AC 2009-2473: MEASURING THE EDUCATIONAL BENEFITS OF DIVERSITY IN STEM EDUCATION: A MULTI-INSTITUTIONAL SURVEY ANALYSIS OF WOMEN AND UNDERREPRESENTED MINORITIES

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Measuring the Educational Benefits of Diversity in STEM Education: A Multi-Institutional Survey Analysis of Women and Underrepresented Minorities

Abstract

Previous research has documented the importance of diversity in higher education and the need to increase diversity in science and engineering fields by broadening participation among women and historically underrepresented minorities. Large-scale research that measures the educational benefits of diversity in science, technology, engineering, and math (STEM) fields, however, has been limited. The present study measured the educational benefits of diversity in STEM fields using a nationally representative sample of 8,000 undergraduates. Results indicated that students who reported more engagement with diverse peers also reported higher learning gains as indicated by two variables: personal/social learning and critical thinking. I also found that sex moderated the relationship between diversity and learning; women benefited more than men from engagement with diverse peers.

Introduction

In a recent report, based on the Supreme Court's rulings in affirmative action cases at the University of Michigan, several national organizations (e.g., National Academy of Sciences, National Academy of Engineering, and National Action Council for Minorities in Engineering) argue that the importance of "increasing diversity" is heightened in the fields of science and engineering.[1] To illustrate the need for increasing diversity, consider national statistics on science, technology, engineering, and math (STEM) workforce participation. Although White, non-Hispanic men compromised 70% of the STEM workforce, relatively few were women and less than 6% were underrepresented minorities [(URM), i.e., African Americans, Latinos, American Indians/Alaskan Natives].[2]

Several steps must be taken to improve the representation of URMs in STEM fields, one of which is "we must clearly articulate the educational case for diversity, showing how [STEM] students and society benefit from it."[3] And while previous research provides evidence of the educational benefits of diversity in collegiate settings[4] and that racially diverse educational environments are associated with positive academic and social outcomes for college students such as improved intergroup relations, mutual understanding, intellectual development, and self-confidence,[5,6] relatively few studies assess whether engagement with diverse peers enriches STEM education. This is the gap addressed by the present study.

Purpose

The purpose of the study was to estimate the educational benefits that accrue to STEM undergraduates who interact with diverse peers. Specifically, in this study, I conducted multivariate analyses on multi-institutional survey data from 8,000 students at 4-year campuses to answer the following: Do STEM students report more learning when they work with diverse peers? Does this relationship vary by race (i.e., URM status) and gender?

Method

This study is part of a larger, longitudinal study titled, Investigating the Critical Junctures: Strategies that Broaden Minority Participation in STEM Fields funded by the National Science Foundation (NSF). While the larger study consists of both quantitative and qualitative components, this report is based on multivariate analysis of the quantitative survey data only.

Data Source

Data were drawn from the 2004-2005 national administration of the College Student Experiences Questionnaire (CSEQ). The CSEQ consists of 191 items designed to measure the quality and quantity of students' involvement in college activities and their use of college facilities. For example, several items elicited information about students' engagement in a series of college activities that have been shown to contribute positively to learning and psychosocial development.[7] For example, the college activities section includes questions that ask how often students engaged in campus events and academic tasks (e.g., hours spent studying, attended a cultural event) during the school year. To date, more than 500 colleges and universities have used the national questionnaire. The CSEQ has been shown to be consistently reliable and valid in college impact studies.[8]

Sample

The sample consisted mostly of women (61%) and 39% were STEM majors, according to the definition published by the National Science Foundation (NSF), which includes social sciences. First-year students represented 43% of the sample, 17% sophomores, 17% juniors, and 23% seniors. Underrepresented minorities comprised 19% of the analytic sample.

Measures

Two dependent variables were used in the present study. The first was a global measure of social and interpersonal learning gains as measured by the CSEQ. Specifically, this outcome was operationalized using 5 items from the CSEQ that are purported to have psychometric and qualitative properties that are consistent with general definitions of this learning outcome.[9] An example of this scale is, "In thinking about your college experience up to now, to what extent do you feel you have gained in developing your own values and ethical standards." Original response options for each individual item ranged from 1 ("very little") to 4 ("very much"). Results of a principal components factor analysis with varimax rotation revealed that these items loaded on a single factor, which accounted for 62% of the inter-item variance. Thus, I calculated a composite (or global index) combining all 5 items (alpha = 0.84); global scores ranged from 5 ("very little") to 20 ("very much"). Precedent for using this composite variable was set in a previous study by the author. [10] The second dependent variable was a single item that measured students' perceived gains in terms of critical or analytical thinking; scores ranged from 1 ("very little") to 4 ("very much").

Independent variables included background traits, aspects of the collegiate experience, and student engagement measures. Background traits included sex (1 = male, 2 = female), race (0 =

non-URM, 1 = URM), age (in years), and advanced degree aspirations (0 = no, 1 = yes). Aspects of the college experience included year in school (dummy coded for 3 groups, “senior” is reference category), academic major (0 = non STEM, 1 = STEM), transfer status (1 = no, 2 = yes), grades (1 = less than C+, 5 = A’s).

Student engagement measures were conceptualized according to the existing literature. Student engagement is defined as “the time and energy that students devote to educationally purposeful activities and the extent to which the institution gets students to participate in activities that lead to student success.”[10] Ten items from the CSEQ were purported to measure students’ engagement with diverse peers; an example of this scale is, “How often, this year, have you had discussions with students whose race differs from your own.” Response options ranged from 1 (“never”) to 4 (“very often”). Results of a principal components factor analysis with varimax rotation yielded two factors, which accounted for 67.47% of the inter-item variance. Thus, I calculated two composites (or global indices) combining all 5 items (alpha = 0.86) that loaded on Factor 1 and all 5 items (alpha = 0.89) that loaded on Factor 2; global scores ranged from 5 (“never”) to 20 (“very often”).

A single item that measured institutional selectivity according to an index from *Barron’s Profiles* of American Colleges also was included. Barron’s rating categorizes institutions into six selectivity groups based on entering students’ class rank, high school GPA, college entrance scores, and the percentage of applicants admitted. Ratings range from 1 (“not at all selective”) to 6 (“very highly selective”).

Data Analysis

Data analysis proceeded in three stages. First, descriptive statistics were calculated to describe the analytic sample and to determine any existing patterns among data points. Second, correlation analyses were conducted to estimate the magnitude and direction of statistical relationships among independent and dependent variables used in this analysis.

Lastly, statistical tests were employed to measure the “net effect” of engagement with diverse peers on students’ perceived learning gains. It is important to note that less than 3% of the variance in the dependent variable was attributed to institution-level differences, thus multi-level modeling techniques (e.g., HLM) were deemed unnecessary.[11] Hierarchical or sequential linear regression was the analytic technique of choice; variables were entered into the regression equation in consonance with the study’s overarching theoretical model. Astin proposed one of the very first college impact models, which has come to be known as the inputs-environment-outcome (I-E-O) model of change. According to the model, student outcomes (e.g., learning) are functions of two factors including inputs (e.g., demographic traits) and environment (e.g., experiences in college).[12, 13] College impact models concentrate on the origins of change while models based on developmental theory attempt to explain the stages through which change occurs. In this study, I employed Astin’s model to measure the influence of interactions with diverse peers on student learning outcomes among STEM and non-STEM majors.

Results

Descriptive statistics indicate that students report moderate learning gains in terms of critical thinking ($M = 2.91$, $SD = 0.85$; range 1 to 4), personal/social learning ($M = 15.06$, $SD = 3.38$), and uneven engagement with diverse peers [$M_{acquaint} = 14.26$, $SD_{acquaint} = 3.43$, $M_{discuss} = 12.14$, $SD_{discuss} = 4.12$, range from 5 ("never") to 20 ("very often")]. Perhaps surprisingly, STEM majors reported statistically significantly higher acquaintance interactions [$t(7804) = -3.54$, $p < 0.01$], discussions with diverse peers [$t(7812) = -5.54$, $p < 0.01$], and critical and analytical thinking gains [$t(6553.3) = -12.50$, $p < 0.01$] than non-STEM majors. Table 1 presents a summary of the mean comparisons.

Table 1

Descriptive statistics, comparing STEM and non-STEM majors

Outcome	STEM M/ SD	Non-STEM M/ SD
Acquaintance index	14.43/ 3.38	14.15/ 3.45
Discussion index	12.46/ 4.12	11.94/ 4.12
Personal/social learning	15.06/ 3.35	15.06/ 3.41
Critical/analytical thinking	3.05/ 0.83	2.81/ 0.85

Note. M = mean. SD = standard deviation. STEM = science, technology, engineering, and math.

I uncovered statistically significant, yet modest, correlations between "becoming acquainted with" diverse peers and personal/social learning ($r = 0.37$, $p < 0.01$) and critical/analytical thinking skills ($r = 0.23$, $p < 0.01$). Similar results were found for engaging in "discussions" with diverse peers and personal/social learning ($r = 0.32$, $p < 0.01$) and critical/analytical thinking skills ($r = 0.27$, $p < 0.01$). Interestingly, personal/social learning and critical/analytical thinking skills were positively correlated ($r = 0.52$, $p < 0.01$).

Hierarchical linear regression tests were employed to measure the relationship between diversity and students' self-reported learning gains as measured by the CSEQ. The first model, including background traits only, was statistically significant, $F(6, 7035) = 35.80$, $p < 0.01$, $R = 0.17$, $R^2 = 0.03$, accounting for only 3% of the variance in personal/social learning scores.

The last model included all 3 sets of predictors (i.e., background traits, college variables, diversity engagement indices). Final regression results indicate a statistically significant relationship between engagement with diverse peers and self-reported personal/social learning gains controlling for differences in backgrounds traits and aspects of the college experience, $F(14, 7027) = 108.54$, $p < 0.01$, $R = 0.42$, $R^2 = 0.18$, $\Delta R^2 = 0.134$, suggesting that "diversity" explains 13% of the variance in learning over and above that which is explained by background traits and college variables (e.g., major, transfer status) alone. Nine significant predictors of personal/social learning were identified: sex, degree aspirations, freshman status, sophomore status, junior status, transfer status, STEM major, and two diversity indices. Table 2 presents a summary of the regression analysis.

Table 2

Hierarchical regression results from final model predicting personal/social learning

Variable	B	SE	β
Constant	10.01	0.32	
Degree aspirations	0.21**	0.09	0.03
Race	0.12	0.10	0.01
First-generation	0.05	0.08	0.01
Marital status	- 0.28	0.19	- 0.02
Age	0.01	0.08	0.00
Sex	0.72**	0.08	0.10
Freshmen	- 1.16**	0.13	- 0.17
Sophomore	- 0.73**	0.12	- 0.08
Junior	- 0.37**	0.12	- 0.04
STEM	- 0.15*	0.08	- 0.02
Transfer status	- 0.56**	0.12	- 0.06
Grades	0.06	0.04	0.02
Acquaintance index	0.27**	0.01	0.28
Discussion index	0.10**	0.01	0.13

*p < 0.05. **p < 0.01.

Hierarchical linear regression tests were employed to measure the relationship between diversity and students' self-reported learning in terms of critical or analytical thinking skills. The first model, including background traits only, was statistically significant, $F(6, 7086) = 34.34$, $p < 0.01$, $R = 0.17$, $R^2 = 0.03$, accounting for only 3% of the variance in critical/analytical thinking skills gain scores. The last model included all 3 sets of predictors (i.e., background traits, college variables, diversity engagement indices). Final regression results indicate a statistically significant relationship between engagement with diverse peers and self-reported critical/analytical thinking learning gains controlling for differences in backgrounds traits and aspects of the college experience, $F(14, 7078) = 73.95$, $p < 0.01$, $R = 0.36$, $R^2 = 0.13$, R^2-change = 0.064, suggesting that "diversity" explains 6% of the variance in learning over and above that which is explained by background traits and college variables (e.g., major, transfer status) alone. Ten significant predictors of enhanced critical/analytical thinking skills were identified: sex, degree aspirations, freshman status, sophomore status, junior status, transfer status, STEM major, grades, and two diversity indices. Table 3 presents a summary of the regression analysis.

Table 3

Hierarchical regression results from final model predicting critical/analytical thinking skills

Variable	B	SE	β
Constant	1.998	0.08	
Degree aspirations	0.12**	0.02	0.07
Race	0.04	0.03	0.02
First-generation	- 0.03	0.02	- 0.01
Marital status	0.04	0.05	0.01

Table 3 (cont'd)

Hierarchical regression results from final model predicting critical/analytical thinking skills

Variable	B	SE	β
Age	0.02	0.02	0.02
Sex	- 0.09**	0.02	- 0.05
Freshmen	- 0.25**	0.03	- 0.15
Sophomore	- 0.15**	0.03	- 0.03
Junior	- 0.05**	0.03	- 0.03
STEM	0.19**	0.02	0.11
Transfer status	- 0.10**	0.03	- 0.04
Grades	0.08**	0.01	0.10
Acquaintance index	0.03**	0.00	0.11
Discussion index	0.03**	0.00	0.17

*p < 0.05. **p < 0.01.

To test for conditional effects, I added four cross-product terms to the regression equation. Statistically significant changes in "variance explained" (R^2) indicate the presence of conditional effects for gender, $\Delta F(1, 6244) = 13.05$, $p < 0.01$, but not race, $\Delta F(1, 6243) = 4.03$, $p = 0.07$. Findings indicate that women benefit more than men from engagement (i.e, discussions and acquaintance) with diverse peers.

Discussion

The purpose of the study was to estimate the educational benefits that accrue to STEM undergraduates who interact with diverse peers. Specifically, in this study, I conducted multivariate analyses on multi-institutional survey data from 8,000 students at 4-year campuses to answer the following: Do STEM students report more learning when they work with diverse peers? Does this relationship vary by race (i.e., URM status) and gender? Results suggest a number of important conclusions.

High advanced degree aspirations, being a woman, being a senior, majoring in a non-STEM field, being a first-time attendee (rather than a transfer student), and frequent interactions with diverse peers all were positively related with personal/social learning gains. That seniors reported higher learning gains than their freshman, sophomore, and junior peers lends support to the "value-added" impact of college over time; in other words, students may learn more as they advance from freshman to senior year. That those who became acquainted with and had discussions with peers who were different from themselves tended to have higher gain scores suggests that frequent exposure to racial/ethnic and cultural diversity may yield (if not initiate) personal and social development. Students who had varied and frequent discussions with peers who were different from themselves perceived to grow more personally and socially than their peers who had fewer or no discussions with diverse peers.

Similarly, high advanced degree aspirations, being a senior, being a first-time attendee (rather than a transfer student), and frequent interactions with diverse peers all were positively related with critical/analytical thinking gains in college. Being a man and STEM major, however, also were related to critical/analytical thinking gains, unlike results from the personal/social learning analysis. That students who frequently engaged diverse others tended to show higher levels of critical and analytical thinking suggests that exposure to diversity may yield cognitive development among undergradduates. From this study, we can glean that racially/culturally diversified campus environments do more than appear or "sound" good, they promote cognitive growth and complex thinking. For instance, students who have discussions with peers who opinions differ from their own engage diverse perspectives which may cause them to think in new and different ways. In other words, students who engage diverse peers (e.g., in discussions) are more likely to encounter situations and/or perspectives for which they have no pre-existing script; this causes cognitive dissonance. As a result, the individual employs a number of strategies to resolve the dissonance (e.g., talking with others, seeking new information, shifting from old to new perspectives). Theory suggests that cognitive development results from resolution of cognitive dissonance. Exposure to diversity, then, is central to developing solutions and enacting ways of thinking that are much more globally oriented; such approaches can be critical in STEM fields.

Conclusion

Results have a number of important implications for educational practice. This analysis provides additional evidence of the educational benefits of diversity, even among STEM fields. College student educators should consider these results when working with students in such disciplines. By engaging diverse peers, students encounter different perspectives, which is likely to lead to cognitive development. Thus, educators would do well to encourage intentional interaction between diverse learners where they can engage each other in conversation, become acquainted with those whose perspectives and opinions are different, as well as work through tensions that arise because of such differences. Living learning communities or special residential arrangements for engineering and/or STEM students hold promise for student success. Physical arrangements in the classroom also seem to be related to this findings; faculty members might adopt pedagogical strategies that encourage student cooperation, study groups, and team assignments, realizing that not only will students learn to function in a diverse, global society but also benefit in terms of learning outcomes.

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