoke about field trip activities that introduced him to different aspects of the geosciences and also made the material more relevant.

**Role models** - Role models are cited as a factor that affects entry into STEM (Office of Technology Assessment, 1988). We did not find geoscience specific examples of minority role models influencing geoscience career choice, probably due to the dearth of minority geoscientists.

**Institutional Factors - Geoscience culture -** Informal interactions and social activities in the geoscience department were geoscience-specific behaviors identified in the critical incidents as being responsible for retaining respondents in the geosciences. One respondent reported that students interacted more cooperatively and less competitively than other majors, creating a sense of community. This geoscience 'culture,' characterized by positive informal interactions and social activities, is an attraction/retention factor that distinguishes geoscience from other STEM majors. Geoscience faculty with open door policies and the small size of geoscience programs enabled substantial positive interaction between students and faculty, helping to retain students in their major. Field trips provided additional opportunities for informal interactions between professors and students. Faculty were also instrumental in recruiting students. In one incident, a geoscience professor invited a student to attend a gathering for majors and encouraged her to take his class and enroll in the major. As a result, the student became a geoscience major.

**Economy** - The job market in the geosciences affects recruitment and retention in the pipeline. From our research, we learned that the booming oil market in the 1980s saw an increase in the number of geoscience majors, and the subsequent "bust" brought a decrease in their number. Understanding the job market and career opportunities available to geosciences graduates can help to recruit and retain students in the pipeline. Several OEDG projects explicitly provide information about geoscientist salaries, particularly for petroleum geoscientists.

**Encounters with racism** - Seymour and Hewitt (1997) found that racism and negative stereotypes were barriers for students of colors in STEM. Students were in greater dangers of transferring out of STEM when they internalized negative stereotypes. For example:

> I know a Black woman who switched to art; she was going to be a physics major. Her physics professor came and told her, 'Why are you in my classroom? What you can possibly want to know about physics?' And it was horrible for her…and, coming from a professor, you know, that is devastating for a student (p. 358).

Jordan (2006) also collected narratives on the role race played in the education and careers of African American female scientists. In our own CI study, we collected an incident of an underrepresented minority student receiving negative comments from classmates concerning an internship. One of her classmates said the student received the internship because of her minority status. The student heard similar "cheap shots" from other students as well; these comments made the student struggle even more with her own confidence about her ability in the field. Students' reaction to racism is another pipeline factor. To help deal with this issue, one OEDG program was developed to recruit and bring together a "critical mass" of minority graduate students, to alleviate both their sense of isolation and to provide support for dealing with negative stereotypes.

## DISCUSSION

Our geoscience pipeline model provides a framework for the design and the assessment of the effectiveness of geoscience diversity projects. Projects can be designed to address factors in the model; their efficacy can be assessed through demonstration of changes in knowledge, attitudes, and behaviors reflective of these factors.

We used this model to determine the potential efficacy of projects funded by the OEDG Program through 2005. The approaches used by these projects, as summarized in Table 2, show that provision of research experiences was the most widely used approach for directly serving students, with 36 (63%) projects employing this approach. Nearly as many (34, or 60%) took students on field trips - an approach included in the model, which can also enhance students' appreciation of the outdoors. It is noteworthy that three-quarters of the projects (43) directly targeted college undergraduates and two-thirds (38) directly targeted middle/high school students.

Most projects also directly targeted teachers. Over two-thirds (39, or 68%) provided geoscience professional development for teachers in their attempts to increase the number of underrepresented minorities choosing careers in the geosciences. These projects could help attract or retain students through enabling effective instruction and by providing engaging geoscience courses. A majority of these programs (34, or 60%) directly served middle/high school teachers.

Nearly all of these approaches can be explicitly linked with factors in our Geoscience Pipeline model. For example, curriculum/material development and dissemination could enable teachers to provide the types of science instruction or engaging geoscience courses that create or maintain an interest in the geosciences. The provision of resources to students provides them with fiscal abilities, enabling participation in extracurricular activities that could create an interest and awareness of the geosciences. It is not difficult to envision clear and direct linkages from each approach to at least one factor in the Pipeline model. In other words, there are underlying mechanisms through which these diversity projects can promote their goal of increasing the numbers of underrepresented minorities in the geosciences.

However, approaches (such as extracurricular activities or field trips) that directly correspond to factors in the pipeline do not guarantee that participants will become geoscientists. Going on a field trip will have no attraction/retention impacts unless the experience results in knowledge or behaviors that are consistent with retention in the pipeline. In other words, one cannot demonstrate the effectiveness of field trips by simply showing that a student was on a field trip. One must show that the field trip was associated with knowledge or behavior change consonant with retention. Several OEDG projects have done this. They have developed and implemented survey measures to assess changes in attitudes and behaviors indicative of students' geoscience awareness and planned course taking behaviors to serve as indicators of their retention in a geoscience career pipeline (Fuhrman et al, 2004; Hanks et al., 2005; Hanks et al., 2007a; Hanks et al., 2007b; Miller et al., 2007).

We have identified several pipeline factors that appear to be unique to the geosciences, including an appreciation of the outdoors, field trips, and the geoscience culture. It is likely that there are other factors. The collection of additional critical incidents would, almost certainly, have enabled their identification. Finally, we would like to note that it was not our intention to address the question of the relative importance of the different components of the model. This should be the topic of future research. We believe and hope that our model provides a framework for the design of such studies.

## ACKNOWLEDGEMENTS

This research was funded by the National Science Foundation, Contract number GS-10F-0112J. All opinions, findings, conclusions, and recommendations presented in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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