# Perceptions and Preferences of High School Students in STEM: A Case Study in Connecticut and Mississippi

**Bin (Brenda) ZHOU**
**(Corresponding Author)**
**Department of Engineering, Central Connecticut State University**
**New Britain, CT 06050, U.S.A.**

**Clifford ANDERSON**
**Department of Engineering, Central Connecticut State University**
**New Britain, CT 06050, U.S.A.**

**Feng WANG**
**Department of Civil and Environmental Engineering, Jackson State University**
**Jackson, Mississippi 39217, U.S.A.**

**and**

**Lin LI**
**Department of Civil and Environmental Engineering, Jackson State University**
**Jackson, Mississippi 39217, U.S.A.**

## ABSTRACT

This study uses data collected at two National Summer Transportation Institute (NSTI) programs in Connecticut and Mississippi to investigate high school students' perceptions and preferences about education in science, technology, engineering and mathematics (STEM). Family background has a significant impact on a high school student's interest in STEM, as shown during the student recruitment stage and by the analysis of the students' college education plans prepared upon graduation from the two NSTI programs. The building exercise and competition instrument is the most effective among the few examined, while passive learning is not what young people prefer when briefly introduced in the two NSTI programs.

**Keywords**: STEM Education, Pre-university Outreach, Discrete Choice Model, Educational Instruments

## 1. INTRODUCTION

National Summer Transportation Institute (NSTI) programs are one of the Federal Highway Administration's (FHWA) educational initiatives. "The NSTI program is managed by FHWA's Office of Civil Rights ... The program focuses on raising students' awareness in transportation careers and encourages students to pursue transportation courses at the college/university level." [1] The two NSTI programs in Connecticut and Mississippi seek ways to promote STEM among students who will soon be making education and career decisions.

The two NSTI host sites are Central Connecticut State University (CCSU) in Connecticut and Jackson State University (JSU) in Mississippi. CCSU is a regional, comprehensive public university, with a traditional diverse student body – more than 15 percent of students are of minority heritage. JSU is the fourth largest institution of higher learning in Mississippi and a historically black university. The CCSU NSTI is a one-week, non-residential program (e.g., students need to commute to CCSU each day using private vehicles or public transit). The JSU NSTI is a three-week, residential program, where selected students live in university housing for three-weeks and participate in the on-campus activities. The two NSTI programs cover a range of transportation modes introduced through a variety of activities, including lectures and hands-on labs led by college professors, presentations by transportation professionals from the private and public sectors, and field trips to transportation hubs. These two NSTI programs located in two different states have different program schedules and daily activities, but efforts are made during the program planning stage to coordinate educational activities, ensuring that these two programs share a few common educational schemes. In addition, similar sets of opening surveys and end-of-program surveys are administrated at both host sites.

## 2. LITERATURE REVIEW

The United States is a global leader in large measure because of the desire and skill of its citizens, the vision of its leaders, and the system of government established by the founding fathers that has facilitated personal, community and national success. Throughout US history, it has nurtured and encouraged citizens to become scientists, engineers and innovators. While world-wide demand for scientists and engineers is increasing, today few American students pursue expertise in the fields of science, technology, engineering and mathematics (STEM). Only 16 percent of American high school seniors are proficient in mathematics and interested in a STEM career. Even among those who do go on to pursue a college major in the STEM fields, only about half choose to work in a related career. The United States is falling behind internationally, ranking 25th in mathematics and 17th in science among industrialized nations." [2]

Arousing high school students' interest in STEM college education and recruiting more students in STEM majors are the focus of STEM education research. Many prior investigations revealed the effectiveness of STEM educational programs in attracting high school students to STEM disciplines (e.g., [3, 4, 5, 6, 7]). However, they scarcely identified the factors that influence students' interest and the processes of such influences. Some studies went a step further to investigate how those programs foster students' interest in STEM (e.g., [8, 9]). Although these studies tried to explore factors that influence students in various STEM programs, lack of quantitative evidence or inference made it impossible to accurately assess the contributing factors.

A number of studies investigated the influencing factors of STEM outreach programs using more rigorous statistical and/or numerical analyses. For example, Jordan and Sundberg [10] used a mean comparison technique between pre- and post-assessments. Hubelbank et al. [11] relied on a series of t-tests. Bachman et al. [12] and Elam et al. [13] applied a comparison of the mean score method. In summary, prior studies frequently stated effectiveness of STEM outreach programs, but statistical and/or numerical analyses in current literature could hardly provide enough evidence to establish proof. Inconsistent results from previous studies make it necessary to further explore the influencing factors in arousing students' interest in STEM disciplines. Furthermore, the exact influencing factors as well as their impacts on students' STEM learning achievement need to be identified and formulated.

## 3. DATA DESCRIPTION

The primary data source for this study is the opening and end-of-program surveys conducted during the two NSTI programs in Connecticut and Mississippi. Coupled with demographic information collected at the student recruitment stage, the survey data can reveal participants' perceptions and preferences in STEM college education and attainment of potentially positive influencing factors. If STEM programs can inspire students to cultivate positive influencing factors and increase positive influencing factor experiences for targeted groups, these programs can achieve more success in promoting STEM education and careers.

Among the 40 students (18 from Connecticut and 22 from Mississippi) who completed both surveys, 23 are female and 17 are male. More than half of the participants are from households with less than $75,000 annual income, indicating the study mean represents the middle income tier (the median household income in the United States in 2015 was $56,516 [14]). While a relatively large number (16 out of 40 students) had never attended a similar program that promoted STEM, the majority (60 percent) did get exposure to STEM from previous educational activities. The study participants have a genuine interest in STEM and a high potential to join a future workforce in a STEM field. The preferences expressed by these students are important when designing a challenging and attractive STEM curriculum, and their perceptions can reveal opportunities to attract young talent to STEM.

Educational and occupational information on participants' parents and relatives (e.g., siblings, grandparents, uncles, aunts) reveals the family culture of these young people who are interested in STEM. A remarkably high percent of participants' parents graduated from college: 82.5% of mothers graduated from college, as compared to a national average of 32.0% for females age 25 and over who have at least a Bachelor's degrees [15], and 65.0% of fathers graduated from college, as compared to a national average of 31.9% [15]. Apparently, parents' educational background is a significant factor for participation in the two NSTI programs. This suggests a corresponding impact on their children's interest in STEM.

In addition, a family member's occupation may have an important influence on a student's STEM interest. When participating students are exposed to STEM in their early years because a parent(s) or relative worked in a STEM-related field, they should be more aware of opportunities in STEM and more interested in pursuing a career in STEM. For the 40 participants in the two programs: the mothers of 15.0%, the fathers of 35.0%, and relatives of 37.5% worked in a STEM-related job. 62.5% of participants have at least one parent or relative who worked in a STEM field, exposing them to STEM opportunities. This influence has likely increased the potential for a high school student to participate in the NSTI programs.

When asked how participants heard about the NSTI programs, about half respondents stated that they learned it from "Family and/or Friends", indicating the importance of family/friend support when inviting youth to enter STEM educational opportunities. Unsurprisingly, about a quarter respondents heard about the NSTI programs from "School", due to extensive out-reach campaigns by the Connecticut and Mississippi programs. The out-reach is directed to educators at local high schools. Similar results are found with student responses about why participants were interested in the program.

## 4. METHODOLOGY AND RESULTS

A key research objective is to discover influencing factors in participants' perceptions of their NSTI experiences, as well as in their pursuit of college education in STEM fields. The alternatives offered in survey questions are in an ordered fashion. For example, the probability of pursuing college education in STEM, using five categories of very likely (> 80% chance), probably (80% - 60% chance), decent chance (59% - 40% chance), maybe (39% - 20% chance), and probably not (< 20% chance). Because this data is based on rank ordering, an ordered probit model is selected for the data analysis to examine the influencing factors and curriculum components that would produce positive indicators of STEM program success.

The ordered probit model is a member of a large family of discrete choice models that have been widely applied in economics, marketing, transportation planning, etc. The model is built based on a random utility maximization framework. For detail on ordered probit model specifications, readers may wish to refer to Green's (2000) econometrics textbook.

All relevant explanatory variables, including demographics (i.e., gender, household annual income, household size, and number of children), parent educational attainment, parent and relative occupations, past participation in STEM-oriented program(s), are initially included. Explanatory variables offering p-values larger than 0.10 are removed in a stepwise fashion. Several types of variables do not meet the test of statistical significance, but many remained. The following paragraphs discuss the model results.

In the end-of-program survey administered upon graduation from the NSTI programs, participants are asked about their probability of pursuing college education in STEM. The question uses five ordered options: probably not (< 20% chance), maybe (39% - 20% chance), decent chance (59% - 40% chance), probably (80% - 60% chance), and very likely (> 80% chance). Table 1's ordered probit model results suggest that participants whose mother graduated from college and/or have relative(s) working in a STEM field are more likely to pursue a college education in STEM, shown by the positive coefficients to "mother graduated from college" and "relative(s) work in a STEM field" explanatory variables. As discussed in the previous section, a remarkably high percent of participants' mothers had at least a college degree when comparing to the national average (82.5% vs. 32.0%). The model still discovers the vital role a mother plays in a child's choice of college education and inclination to STEM-related fields. It is probably due to the greater interactions between a mother and her child on various aspects of a child's life, including college education and choice of major. Similarly, many participants (37.5%) have at least one relative (e.g., siblings, grandparents, uncles, aunts) working in a STEM field. The model results show that exposure to STEM through a relative increases the probability of pursuing college education in STEM. Once again, exposure to STEM opportunities though family members has a positive impact on a high school student's interest in STEM college education.

Not surprisingly, female participants are less likely to pursue college education in STEM (shown by the negative coefficient for "Female" in Table 1), even though they applied for and were selected to a STEM-oriented summer program. Various strategies have been proposed in past studies [17]. It is important that similar STEM outreach programs follow these recommendations to advance females in STEM. The model results also suggest that an increase in the number of children in the household decreases the probability of pursuing college education in STEM. One possible reason can be attributed to financial resources spread thin for a household with more children. Talented young people from larger families may be less willing to challenge themselves when selecting a major in college, or may need to choose between going to college and finding a job immediately after high school.

Table 1: Ordered Probit Model Results for Probability of Pursuing College Education in STEM upon Graduation from NSTI Programs

| **Explanatory Variables** | **Coefficients** | **t-statistics** |
|---|---|---|
| Mother graduated from college | 1.18 | 2.07 |
| Relative(s) work in a STEM field | 0.80 | 1.81 |
| Number of children in household | -0.28 | -1.74 |
| Female | -1.37 | -2.81 |
| Threshold 1 | -2.23 | -3.70 |
| Threshold 2 | -0.98 | -2.24 |
| Threshold 3 | -0.46 | -1.68 |
| Threshold 4 | -0.02 | -1.23 |
| Pseudo $R^2$ | 0.161 | |

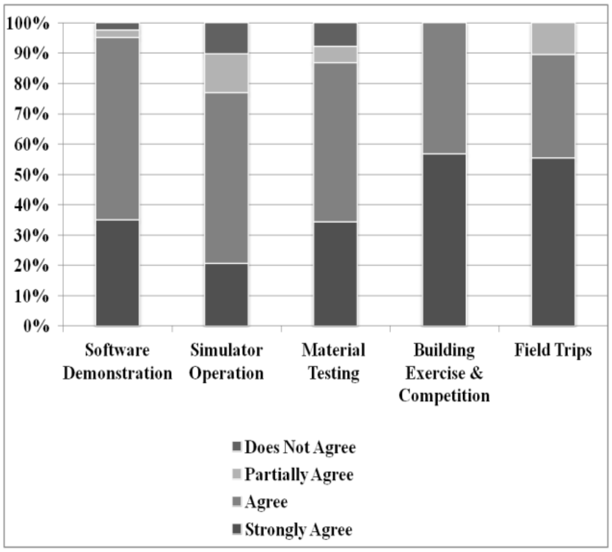
In addition to high school students' perceptions about STEM college education, this paper investigates a few educational instruments to discover what is appealing to future STEM students. These findings can help educators and summer program directors develop curriculum activities that stimulate student preferences and learning styles, and thus initiate greater interest in STEM careers. Five educational instruments are considered in this study, including software demonstration/learning, simulator operation, material testing, building exercise and competition, and field trips. Participants are asked whether each educational instrument help them better understand STEM, using a scale with 1 being does not agree, 2 being partially agree, 3 being agree, and 4 being strongly agree. The building exercise and competition instrument receives the highest score of 3.57, indicating young people learn more effectively though hands-on activities after understanding the relevant principles and/or theories. They also seem to embrace the idea of a competition, probably due to the feeling of success associated with winning a competition or providing a design that demonstrates a successful attribute.

The educational instrument with the second highest score is field trips (3.45 out of 4.0). The reasons could be two-folded. First, young people appreciate interactions with professionals in the field; these professionals are good at explaining things from practical point of view, as compared to teachers/professors who tend to focus on abstract concepts, theories and derivations. Second, young people are keen to keep up with current projects and ideas that are changing the world. Young people need to understand that achievement requires learning the basics and continuously advancing knowledge, but observing real-world projects and applying skills to hands-on projects clearly motivate students in the two NSTI programs.

The two educational instruments with the lowest scores are simulator operation (2.87 out of 4.0) and material testing (3.13 out of 4.0). This looks counter-intuitive because these two instruments also involve hands-on activities, like the building exercise and competition (the one rated the highest). However, two subtle but critical differences between the "winner" and the two "losers" contribute to the findings. First, building exercise and competition requires a relatively good understanding on the theories/principles before participants can actually building anything. This learning process could happen well before they start the design or could be developed throughout the entire procedure of design, build and competition. In contrast, simulator operation does not require a thorough understanding on how the simulator is designed, how different parts of the simulator are working together, or why the simulator works in a particular way. The material testing instrument has similar challenges. This passive learning is not what young people prefer when briefly introduced in the NSTI programs. Additionally, the creative skills required for the building exercise and competition are not a primary part of the material testing instrument. When each participant or team must provide their own design or product, the students have a chance to innovate and demonstrate their creativity. Young people seem enjoy this opportunity even while gaining STEM knowledge and skills.

The software demonstration has a score of 3.28, placing it at the median of the five educational instruments. Responses for the five educational instruments are illustrated in Figure 1.

Figure 1. Response Distributions on Whether Participants Agree the Educational Instruments Help Them Better Understand STEM




## 5. CONCLUSIONS

This study reveals valuable information on high school students' perceptions of STEM college education and their learning preferences. The results suggest improvement opportunities for programs that aim to promote STEM college education among high school students. The findings are based on two state-preference surveys with a relatively small sample of students, and the projected actions of students are subject to an inherent "optimism bias". Surveys from multiple years can increase the sample size and offer more conclusive statistical inferences. Program participants will be invited to complete a third survey to report their actual choices about higher education and selection of a field of study. While a future study can provide additional insight, the findings of this study provide guidance for educators leading students toward STEM higher education and careers.

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