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Science Literacy Skills of First-Generation and Underrepresented First-Year Students and The STEM Pioneers Intervention

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Abstract

First-generation students and other underrepresented groups face particular challenges at college, which can affect whether they thrive in their courses and remain on track to graduate. For students interested in majoring in a STEM field (science, technology, engineering, and math), science literacy skills are necessary for success in their coursework and future careers. We investigated the impact of demographic factors on science literacy skills, retention, and grade point average (GPA). The STEM Pioneers program at Montclair State University (MSU; Montclair, New Jersey, USA) was designed to support first-generation students with an interest in STEM who have not yet declared a major. We found that first-generation, African American/Hispanic, and female students had lower science literacy skills than their peers when they entered college, and first-generation students had lower retention rates. The science literacy scores of STEM Pioneers students who started with the lowest scores improved significantly, while no significant improvements were observed for the students overall. Prior to COVID-19, students in the STEM Pioneers program had slightly higher retention rates than students in the control group. These findings can be used to make improvements to the program and inform other efforts to support underrepresented students with an interest in STEM.

Keywords: first-generation students, STEM, science literacy, retention, undergraduate

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Science literacy skills of first-generation and underrepresented first-year students and the STEM Pioneers intervention

by

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INTRODUCTION

Challenges facing first-generation students

First-generation students face numerous barriers that result in lower retention and graduation rates (Bettencourt et al., 2020; Engle & Tinto, 2008; Riehl, 1994). Here first-generation students are defined as students who do not have a parent with a bachelor's degree, although other studies define first-generation students as those whose parents did not have any postsecondary education. These barriers start before college. First-generation students tend to have lower high school GPAs and SAT scores, illustrating that first-generation students often enter college with less preparation and weaker study skills (Riehl, 1994). This is further supported by Engle and Tinto (2008), who found that 35% of low-income, first-generation students have taken remedial courses in college, compared to 23% of students who were neither low income nor first-generation. In looking specifically at STEM fields, Bettencourt et al. (2020) found that first-generation status itself did not predict whether a student would earn a STEM degree, but that pre-college STEM experiences seem to be related to the lower graduation rates of first-generation students in STEM majors. While in high school, first-generation students were less likely to enroll in advanced math and science courses, showed lower math self-efficacy, earned lower math test scores, and were less likely to have a parent with a STEM profession. These limited pre-college experiences appear to have inhibited first-generation students' success in college-level STEM courses.

More important than high school background may be the students' in-college experience. Lohfink and Paulsen (2005) found that pre-college indicators (level of rigor of high school courses and college entrance exam scores) were not significantly related to

whether first-generation college students persisted to their sophomore year. Instead, they found that several in-colleges experiences mattered, such as first year GPA: the lower their GPA, the more likely students were to drop out of school. Soria and Stebleton (2012) found significant differences in academic engagement between first-generation and non-first-generation students. First-generation students reported lower levels of contributing to class discussions and interacting with faculty, when other factors, including gender, ethnicity, and GPA, were held constant (Soria & Stebleton, 2012). Additionally, first-generation students are more likely to be part of ethnic groups that have lower rates of college enrollment, and face discrimination on campus. They must adjust to college cultures that differ from their home cultures (Engle & Tinto, 2008). The challenges are compounded for many first-generation students because they are also members of other disadvantaged groups, and thus "inhabit intersecting sites of oppression" (Lohfink & Paulsen, 2005). The struggles faced by first-generation students in college are often explained as a result of a lack of social capital, the "privileged knowledge, resources, and information attained through social networks" that are passed from college-educated parents to their children (Soria & Stebleton, 2012).

Engle and Tinto (2008) found that although low-income, first-generation students were about as likely to have an undeclared major in their first year as their peers, undeclared, low-income, first-generation students were about four times more likely to withdraw from college than undeclared students who were neither low-income nor first-generation (42% of undeclared low-income, first-generation students withdrew compared to 11% of their undeclared peers). In their first year, low-income, first-generation students were as likely to major in math, science, computer science, or engineering as

their peers. However, low-income, first-generation students with math and science majors as their first major were 15% less likely than their peers to stay in their major, the largest gap observed for any major/field (Engle & Tinto, 2008). Bettencourt et al. (2020) found that only 9% of first-generation students completed college to earn a STEM degree, compared to 15% of non-first-generation students. Thus the combination of pre-college limitations combined with the challenges discussed earlier result in a "cumulative disadvantage" for first-generation students (Bettencourt et al., 2020).

Supporting first-generation students

Engle and Tinto (2008) offer recommendations to colleges for supporting low-income, first-generation students. Since a majority of low-income, first-generation students who withdraw do so after their first year, their study recommends focusing programming on the first year. Other recommendations include learning communities (where students are enrolled in multiple courses together), mentoring, advising systems, tutoring and developmental coursework, social support services, and teaching methods to promote student engagement with peers and faculty (Engle & Tinto, 2008).

The STEM Pioneers program at Montclair State University (MSU) targets first-year undergraduate students who have expressed an interest in STEM majors, but have not yet declared a major. The program is focused on first-generation college students, many of whom are also members of other groups underrepresented in STEM, such as African American, Hispanic, and female students. Participating students enroll in a science literacy course in their first fall semester, and peer mentoring is available. The STEM Pioneers program follows several of the recommendations by Engle and Tinto

(2008): it is focused on first year students, incorporates learning communities, and provides mentoring.

Science literacy

Science literacy can be defined as "the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (Organisation for Economic Co-operation and Development, 2003) and includes the ability "to think critically and independently, to recognize and weigh alternative explanations of events and design trade-offs, and to deal sensibly with problems that involve evidence, numbers, patterns, logical arguments, and uncertainties" (American Association for the Advancement of Science, 1993). Science literacy skills, including applying the scientific process and quantitative skills, are a key focus of the STEM Pioneers program because these skills are essential in order for program participants to be successful in completing coursework for a STEM degree. Beyond college, strong science literacy skills are required to pursue a career in a STEM field, but also to prepare students to be informed and engaged citizens regarding current issues involving science and technology, regardless of career.

Diversity in STEM fields

An additional benefit of programs such as STEM Pioneers, which include large proportions of female, African American, or Hispanic students, is to improve diversity in STEM fields, thus increasing the talent pool. According to the U.S. Department of Commerce, women are underrepresented in both earning STEM undergraduate degrees

(except for in physical and life sciences) and in holding STEM jobs. In 2009, women earned about 27% of STEM undergraduate degrees (social science majors were excluded in this report) and held about 24% of all STEM jobs (education and social scientist jobs were excluded in this report) (Beede, Julian, Langdon, et al., 2011). About half as many African American and Hispanic workers are employed in STEM positions (excluding education and social scientist jobs) as would be expected based on their proportion of the workforce. While similar percentages of white (22%), African American (17%), and Hispanic (21%) college graduates earn a STEM major (excluding social science majors), white students (35%) make up a larger percentage of college graduates than African American (22%) and Hispanic students (14%) (Beede, Julian, Khan, et al., 2011).

In this work, we investigated the impact of demographic factors such as first-generation status, ethnicity, and gender of incoming first-year students on science literacy skills, GPA, and retention. We also analyze the impact of the STEM Pioneers program on science literacy, GPA, retention, motivation, and declaration of STEM majors by students who participated in the first three cycles of the program.

METHODS

The STEM Pioneers program

The STEM Pioneers program at MSU targets incoming first-generation first-year undergraduate students who have expressed an interest in STEM fields, but have not yet declared a major. Participating students enroll as a cohort in a science literacy course (CSAM101: Science Matters), a first-year college writing course (WRIT105) and New Student Seminar (GNED199; a one credit course to acculturate students to campus life)

in their first fall semester. The program initially included an optional second semester follow-up program, but student enrollment was too low to be able to offer it for more than the first two cycles of the STEM Pioneers program. The program includes additional supports, such as peer mentoring sessions and cohort building field trips to STEM-themed locations, including a historic site and nature experiences. The program does not include financial support. The instructors participate in a dedicated faculty development learning community.

Summary of subjects

The 139 students included in this study were all first-year undergraduate students at MSU when they began participating in the study. The students in this study were in three cohorts, beginning their college experience in the fall semesters of 2017, 2018, and 2019. Students were invited verbally or via email to participate in the study. The 56 control group students were invited from introductory science courses that were selected for having both STEM and non-STEM major first-year students. The 83 students in the STEM Pioneers Program were invited to take part in surveys during their science literacy class (CSAM101).

A majority of the STEM Pioneers students were first-generation college students (83.1%), African American or Hispanic (65.1%), and/or female (73.5%) (Table 1). First-generation college students are defined in this study as students who do not have a parent who attended college for at least four years. The STEM Pioneers program enrolled a higher percentage of first-generation college students (83.1%) than the control group (48.2%) and a higher percentage of African American/Hispanic students (65.1%) than the control group (46.4%) (Table 1). Nearly all of the students in the STEM Pioneers

program had not yet declared a major when they started college (95.2%), compared to about a third of the students in the control group (33.9%). Students in the STEM Pioneers program and in the control group reported similar levels of hours worked per week (an average of 10.2 ± 1.1 hours).

Table 1. Demographic characteristics of students in study.

	Percentage of all students in study	Percentage of students in STEM Pioneers	Percentage of students in control group
First-generation	69.1%	83.1%	48.2%
African American/ Hispanic	57.6%	65.1%	46.4%
Female	76.3%	73.5%	80.4%
Undeclared	70.5%	95.2%	33.9%

Test of Scientific Literacy Skills

In order to assess science literacy skills at the beginning and end of students' first semester, we used the Test of Scientific Literacy Skills (TOSLS). The TOSLS is a 28 multiple-choice question assessment on scientific literacy skills developed by Gormally et al. (2012). The instrument was piloted and revised over the course of five semester cycles in general biology undergraduate courses. Analysis showed that the TOSLS instrument is reliable and valid in a biology education context (Gormally et al., 2012). The TOSLS has also been applied in chemistry and earth science courses and a range of general education natural science courses (Shaffer et al., 2019; Waldo, 2014). The TOSLS has been described as “discipline-nonspecific” (Waldo, 2014), and was chosen for this study for its general scientific skills. Overall results on the TOSLS are reported as total points out of a possible 28, and results for specific skill categories are reported as

percent correct, due to varying numbers of questions for each category. Skills tested include the following: (Gormally et al., 2012)

1. Scientific process and inquiry skills

    1A. Identifying valid scientific arguments

    1B. Conducting an effective literature search (evaluating validity of sources)

    1C. Evaluating the use of scientific information

    1D. Understanding elements of research design

2. Quantitative skills

    2A. Creating graphs

    2B. Reading and interpreting graphs

    2C. Solving problems using quantitative skills

    2D. Understanding basic statistics

    2E. Justifying inferences, predictions, and conclusions based on quantitative data

Motivated Strategies for Learning Questionnaire

The Motivated Strategies for Learning Questionnaire (MSLQ) is a Likert-scaled instrument for students to self-report their motivation and use of learning strategies, developed by Pintrich et al. (1993). Analysis of data from 380 undergraduates showed that the MSLQ instrument is reliable and valid in undergraduate courses in a variety of fields (Pintrich et al., 1993). The version used in this study contained 44 items out of the original 81 available (Pintrich & De Groot, 1990). The scales ranged from 1 (not at all

true of me) to 7 (very true of me), and the average in each category was calculated. The rating on some negatively worded items was reversed, and results are reported as averages out of a maximum of 7. As listed in Pintrich and De Groot (1990), beliefs and behaviors tested include:

1. Motivational beliefs
    - 1A. Self-efficacy
    - 1B. Intrinsic value
    - 1C. Test anxiety
2. Self-regulated learning strategies
    - 2A. Cognitive strategy use
    - 2B. Self-regulation

Self-efficacy refers to the student's perceived competence and confidence in the course, and is indicated by agreement with statements such as "I expect to do very well in this class." Intrinsic value refers to the student's intrinsic interest and perceived importance of the class topics, and is indicated by agreement with statements such as "I like what I am learning in this class" and "Understanding this subject is important to me" (Pintrich & De Groot, 1990). The self-efficacy portion of the MSLQ was used in a study of over 600 undergraduate STEM students by Wilson et al. (2015). They found that women reported significantly lower levels of self-efficacy than men, although this difference was not present in some engineering fields.

Data collection and analysis

At the beginning and end of the fall semester, participating students were administered a demographic survey, the TOSLS, and the MSLQ. These surveys were taken on paper, in class. A researcher was present for the administration, but the instructors were not. Students were given up to 70 minutes to take the TOSLS and MSLQ and complete the survey, although they did not all use the full time. Results were transcribed into Excel files afterward. This study was approved by the Montclair State Institutional Review Board Protocol (IRB-FY15-16-267).

The data were analyzed using statistical tests in RStudio (Version 1.2.5042) (RStudio Team, 2020), using the tidyverse (Wickham et al., 2019), plotrix (Lemon, 2006), and rstatix (Kassambara, 2020) packages. The statistical tests included chi-squared tests, t-tests, and two-way mixed ANOVA tests. When the two-way mixed ANOVA test showed a statistical difference, post-hoc tests, with Bonferroni adjustment, were used to analyze for a group effect at each time point and to make pairwise comparisons between groups. For the t-tests, the Welch t-test was used when the variances were unequal and the Wilcoxon test was used when distributions were not normal. A statistically significant difference was found between the groups when $p < .05$.

RESULTS

Impact of demographic factors

Similar starting points for motivation and learning strategies

The MSLQ was used to investigate student motivation and use of learning strategies. We examined science literacy skills, GPAs, and retention rates in the context of students' motivation and learning strategies, because these could be driving forces for the other measures of achievement. We wanted to determine if motivation or learning strategies explained differences in students' TOSLS scores, GPAs, and retention rates.

No significant differences on the initial motivation (self-efficacy and intrinsic value) or learning strategies scores as measured via the MSLQ were found among the demographic groups (first-generation status, ethnicity, and gender) of all participating students in the study (STEM Pioneers and control group), as shown by t-tests and Wilcoxon tests. When using two-way mixed ANOVA tests to compare pre- and post-semester MSLQ scores, no significant interactions were found between demographic groups and pre- to post-score changes. This implies that something other than motivation or learning strategies, such as students' backgrounds, opportunities, or resources, was responsible for differences in TOSLS scores, GPAs, and retention rates (discussed below).

Retention rates

For all students, both STEM Pioneers and control group, a chi-squared test showed that first-generation students had a significantly lower retention rate to their sophomore year (67.7%) than non-first-generation students (85.0%) ($X^2(1, N = 136) = 4.26, p = .039$)

(Table 2). Retention rates for African American/Hispanic students and students of other ethnicities, and for male and female students, were similar. The lower retention of first-generation students illustrates the importance of designing and implementing programs that target this population, such as the STEM Pioneers program.

Table 2. Retention rates and average GPAs for different demographic groups. The retention rates shown are for fall of their sophomore year and the GPAs are for fall of their first year. The students include both STEM Pioneers and control group students.

	Retention rate	Average GPA		Retention rate	Average GPA
First-generation	67.7%	2.71 ± 0.10 (N = 96)	Non-first-generation	85.0%	3.05 ± 0.10 (N = 40)
African American/ Hispanic	73.8%	2.79 ± 0.09 (N = 80)	Other ethnicities	72.9%	2.86 ± 0.12 (N = 59)
Female	72.6%	2.84 ± 0.09 (N = 106)	Male	75.8%	2.76 ± 0.15 (N = 33)
Undeclared	71.4%	2.78 ± 0.09 (N = 98)	Declared	78.0%	2.91 ± 0.13 (N = 41)

Grade point averages

For all students (STEM Pioneers and control group), first-generation and undeclared major students had lower GPAs in the fall of their first year than the other students (Table 2). However, these differences were not statistically significant, as shown by Wilcoxon tests.

Science literacy skills

For all students, both STEM Pioneers and control students, certain groups of students started their first semester of college with lower science literacy skills, as measured on the TOSLS. These groups included first-generation college students, African American or

Hispanic students, and women, as shown in Figure 1. There was a significant difference in the TOSLS pretest scores for first-generation college students (10.5 ± 0.4 S.E.) and non-first-generation students (12.7 ± 0.8) (W = 1306, p = .008), as shown by the Wilcoxon test. There was also a significant difference in the TOSLS pretest scores for African American/Hispanic students (10.2 ± 0.4) and students of other ethnicities (12.5 ± 0.6) (t(90.43) = -3.1183, p = .002), as shown by the Welch t-test. Additionally, there was a significant difference between male students (12.2 ± 0.6) and female students (10.8 ± 0.4) (W = 1965, p = .038), as shown by the Wilcoxon test. Finally, there was a significant difference in the TOSLS pretest scores for undeclared major students (10.6 ± 0.4) and declared major students (12.5 ± 0.8) (W = 1448, p = .029), as shown by Wilcoxon test. Students who had declared a major demonstrated better science literacy skills than students who had not declared a major.

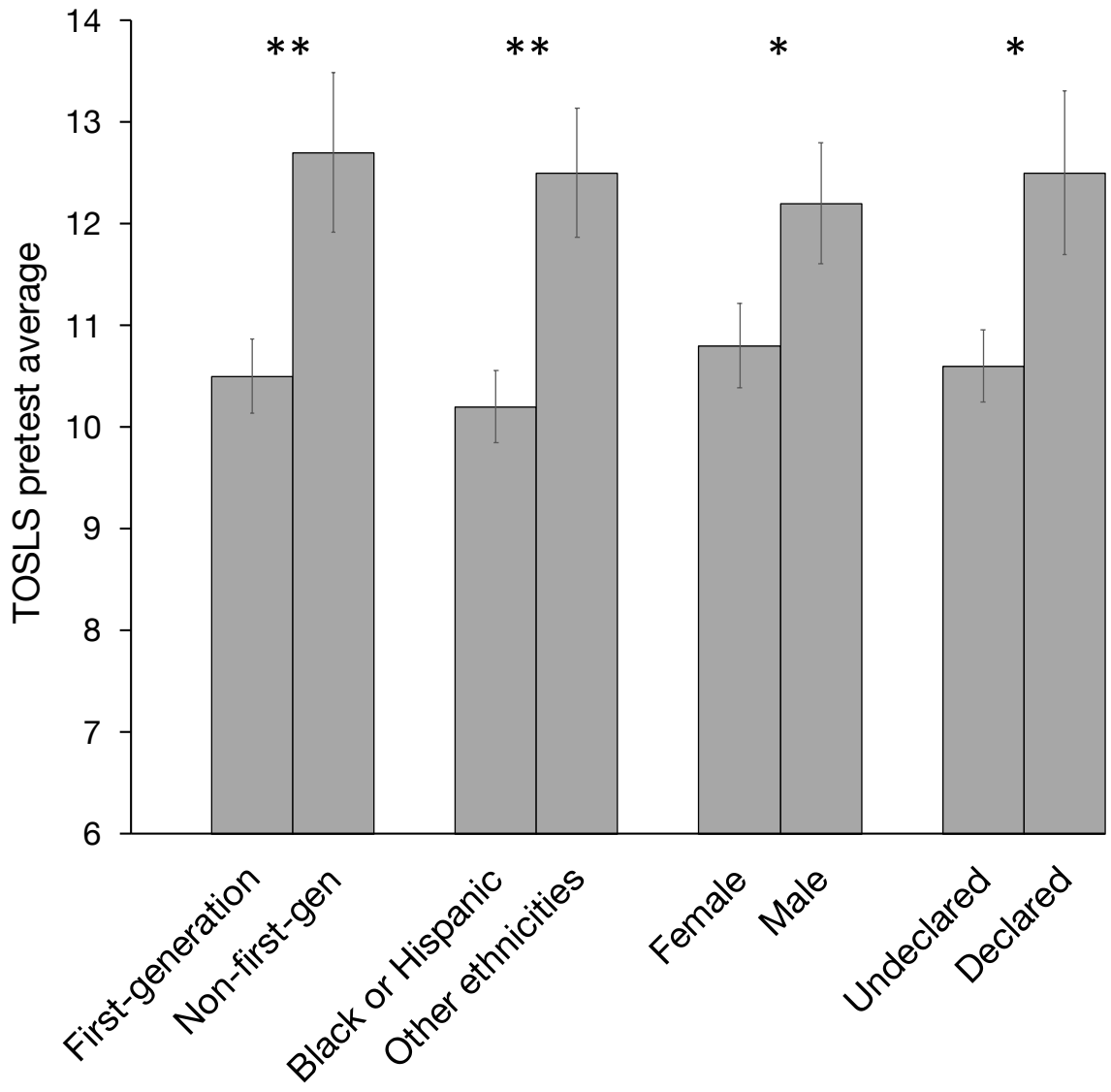

Figure 1. TOSLS pretest averages for different demographic groups. Average TOSLS pretest scores were compared for demographic groups using Wilcoxon or Welch t-tests. * indicates significant difference with $p < .05$, and ** indicates significant difference with $p < .01$. Error bars show standard errors.

Effect of STEM Pioneers program on participants

Undeclared students in STEM Pioneers and control group started with similar science literacy and motivation scores

The STEM Pioneers program was designed to serve undeclared major students. In order to eliminate additional factors that may have influenced outcomes, we compared undeclared students in the STEM Pioneers program with undeclared students in the control group. Undeclared students who were enrolled in the STEM Pioneers program and undeclared students in the control group had similar TOSLS pretest scores (Table 3). This means that undeclared students in both groups began the year with comparable levels of scientific literacy. Undeclared students in both groups also had similar motivation pre-semester scores (for both self-efficacy and intrinsic value subcategories) and similar learning strategies pre-semester scores. The similar starting points in terms of science literacy skills, motivation, and learning strategies for undeclared students in STEM Pioneers and in the control group facilitates our comparison of data collected about these two groups.

Table 3. Average scores for undeclared students, in the STEM Pioneers program and in the control group. These scores are for the beginning of their first year fall semester.

	Undeclared students in STEM Pioneers	Undeclared students in control group
TOSLS pretest average	10.4 ± 0.4 (N = 79)	11.6 ± 0.7 (N = 16)
Motivation average	5.46 ± 0.08 (N = 78)	5.20 ± 0.23 (N = 19)
Learning strategies average	5.12 ± 0.09 (N = 78)	5.38 ± 0.16 (N = 19)

Grade point averages and retention rates

Students enrolled in STEM Pioneers had higher retention rates than those in the control group for cohorts 1 and 2, although these were not statistically significant differences. Students in the control group had a higher retention rate for cohort 3, and a slightly higher retention rate overall, although neither of these were significant differences. A limitation of the retention data is the effect of COVID-19, which may have influenced students' enrollment for fall 2020. This was the fall of sophomore year for cohort 3, which had a non-statistically significantly lower sophomore retention rate than the first two cohorts. To address this limitation, retention data were analyzed by cohort (Table 4).

Table 4. Retention rates by cohort for students in STEM Pioneers and for students in the control group. The retention rates shown are for fall of sophomore year.

Cohort	Retention rate, STEM Pioneers	Retention rate, control
1	75.0%	66.7%
2	80.0%	74.1%
3	58.3%	85.7%
Overall	72.3%	75.0%

The STEM Pioneers program targeted undeclared major and first-generation students, so these groups of students were compared in STEM Pioneers and in the control group. Undeclared major students in the STEM Pioneers program had a slightly higher retention rate to sophomore year (72.2%) than those in the control group (68.4%), although this difference was not statistically significant based on a chi-squared test. First-generation students in STEM Pioneers had a higher retention rate and higher GPAs (for

fall and spring semesters of their first year) than first-generation students in the control group (Table 5). These differences were not significant by the Wilcoxon test (for GPAs) or by chi-squared test (for retention rates). These patterns suggest that the Pioneers program may have helped first-generation students (with regards to GPA and retention) to some extent, but a larger sample size would be necessary to demonstrate statistical significance for these findings.

Table 5. GPAs and retention rates for first-generation students, in both the STEM Pioneers program and in the control group. The retention rates shown are for fall of sophomore year.

	GPA (fall first year)	GPA (spring first year)	Retention rate
First-generation, STEM Pioneers	2.76 ± 0.11 (N = 69)	2.70 ± 0.11 (N = 69)	69.6%
First-generation, control	2.60 ± 0.20 (N = 26)	2.46 ± 0.22 (N = 27)	63.0%

Science literacy skills

The STEM Pioneers program, and specifically the fall semester science literacy class, did not appear to be effective in improving science literacy, as measured by the TOSLS. When using a two-way mixed ANOVA test to compare pretest and posttest TOSLS scores, no significant differences were found by enrollment in the STEM Pioneers program. In comparing the pretest and posttest scores of the students in STEM Pioneers (Table 6), a paired t-test showed that there was no significant change across the semester. Of the participating students, 34 showed a decrease in TOSLS score, 28 showed an increase in TOSLS score, and 10 showed no change.

Table 6. TOSLS pretest and posttest average scores for STEM Pioneers.

	TOSLS pretest average	TOSLS posttest average
All STEM Pioneers	10.4 ± 0.4 (N = 83)	9.89 ± 0.49 (N = 73)
STEM Pioneers who initially scored 7 or below	5.71 ± 0.27 (N = 17)	8.36 ± 0.71 (N = 14)

However, an improvement was found when looking at the students who started with the weakest science literacy skills. For students in STEM Pioneers who initially scored 7 or below on the TOSLS, there was a significant difference between TOSLS scores at the beginning and end of the semester, as shown by paired t-test ($t(13) = -3.544$, $p = 0.004$) (Table 6). This may suggest that the STEM Pioneers intervention better served the learning needs of the students with the poorest science literacy skills, who may have had little opportunities for exposure to science in the past.

Overall, the STEM Pioneers students performed better on the skill categories relating to the scientific process than on the quantitative skills. Table 7 shows the pretest and posttest averages for each skill category for the STEM Pioneers students. The STEM Pioneers students showed the greatest improvement in the skill of solving problems using quantitative skills. For the Pioneers overall ($V = 258.5$, $p = 0.034$) and for cohort 1 ($V = 10.5$, $p = 0.026$), this was a significant improvement over the course of the semester, as shown by the Wilcoxon test. Their improvement in this category was likely supported by concurrent enrollment in math classes. The STEM Pioneers students overall showed a significant decline ($V = 865.5$, $p = 0.022$) in the skill of understanding elements of research design. When each cohort was examined separately for this skill, it was only

cohort 3 that showed a significant decline (V = 88, p = 0.002), and cohort 1 showed an improvement. The STEM Pioneers students also showed a borderline significant drop (V = 626, p = 0.053) for the skill of identifying valid scientific arguments, and cohort 3 showed a significant drop in this skill (V = 85, p = 0.038).

Table 7. Pretest and posttest averages for each TOSLS skill category, for the STEM Pioneers students. The TOSLS was administered at the beginning and end of the fall semester of their first year.

Skill	Pretest average	Posttest average
Identifying valid scientific arguments	45.4% ± 3.5	37.9% ± 4.1
Evaluating validity of sources	31.1% ± 2.1	35.3% ± 2.9
Evaluating the use of scientific information	48.6% ± 3.2	43.4% ± 3.9
Understanding elements of research design	40.4% ± 2.6	33.6% ± 2.5
Creating graphs	18.1% ± 4.3	13.7% ± 4.1
Reading and interpreting graphs	43.7% ± 3.1	35.6% ± 3.3
Solving problems using quantitative skills	27.7% ± 2.7	37.4% ± 3.6
Basic statistics	29.7% ± 2.9	30.1% ± 3.1
Justifying inferences, predictions, and conclusions based on quantitative data	39.8% ± 3.8	37.7% ± 4.0

Motivation

Students in all three STEM Pioneers cohorts experienced drops in their motivation (self-efficacy and intrinsic value) and learning strategies scores over the course of the semester (Table 8). As shown by paired t-test, there was a significant difference in the motivation scores between beginning (5.47 ± 0.08) and end (5.17 ± 0.11) of the semester (t(71) =

3.38, $p = .001$), and also a significant difference in the learning strategies scores between beginning (5.12 ± 0.10) and end (5.00 ± 0.09) of the semester ($t(71) = 2.07$, $p = .042$). The drop in average motivation scores was larger than the average drop in learning strategies scores. Breaking the motivation score into subscales, there were slightly bigger drops in intrinsic value scores than for self-efficacy scores. Perhaps, with more exposure to STEM fields, students discovered that the subjects were not what they expected and not what they were truly interested in. This explanation is consistent with a drop in likelihood of declaring a STEM major. On a scale of 1 to 5, with 1 indicating "definitely" and 5 indicating "no way," undeclared Pioneers students reported a drop in how likely they were to declare a STEM major between the beginning (2.89 ± 0.12) and end of the semester (2.99 ± 0.15). The control group students did not show a change in average motivation score, but they did also experience a downward trend in learning strategies (from 5.24 ± 0.12 to 5.14 ± 0.12). As shown by a two-way mixed ANOVA test, enrollment in the STEM Pioneers program (as opposed to being in the control group) had no significant effect on the change in motivation or learning strategies scores from pre to post administration.

Table 8. MSLQ averages for students in the STEM Pioneers program. Scores are for the beginning and end of their first year fall semester. Intrinsic value and self-efficacy are subscales of motivation.

	Beginning average (N = 82)	Ending average (N = 73)
Motivation	5.47 ± 0.08	5.17 ± 0.11
· Intrinsic value	5.49 ± 0.09	5.10 ± 0.11
· Self-efficacy	5.46 ± 0.09	5.23 ± 0.12
Learning Strategies	5.12 ± 0.10	5.00 ± 0.09

Declaration of STEM major

Students in the STEM Pioneers program were somewhat more likely to declare a STEM major than students in the control group. Of initially undeclared students, more students in STEM Pioneers (14%) had declared a STEM major by the fall of their sophomore year than in the control group (0%), although this difference was not significant, as shown by chi-squared test. STEM majors declared by initially undeclared students in the STEM Pioneers program included economics (2 students), psychology (2 students), sociology (2 students), biology (1 student), earth and environmental science (1 student), information technology (1 student), and physics (1 student). A similar number of initially undeclared STEM Pioneers declared a major in a non-STEM field, and most remained undeclared in the fall of their sophomore year.

DISCUSSION

The primary goal of the STEM Pioneers program was to increase science literacy among first-year, first-generation students who had not yet declared a major, but were interested in science. Additionally, the program aimed to bring these students into a science major and encourage them to continue seeking a degree at the university. We analyzed data from the TOSLS, the MSLQ, retention rates, major declaration, and GPAs, both from students enrolled in the STEM Pioneers program and students in a control group.

Science literacy

We found that first-generation, African American/Hispanic, and female students scored significantly lower on the TOSLS than their peers (Figure 1). Our findings were consistent with studies in the literature that found lower science literacy scores for African American/Hispanic and first-generation students (Nuhfer et al., 2016; Shaffer et al., 2019). We also found that undeclared major students scored lower on the TOSLS, with a significant difference (Figure 1). To our knowledge, no previous reports comparing TOSLS scores of students who have declared a major and those who are undeclared are available in the literature. This finding suggests that students with lower science literacy skills may lack confidence in declaring a STEM major. This is further indication of the importance of programs such as STEM Pioneers that target undeclared major students with an interest in STEM and support them in declaring and succeeding in STEM majors.

Shaffer et al. (2019) administered the TOSLS to more than 700 undergraduate students. They found that African American/Hispanic and female students had lower TOSLS averages (a significant difference only for ethnicity). Our results are consistent

with Shaffer et al. in that African American/Hispanic and female students tested for this project scored lower on the TOSLS. However, Shaffer et al. (2019) also found that there was no significant difference by ethnicity or gender after taking into account other variables, including SAT math and reading scores, previous semester GPA, year in college, and STEM major status. Their study found that the most significant predictor of performance on the TOSLS was the SAT reading score. Shaffer et al. (2019) concluded that ethnicity and gender do not contribute to science literacy skills, but that aptitude and training (measured by SAT scores, GPA, year in college, and STEM major status) are correlated with science literacy skills. The SAT reading score more strongly correlated with TOSLS scores than did the SAT math score. The authors further noted that fundamental literacy is necessary to succeed on the text-heavy TOSLS, and that the SAT reading section requires students to identify evidence in the passages and comprehend tables or graphs, which are skills tested on the TOSLS. Students in STEM majors scored higher than non-STEM majors on the TOSLS.

Another science literacy assessment tool, the Science Literacy Concept Inventory (SLCI), has also been found to be reliable and valid (Nuhfer et al., 2016). The SLCI differs from the TOSLS by focusing more on the nature of science (what constitutes a scientific theory, science versus technology, ethics, etc.). Furthermore, the SLCI does not include any figures or a focus on quantitative analysis. In a study involving more than 17,000 undergraduates, Nuhfer et al. (2016) found that first-generation students scored lower on the SLCI than did non-first-generation students, with a significant difference, and found no difference by gender. This study is consistent with our finding that first-generation students had lower TOSLS scores, but not with our finding that women scored

lower than men. Their study also found significant differences across ethnicities, but these were partly explained by the socio-economic conditions of first-generation status, native English speaking status, and interest in majoring in science. For example, white students had the highest average SLCI scores, but were advantaged by both having the lowest percentage of first-generation students and the highest percentage of native English speakers (the study found that native English speakers scored higher than non-native speakers, with a significant difference). Their study further showed that students who had declared, or were interested in declaring, a science major scored higher, with a significant difference, than nonscience majors. The much larger sample size in the Nuhfer et al. (2016) study enabled more analyses by demographic groups than we could do with our smaller sample size, where many students belonged in multiple groups.

The STEM Pioneers program was successful in improving science literacy skills for the students entering with the lowest levels, but not for the group as a whole (Table 6). Science literacy is a complex set of skills, and the tool used to measure these skills matters. While we did not see a change based on the TOSLS over the course of the fall semester for the students as a whole, this does not mean that the students did not learn any science literacy skills. The STEM Pioneers students showed a significant improvement in the skill of solving problems using quantitative skills (Table 7). The STEM Pioneers students performed better on the skills relating to the scientific process than on the quantitative skills (Table 7), consistent with findings by Waldo (2014). Furthermore, findings are limited to what the TOSLS instrument assesses. Other instruments, such as the SLCI, might have shown different results, because of their varied skill emphases. The TOSLS includes a number of figures and questions involving

quantitative analysis and graph interpretation, while the SLCI is more focused on the nature of science and is fully text-based (Gormally et al., 2012; Nuhfer et al., 2016). There is agreement that science literacy is important, but it is defined and measured in multiple ways.

Our findings show that, despite motivated and talented instructors, it is difficult to improve science literacy as measured by the TOSLS, particularly in a short amount of time, such as a single semester or within a single course. In a study by Waldo (2014), students starting their second (or more) general education science course scored significantly higher on the TOSLS than students starting their first such course. Since it is unlikely that students in the Waldo study took more than the two required science courses, this suggests that a single course can improve science literacy skills. Our findings are not consistent with Waldo's findings, but they are somewhat consistent with reported findings using the SLCI (Nuhfer et al., 2016). Small changes in SLCI scores between pre- and post-course administrations showed that it is challenging for a single course to produce improvements in science literacy, although the posttest averages were significantly different than the pretest averages with a 2.95% improvement. Furthermore, there was little difference found in SLCI scores among students who had taken zero, one, or two science courses.

However, multiple science courses over a longer period of time have shown significant results, indicating that science literacy needs to be nurtured over time. Students' science literacy skills may also improve with time as they complete college courses (in any field) that develop their general literacy. Students who had taken three science courses showed a significant increase on the SLCI over those who had taken

none, and students who had taken more than four science courses showed significant increases over students who had taken fewer courses (Nuhfer et al., 2016). The SLCI averages for seniors were significantly higher than those for first-year students, and higher TOSLS scores have been reported for seniors compared to first-year students (Shaffer et al., 2019). Thus, developing science literacy may be an unrealistic goal for the STEM Pioneers program to accomplish alone in one semester. Instead, the program could be one component in pursuing this goal, setting students up for further learning gains during later science course work, thus leveling the playing field. One strategy that we may explore in the future is to focus on a single TOSLS skill category for a semester and have students practice this skill repeatedly. It is possible that trying to teach so many challenging skills dilutes the effect and that a singular focus might have been more effective.

Retention and major declaration

With regard to retention, we found that students who withdrew and students who continued their enrollment had very similar TOSLS, motivation, and learning strategies pre-semester scores; t-tests and Wilcoxon tests showed no significant differences between retained and withdrawn students in these pre-semester scores. Thus, in our study population, science literacy skills, motivation, and learning strategies did not explain why students may or may not have withdrawn.

We found that first-generation students (67.7%) had lower retention rates than non-first-generation students (85.0%) ($X^2(1, N = 136) = 4.26, p = .039$). These findings are consistent with studies in the literature. Engle and Tinto (2008) found that 76% of low-income, first-generation students at public four-year colleges returned for their

second year, compared to 84% of students in neither category. After six years, 34% of low-income, first-generation students at public four-year colleges earned a bachelor's degree, compared to 66% of students who did not belong in either category. Soria and Stebleton (2012) found a significant difference between sophomore retention rates of first-generation and non-first-generation students. First-generation students were 45% less likely to be retained for their sophomore year, when other factors, including gender, ethnicity, and GPA, were held constant.

We found that STEM Pioneers in cohort 3 had a lower retention rate than the first two cohorts (Table 4), likely due to COVID-19 occurring during their sophomore year. The students in STEM Pioneers may have been more vulnerable to the effects of COVID-19 due to their intersecting identities in other disadvantaged groups. A majority of students in STEM Pioneers were first-generation and undeclared major students, which was not the case for students in the control group.

On the other hand, students with an undeclared major who were enrolled in the STEM Pioneers program had a slightly higher retention rate (72.2%) than those in the control group (68.4%). Also, first-generation students in STEM Pioneers had higher retention rates than those in the control group (Table 5). By the beginning of their sophomore year, of the initially undeclared students, more students in STEM Pioneers (14%) declared a STEM major than those in the control group (0%). Although these were not statistically significant differences, these findings illustrate the potential of STEM Pioneers and inform other efforts to support underrepresented students interested in STEM.

CONCLUSION

The STEM Pioneers program at Montclair State University was designed to support first-generation college students who were interested in majoring in a STEM field, but had not yet declared a major. The students enrolled in a science literacy course in their first year to help them develop skills needed for them to succeed in STEM major courses and careers.

In this study, we found that first-generation students had a significantly lower retention rate to sophomore year than did non-first-generation students. We found significant differences on the TOSLS scores when the scores were analyzed by first-generation status, ethnicity, gender, and major declaration status. These differences cannot be explained by differences in the students' motivation or use of learning strategies, as no significant differences were found on the MSLQ scores. It is interesting that undeclared major students scored significantly lower on the TOSLS compared to students who had declared a major. This is the first report of this observation and highlights the importance of offering this population support services and programming. Modest benefits of the STEM Pioneers program were seen in higher retention rates and GPAs for the first-generation students in the program compared to those in the control group. More initially undeclared students in STEM Pioneers than in the control group declared a STEM major. No significant differences between the TOSLS scores at the beginning and end of the semester were found for the STEM Pioneers students overall, but students who started with the lowest scores did show a significant improvement over the semester.

Programs like the STEM Pioneers play an important role in supporting first-generation students as they navigate challenges in a college environment. Because many first-generation students are also members of other groups underrepresented in STEM fields, such as African American, Hispanic, and female students, these programs also help to increase diversity in STEM fields and prepare more people for careers in STEM. The findings in this study demonstrate both the potential and the challenges of the STEM Pioneers program, and can be used to guide other efforts to support first-generation students in STEM.

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