METTE Research Team

Research Brief—

Students in Manufacturing and Other STEM Fields at Two-Year Colleges: An Exploration of Aspirations and Enrollment

Xueli Wang, Hsun-Yu Chan, L Allen Phelps, and Janet L. Washbon

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Students in Manufacturing and Other STEM Fields at Two-Year Colleges: An Exploration of Aspirations and Enrollment

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Executive Summary

Based on a nationally representative sample, the present study aims to illustrate the profile of students who aspired to enter manufacturing programs in public two-year colleges as well as those who actually enrolled in such programs. In addition, this study distinguishes these students from their counterparts in other science, technology, engineering, and math (STEM) fields in two-year colleges by exploring related demographic characteristics and educational factors. A subset of the Education Longitudinal Study of 2002 (ELS:2002) database was used, and only students enrolled in manufacturing and other STEM fields in public two-year colleges were analyzed. Two logistic regression models were analyzed using the same set of hypothesized influential predictors. The two models shared similar significant predictors. Based on the statistical results, this brief also discusses implications for future policy and research.

Key Findings

- Male students were more likely than females to aspire to and actually enroll in manufacturing-related fields compared to other STEM fields at two-year colleges.
- Students who were in the academic track in high school were more likely to aspire to enter manufacturing fields, while those who were in both academic and occupational tracks were more likely to actually enroll in such fields instead of other STEM fields.
- Having at least one advanced placement (AP) math credit in high school was associated with higher probabilities of both aspiring to enroll and actually enrolling in manufacturing fields at two-year colleges.
- Students with more science classes in high school were more likely to actually enroll in manufacturing fields instead of other STEM fields.
- Postsecondary education experiences in terms of interaction with instructors and academic advisors were not significantly associated with the possibility of aspiring to and enrolling in manufacturing fields.

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Introduction

In the manufacturing workforce development, the importance of receiving further education and training beyond high school cannot be over-emphasized (Silver, Warner, Goodwin, & Fong, 2002). Traditionally, a high school diploma was considered sufficient for most jobs in manufacturing, but this requirement has been elevated to postsecondary education training as the manufacturing technology evolves (Washbon, 2012). U.S. Bureau of Labor Statistics (BLS, 2012) has projected that nearly half (about 45%) of all job openings in the next ten years will require middle levels of skill—significantly more than those that will require high levels of skill or a baccalaureate (33%) or low levels of skill (22%). In their analysis of the BLS projections, Holtzer and Lehrman (2009) contend that the demand for workers to fill jobs in the middle of the labor market—those that require more than a high school diploma, but less than a four-year degree—will likely remain quite robust relative to its supply, especially in growing or expanding economic sectors.

Two-year community and technical colleges, which offer associate degrees and certificates in manufacturing and related fields, are recognized as playing a major role in educating skilled workers and preparing students to enter four-year college and universities for advanced knowledge in manufacturing, technology, engineering, and other science-based fields (National Research Council and National Academy of Engineering, 2012). Moreover, recent downturns in the gross domestic product of manufacturing and other sectors have placed higher expectations on two-year colleges to educate skilled workers (Phelps, 2012). To highlight the importance of postsecondary education and skills attainment to economic productivity, new governmental initiatives are being launched. In March 2012, President Obama announced plans to create a National Network for Manufacturing Innovation. This national network will:

> [C]reate up to fifteen Institutes for Manufacturing Innovation around the country. The Institutes will bring together industry, universities and community colleges, federal agencies, and our states to accelerate innovation by investing in industrially-relevant manufacturing technologies with broad applications to bridge the gap between basic research and product development, provide shared assets to help companies – particularly small manufacturers – access cutting-edge capabilities and equipment, and create an unparalleled environment to educate and train students and workers in advanced manufacturing skills. (Office of the Press Secretary, March 9, 2012)

For community and technical colleges to better serve and assist students pursing manufacturing related fields, a more basic but often neglected question is whom the colleges are recruiting, educating, and graduating. In other words, what kinds of students are more likely to be interested in and actually enroll in manufacturing fields at two-year colleges? What are the characteristics of students who aspire to, and actually enter, manufacturing fields? While empirical research and field experiences have shed light on several important student characteristics who majored in the aggregated science, technology, engineering, and math (STEM) fields (e.g., Beggs, Bantham, & Taylor, 2008; Boyer, 1993; Crisp, Nora, & Taggart, 2009; Heinz & Hu, 2009; Porter & Umbach, 2006), there is little specific information on students in manufacturing fields, particularly at two-year colleges.

Given that manufacturing is often linked in policy initiatives to the broader STEM disciplines, targeted research in this area will also benefit from a holistic perspective that takes into account factors shaping students' academic goals and choices related to manufacturing as compared to other STEM fields. Also, manufacturing fields traditionally are included under the bigger STEM umbrella since they share certain core characteristics (e.g., math intensive). Nevertheless, manufacturing has an additional feature in two-year colleges setting, namely the emphasis on hands-on technical skill attainment. It may be insightful, therefore, to have a special focus on manufacturing-related programs in contrast to other STEM disciplines. This nuanced analysis will enable program leaders and instructors at two-year colleges to improve student recruitment efforts, as well as provide support and services that help students succeed in this challenging, highly skilled sector.

Focusing on the starting point of students' career pathway in manufacturing, the current study provides a national context for our ongoing research project entitled "Improving Educational Outcomes in Manufacturing Engineering Technologist and Technician Education (METTE) Programs," funded by the National Science Foundation (No. 1104226). This study explores how two-year college students' demographic backgrounds, high school academic preparation, and postsecondary educational experiences are related to their academic aspirations and choices surrounding manufacturing-related fields versus other STEM fields. Results from this study will help leaders and policy makers in their efforts to improve students' career and college readiness in both high school and the initial phase of postsecondary education. This analysis provides policy makers, administrators, instructors, and academic advisors with a detailed understanding of factors influencing students' decisions to consider and initially pursue manufacturing fields and other STEM majors in public two-year colleges across the nation.

Research Questions

This study examines the following two questions:

1) What demographic, high school, and postsecondary factors are associated with recent high school graduates' aspirations to major in manufacturing-related fields versus other STEM fields at two-year colleges?
2) What demographic, high school, and postsecondary factors are associated with students' enrolling in manufacturing-related fields versus other STEM fields of study?

Method

Data Source

Data for this study come from the Education Longitudinal Study of 2002 (ELS:2002), a national, longitudinal survey designed to depict the educational experience and its correlates of high school students in the 2000s. Sponsored by the National Center for Education Statistics (NCES) of the Institute of Education Sciences (IES), US Department of Education and conducted in collaboration with several research institutes, ELS:2002 provides data pertaining to survey participants' high school and postsecondary learning experiences, as well as their transition to and success in postsecondary education and the workforce. ELS:2002 adopts a longitudinal design, so the same participants were surveyed multiple times. The baseline study was completed in 2002, when the participants were high school sophomores. Data used for this study drew upon the first and second follow-up surveys of ELS:2002. The public-use file contained approximately 15,360 participants. The first follow-up survey was conducted in 2004 and included approximately 13,420 high school seniors. Participants' high school transcript data (e.g., course-taking records for grades 9-12 at the individual level, GPA, achievement test score) were added to the database at this stage of data collection. Such data provide researchers with individual students' complete high school educational experiences, serving as predictors of future academic progress or workforce development. In the present study, most high school data were derived from this wave of study. The first follow-up survey also includes participants' demographic data, and in the present study, this information was used. The second follow-up survey was completed in 2006, effectively two years after high school graduation for most survey participants. New variables were added to the database, such as individuals' postsecondary enrollment and experiences, social and economic returns of education, and newly acquired adult roles.

For the present study, the longitudinal nature of ELS:2002 enables us to investigate how students' educational experiences, along with their demographic backgrounds were associated with individuals' academic interests and choices. A mixture of self-report data (e.g., frequency of interacting with faculty) and transcript data (e.g., high school GPA, number of high school math credits) allow researchers to use both subjective and objective data to link with later academic development and outcomes. For more information on ELS:2002, please consult NCES's website (http://nces.ed.gov/surveys/els2002).

Sample

The unweighted sub-dataset of public two-year college enrollees contained about 3,470 cases. Given that the present study focuses on high school graduates enrolled in public two-year colleges who aspired to or majored in manufacturing and other STEM fields, only participants who meet this requirement were selected in the analyses. Following the procedure stated below, in the unweighted sample, 130 students planned to study manufacturing fields and 230 indicated a preference for other STEM fields—totaling to only about 10% of all 2006 respondents attending public two-year colleges.

To distinguish students' academic aspirations and actual enrollment in manufacturing-related fields or other STEM majors, two new variables were created. First, students' academic aspirations were measured in 2006 with an item retrospectively asking students (approximately two years after high school graduation) to think about to what field they aspired to study upon entering college. Students who identified "Precision Production" and "Engineering Technologies/Technicians" were considered manufacturing-oriented, while students who identified "Computer or Information Sciences," "Natural Sciences or Mathematics," and "Environmental Studies" were considered aspirants for other STEM fields. Students whose academic aspirations were not related to either manufacturing or other STEM fields were dropped from the study.

Second, students' actual enrollment was also measured in 2006. Students who identified that their fields of study were "Precision Production" and "Engineering Technologies/Technicians" were considered enrolling in manufacturing, while those who identified "Agricultural/Natural Resources/Related," "Biological and Biomedical Sciences," "Computer/Info Sciences/Support Tech," "Mathematics and Statistics," "Physical Sciences," and "Science Technologies/Technicians" were categorized as being enrolled in other STEM fields. Again, students who majored in neither manufacturing nor other STEM fields were dropped from the study. There were about 60 participants enrolled in manufacturing fields and 140 in other STEM fields in the unweighted sub-dataset. The rest 3,270 participants were not included in the model of enrollment. Students who indicated that they were enrolled in health-related fields other than biomedical sciences were not included in this study.

Outcome Variables and Predictors

To answer the first research question, the outcome variable was participants' self-report of their academic aspirations, retrospectively measured in 2006. This variable was dummy coded (1 = "Manufacturing Aspirants" and 0 ="Other STEM Aspirants"). For the second research question, the outcome variable was participants' self-report of their actual major in 2006. This variable was also dummy coded (1 = "Manufacturing Major" and 0 = "Other STEM Major).

Analyses addressing the two research questions involved almost the same set of predictors (shown in Table 1). The only difference was that in the second research question, participants' self-reported academic aspirations were entered as one of the predictors for their choice of major field of study.

Data Analysis

Two logistic regression models were tested. Logistic regression is used when researchers attempt to investigate the relationship between predictors and a dichotomous outcome. By calculating delta-p statistic following the logistic regression analysis, researchers are able to interpret the change in the probability of being in a particular outcome group, given the change in predictors or different demographic background when controlling for other variables (Peng & So, 2002). In the present study, the outcome variables in both models were dichotomous. Both outcome variables were regressed on a set of predictors as summarized below, and the main interest was to explore how they were associated with the outcome variable. Both hypothesized models were analyzed using Stata, a statistical software.

In addition, given the nature of the ELS:2002 dataset, sampling weight and primary sampling unit (PSU) information were accounted for in the analyses. Due to the incorporation of data gathered at the second follow-up wave (i.e., "Interaction with Faculty," "Consulting with Advisor," and the two outcome variables), the second follow-up panel weight (longitudinal weight) for all sample members who responded both in the first and second follow-up survey was used. The PSU used in the present analyses denoted the high schools the participants enrolled in. This subset of ELS:2002 database included 690 schools. To calculate standard errors correctly, strata with single sampling unit were centered at the overall mean. Diagnostic statistical tests were also conducted in Stata after estimating both models to ensure the models were correctly specified and statistical assumptions were met.

Table 1

Summary of Variables

Variable	Description	Wave	Role	Property
Gender	Biological sex (1=Female, 0=Male)	F1[1]	Predictor	Dichotomous
Native Language	Whether English is student's native language (1=Yes, 0=No)	F1	Predictor	Dichotomous
First-generation	Whether he/she is the first college student in household (1=Yes, 0=No)	F1	Predictor	Dichotomous
Ethnicity	White or minority background (1=White, 0=Minority)	F1	Predictor	Dichotomous
Academic Track [a]	Transcript indicated curriculum concentration (1=Academic, 2=Occupational, 3=Both, 4=Other Track)	F1	Predictor	Categorical
AP Math Courses	Whether he/she has any advanced placement math credit(1=Yes, 0=No)	F1	Predictor	Dichotomous
AP Science Courses	Whether he/she has any advanced placement science credit or not (1=Yes, 0=No)	F1	Predictor	Dichotomous
HS Cumulative GPA	Transcript reported cumulative GPA	F1	Predictor	Continuous
HS Math Achievement	First follow-up mathematics standardized score (T-score)	F1	Predictor	Continuous
HS Math Credits	Total high school math credits	F1	Predictor	Continuous
HS Science Credits	Total high school science credits	F1	Predictor	Continuous
Interaction with Faculty	Talk with college faculty about academic matters outside of class (1=Never, 2=Sometimes, 3=Often)	F2[2]	Predictor	Continuous
Consulting with Advisor	Meet with advisor about academic plans (1=Never, 2=Sometimes, 3=Often)	F2	Predictor	Continuous
Academic Aspiration [b]	Academic interest in manufacturing or other STEM fields (1=Manu-facturing, 0=Other STEM fields)	F2	Outcome/ Predictor[3]	Dichotomous
College Major	Actual enrollment in manufacturing or other STEM fields (1=Manu-facturing, 0=Other STEM fields)	F2	Outcome	Dichotomous

[1] First follow-up survey
[2] Second follow-up survey
[a] See Endnote 1 for a detailed description of academic track.
[b] Academic aspiration was the outcome variable in the Model of Aspirations to Enroll, and a predictor in the Model of Enrollment.

Findings

Descriptive Statistics

A summary of the descriptive statistics is shown in Table 2 to Table 3. Note that given the use of a national database with clustering and sampling weight features, the actual sample size of each category is less informative than the percentage. Also, for participants' characteristics on continuous variables, the PSU and sampling weight were considered when calculating means and standard deviations.

In the model of aspirations to enrollment, the weighted proportion showed that in total, there were more males (76.8%) than female students (23.2%). Most manufacturing and other STEM disciplines aspirants were non-first-generation college students (74.1%), native English speakers (86.5%), White (62.0%), took "Other Track" in high school (63.2%), and did not take any AP math (92.0%) and AP science class (94.4%). In the model of enrollment, the demographic profile was similar that there were more males (67.0%). Most enrollees in manufacturing and other STEM fields were non-first-generation college students (73.6%), native English speakers (79.4%), White (60.4%), took "Other Track" in high school (58.2%), and did not take any AP math and science classes (87.5% and 92.1%, respectively).

For both manufacturing with other STEM aspirants and enrollees, male students dominated both fields. English native speakers, non-first-generation, and White students outnumbered their counterparts. A higher proportion of students who have taken AP math classes in high school aspired to and enrolled in manufacturing than in other STEM fields. In regard to high school academic preparation, most students accumulated about three credits in math and science. During the first year of college, most students at least sometimes interact with their instructors and consult with their academic advisors for academic matters.

Table 2

Characteristics of Samples

Variable	Weighted mean	Weighted standard deviation
High School Cumulative GPA	2.80	.06
High School Math Achievement	47.73	.24
High School Math Credits	3.31	.03
High School Science Credits	2.92	.03
Interaction with Faculty in College (1=Never, 2=Sometimes, 3=Often)	1.85	.01
Consulting with Advisor in College (1=Never, 2=Sometimes, 3=Often)	1.93	.03

Table 3

Crosstable of Demographic Characteristics of Participants

Variable	Academic Aspiration		Field of Study	
	Manufacturing	Other STEM	Manufacturing	Other STEM
Gender				
Male	45.1%	54.9%	29.8%	60.2%
Female	12.2%	87.8%	11.9%	88.1%
Native Language				
English	37.5%	62.5%	33.7%	66.3%
Other	37.4%	62.6%	18.7%	81.3%
First-generation				
Yes	33.9%	66.1%	32.1%	67.9%
No	38.7%	61.3%	30.1%	69.9%
Ethnicity				
White	43.0%	57.0%	32.0%	68.0%
Non-White	28.3%	71.7%	28.4%	71.6%
High School Pathway				
Academic	59.7%	40.3%	40.1%	59.9%
Occupational	37.9%	62.1%	22.1%	77.9%
Both	65.5%	34.5%	65.6%	34.4%
Other	29.0%	71.0%	28.8%	71.2%
AP Math Courses				
Some	76.4%	23.6%	58.4%	41.6%
None	33.7%	66.3%	27.2%	72.8%
AP Science Courses				
Some	40.9%	59.1%	39.6%	60.4%
None	36.9%	63.1%	30.4%	69.6%

Note. Percentages are weighted. Participants who aspired to or enrolled in neither manufacturing nor other STEM fields were not included.

Model of Aspiration to Enroll in Manufacturing

There are several ways to interpret regression coefficients in logistic regression models. In the present study, delta-p was calculated for statistically significant variables when holding other continuous variables constant at mean level (Please refer to Table 4 and Table 5 for details). As a result, gender, high school course track, and AP math credits were associated with students' aspiration to enroll in manufacturing. When controlling for other variables, male students were 39.7% more likely to aspire to enroll in manufacturing fields (instead of other STEM fields) than females. Also, for female students choosing the academic track in high school, they were 10.0% more likely than females in other tracks to aspire to enroll in manufacturing fields. For male students, they were 28.4% more likely to aspire to enroll in manufacturing field than males in other tracks.

Finally, for female students who were in an academic track, they were 70.3% more likely to aspire to enroll in manufacturing field if they have taken at least one AP math credit during high school, compared with other girls who did not take any. This ratio became 25.8% for male students who were in academic track and have had at least one AP math credit. Other predictors were not statistically associated with students' aspiration to enroll in manufacturing versus other STEM disciplines. Overall, 69.46% of the participants could be correctly specified by the hypothesized model. Results of model diagnosis revealed that this model was correctly specified and the hypothesized model fitted the data fairly well. [2]

Table 4

Results of Logistic Regression Model Predicting Aspiration to Enroll in Manufacturing

Variable	*B*	*SE*	Wald test	Odds ratio
(constant)	1.70	1.72	.99	
Female	-2.73	.58	-4.72*	.07
First Generation	-.36	.43	-.85	.70
Native Language	-.31	.54	-.56	.73
White	.79	.48	1.64	2.20
Academic Track	1.21	.52	2.33*	3.35
Occupational Track	.25	.48	.53	1.28
Math Achievement	-.04	.03	-1.27	.96
GPA	-.11	.22	-.50	.90
Math Credits	.05	.19	.27	1.05
Science Credits	.10	.19	.54	1.11
AP Math Courses	3.49	1.26	2.76*	32.79
AP Science Courses	-1.75	1.00	-1.76	.17
Interaction with Faculty	-.29	.30	-.95	.75
Consulting with Advisor	-.05	.30	-.16	.95

*p<.05

Table 5

Delta-P of Model of Aspirations to Enroll

Variable	P (x=1)	P (x=0)	Delta-p
Female*	5.0%	44.7%	-39.7%
First Generation	65.4%	73.1%	-7.7%
Native Language	73.1%	78.7%	-5.6%
White	73.1%	55.2%	17.9%
Academic Track*	15.0%	5.0%	10.0%
Occupational Track	50.9%	44.7%	6.2%
AP Math Courses*	85.3%/98.9%	15.0%/73.1%	70.3%/25.8%
AP Science Courses	3.0%/32.0%	15.0%/73.1%	-12.0%/-41.1%

Note. Selected cell entries are female's probability /males' probability and delta-p.
* Significant variable

Variable	P (x=mean)	P (x=mean+1SD)	Delta-p
Math Achievement	15.0%/73.1%	14.9%/72.9%	-0.1%/-0.2%
GPA	15.0%/73.1%	14.9%/72.9%	-0.1%/-0.2%
Math Credits	15.0%/73.1%	15.0%/73.0%	0.0%/0.0%
Science Credits	15.0%/73.1%	15.1%/73.1%	0.1%/0.0%
Interaction with Faculty	15.0%/73.1%	15.0%/73.0%	0.0%/-0.1%
Consulting with Advisor	15.0%/73.1%	15.0%/73.0%	0.0%/0.1%

Note. Cell entries are female's probability /males' probability and delta-p.

Model of Enrollment in Manufacturing

When considering students' actual enrollment in manufacturing-related fields and controlling for other variables, aspirations to enroll appeared to be the only significant predictor (β=7.41, SE=1.50, $p<.05$, odds ratio=1652.43). In this model, it is very likely that the association between enrollment in manufacturing or other STEM fields and demographic background and high school academic achievement variables was masked by their intrinsic interest in these fields. This finding illuminates the importance of academic aspirations and the central role of personal interest in educational and career planning. However, in the present study it was important to explore how other variables or demographic background characteristics were associated with students' actual enrollment in manufacturing or other STEM fields. Thus, aspiration of enrollment was omitted from the model (result shown in Table 6 and Table 7).

As a result, first of all, after setting other variables constant as in the model of aspiration, male students were 24.6% more likely to enroll in manufacturing-related majors, rather than other STEM fields, than females, when they were all English native speakers, not first-generation college student, White, and were in neither academic nor occupational track during high school. Second, female students taking both academic and occupational track were 47.0% more likely than girls in any other track to enroll in manufacturing majors, while males in both academic and occupational track during high school were 64.0% more likely to enroll in manufacturing majors than boys in other tracks.

Taking science courses during high school was found to have a positive relationship with enrolling in manufacturing majors. For females in both academic and occupational tracks, accumulating one standard deviation more science credits above the mean may increase their probability to enroll in manufacturing-related majors by 0.6% when other variables were set constant (the increase would be 1.2% if their cumulative high school science credits were two standard deviations above the mean). For male students with similar demographic background, the increase would be 0.2% and 0.4% when their cumulative high school science credits were one and two standard deviations above the mean, respectively.

Finally, similar to the model of aspiration, taking AP math class was positively associated with enrolling in manufacturing-related programs. For females in both academic and occupational track, taking at least one AP math credit may increase their probability to enroll in manufacturing-related majors by 44.2% when other variables were set constant. For male students with similar demographic background, the increase would be 7.6% when they took at least one AP math credit.

Overall, this model could correctly classified 68.24% of the participants. Results of model diagnosis indicated that the hypothesized model (i.e., model without academic aspiration to enroll in manufacturing) was properly specified and was free from multi-collinearity problem. However, the model did not fit the data well, indicating that more information would be needed to build a better model. [3]

Table 6

Results of Logistic Regression Model Predicting Enrollment

Variable	*B*	*SE*	Wald Test	Odds ratio
(constant)	-6.14	2.02	-3.03	
Female	-2.42	.65	-3.74*	.09
First Generation	.54	.50	1.09	1.72
Native Language	1.71	.91	1.88	5.53
White	-.85	.62	-1.36	.43
Academic Track	-.78	.76	-1.03	.46
Occupational Track	.05	.76	.07	1.05
Both Track	3.38	1.47	2.29*	29.37
Math Achievement	.06	.03	1.81	1.06
GPA	-.21	.26	-.81	.81
Math Credits	.03	.27	.13	1.03
Science Credits	.81	.25	2.30*	2.25
AP Math Courses	2.84	1.27	2.23*	17.12
AP Science Courses	-2.46	1.66	-1.48	.09
Interaction with Faculty	-.08	.42	-.19	.92
Consulting with Advisor	-.14	.42	-.34	.87

$*p<.05$

Table 7

Delta-P of Model of Enrollment

Variable	P (x=1)	P (x=0)	Delta-p
Female*	3.3%	27.9%	-24.6%
First Generation	87.7%	80.5%	7.2%
Native Language	80.5%	42.6%	37.9%
White	80.5%	90.6%	-10.1%
Academic Track	6.1%	12.4%	-6.3%
Occupational Track	12.9%	12.4%	0.5%
Both Track*	50.3%	3.3%	47.0%
AP Math Courses*	94.5%/99.5%	50.3%/91.9%	44.2%/7.6%
AP Science Courses	26.9%/80.5%	81.2%/98.0%	-54.3%/-17.5%

Note. Selected cell entries are female's probability /males' probability and delta-p.
* p<.05

Variable	P (x=mean)	P (x=mean+1SD)	Delta-p
Math Achievement	50.3%/91.9%	50.7%92.0%	0.4%/0.1%
GPA	50.3%/91.9%	50.0%/91.8%	-0.3%/-0.1%
Math Credits	50.3%/91.9%	50.3%/91.9%	0.0%/0.0%
Science Credits*	50.3%/91.9%	50.9%/92.1%	0.6%/0.2%
Interaction with Faculty	50.3%/91.9%	50.3%/91.9%	0.0%/0.0%
Consulting with Advisor	50.3%/91.9%	50.2%/91.9%	-0.1%/91.9%

Note. Cell entries are female's probability /males' probability and delta-p
* p<.05

In summary, both models revealed similar results. That is, when manufacturing and other STEM majors were compared, similar factors were influential in students' college major aspirations and initial enrollment decisions. First of all, males were more likely to aspire to enroll and actually enroll in manufacturing-related majors than females instead of in other STEM fields. Second, taking advanced math courses during high school would improve the likelihood of aspiring to enroll and actually enrolling in manufacturing majors, rather than other STEM disciplines, for both males and females. However, this difference was larger for females than for males. Third, focusing on academic track or taking both academic and occupational tracks in high school increased the chance to choose manufacturing, versus other STEM fields, as their academic interest and initial college major. Fourth, the completion of science courses during high school was associated with enrolling in manufacturing disciplines instead of other STEM fields in college. Again, this relationship was stronger for females than for males. Finally, in the model of enrollment, individuals' aspirations were omitted from the analysis because they greatly attenuated the association between other variables and actual enrollment in METTE or other STEM fields.

Both models fit the data well, were correctly specified, and did not report collinearity among predictors. Both models can categorize more than 68% of the participants into correct academic interest and college major groups. However, the model of enrollment deserves further investigation of other unobserved factors that may be associated with students' enrollment in manufacturing-related majors.

Discussion

Using a subset of ELS:2002 data, the current study explored several influential high school and early two-year college enrollment factors associated with differentiating students' choice of manufacturing versus other STEM career pathways. Logistic regression analyses were performed capitalizing on the complex survey design features of ELS:2002. The results indicated that students of different genders and high school course tracks differed in their possibility of aspiring to enroll, and actual enrollment, in manufacturing or other STEM-related fields. Also, taking an AP math class in high school was associated with a greater chance of being interested in and actually enrolling in manufacturing programs instead of other STEM majors. Finally, taking more high school science credits (e.g., accumulating one standard deviation above the average) was related to higher likelihood to enroll in manufacturing instead of other STEM fields.

In our national, public two-year college student sample, male students were consistently more likely than their female peers to aspire to and enroll in manufacturing-related fields compared to other STEM fields. This choice gap persisted even after other influential factors were accounted for, such as taking AP math classes. While the gender difference in students' choice of major in four- and two-year colleges has been widely documented in empirical studies (e.g., Boyer, 1993; Heinz & Hu, 2009; Leppel, Williams, & Waldauer, 2001; Nores, 2010), females' preference for other STEM fields over manufacturing is worth further investigation. It is likely that manufacturing fields have been perceived as relatively "masculine" disciplines than other STEM majors, because students' perception of a major being more masculine versus feminine has been found to correlate with their choice of major (i.e., on average, females tend to major in relatively "feminine" fields while males in more "masculine" ones; Dawson-Threat & Huba, 1996). While previous research tended to focus more on four-year college students and STEM fields in general, the present study finds similar differences with our sample of public two-year college enrollees, implying that the gap may exist in both four- and two-year colleges, as well as in manufacturing fields.

A feasible way to encourage more female students to be interested in and to enroll in manufacturing-related fields is to provide more information on the job market of manufacturing-related occupations. In their review of enrollment and choice of major data from the National Longitudinal Survey of Youth data collected from 1985 to 1994, Gill and Leigh (2000) found that female students' enrollment in science and engineering fields in both two- and four-year colleges was positively associated with the narrowing gender gap of wages. That is, the wage gap between men and women with an associate or a bachelor's degree in science and engineering fields narrowed during 1985 and 1994, while at the same time, women's overrepresentation in traditionally "feminine" majors (e.g., education) in postsecondary institutions decreased. Also, for women with an associate degree in sciences and engineering, on average they earned 14.9% and 7.6% more in wages than women with only a high school diploma. Although no solid causal inference could be made based on their analysis, it is likely that women's increasing willingness to major in "non-traditional" fields, or even in other STEM-related majors, was a response to the increased wage and salary equity for women. If this was the case, job market information may play an important role in motivating female students to consider manufacturing as a possible academic path leading to a rewarding career path. Also, changing students' perception of manufacturing-related majors and careers may motivate more female students to enroll in such majors, as implied by Dawson-Threat and Huba (1996).

To do so, two-year colleges could cooperate with local employers to make high school students, two-year college students who have not decided on their programs, and their family members aware of the current and future manufacturing career pathway opportunities. For example, helpful information may include regional or national emerging employment opportunities, as well as skills and educational credentials needed (Washbon, 2012). Also, introducing first-hand experiences by providing, for example, job shadowing opportunities may also help students learn the real job world and choose fields of study that align with their career and academic interests.

Though individuals' aspirations to enroll in certain academic fields were not included in the reported, descriptive model of enrollment because of their high correlation with actual enrollment status, this approach by no means negates the importance of academic interest in enrolling in a certain field of study. On the contrary, these academic aspirations seem to matter the most to actual enrollment. Our approach descriptively explored how high school and postsecondary experiences were related to actual enrollment by omitting the aspiration variable. Our future research based on the same ELS:2002 data will move beyond this descriptive approach and employ more complex analytical approaches that specifically investigate the potential mediating role of academic aspirations associated with subsequent enrollment. Also, students who aspired to enter either manufacturing or other STEM fields but did not enroll in such programs in the end may represent a subpopulation that is worth further studying. It is likely that other obligations or considerations prevented individuals from choosing certain fields of study. For example, some career choices seem more feminine or masculine by nature (Dawson-Threat & Huba; 1996), and some jobs or licenses require more academic training. In the present study, it was not feasible to account for individuals' perceptions of certain career choices or required academic training, and the academic categorization was based on subject matters instead of on occupations. Hence, future research should account for these variables to explore their association with academic aspiration, enrollment, and the discrepancy between aspirations and actual enrollment.

Several indicators of high school academic experience, rather than academic achievement, were associated with aspiring to enroll and actually enrolling in manufacturing programs. Taking advanced math courses, for one thing, was found to be associated with a higher probability of aspiring to enroll and actually enrolling in manufacturing fields. Accordingly, it is possible that students with advanced math proficiency had higher aspirations, were more motivated, and foresaw higher chances of success, thus feeling more ready to enroll in manufacturing majors. Given that nearly all manufacturing programs offered in postsecondary education setting require at least high school-level math skills (ACHIEVE, 2008; Silver et al., 2002), it is also possible that less prepared students may shy away from manufacturing to less mathematics-intensive STEM majors. Moreover, the increase in the probability of aspiring to and enrolling in manufacturing field by taking AP math was larger for females. This finding affirms the ACHIEVE (2008) assertion that advanced mathematics course taking during the last two years of high school (beyond Algebra II) opens the door to all postsecondary education programs. Further, ACHIEVE argues that these courses provide students with the critical thinking and problem-solving skills needed in the high demand, math-intensive science and engineering majors. Since this was a gender-specific finding in this analysis, it is important for researchers to further explore the high school academic experiences that effectively motivate males to choose manufacturing programs.

In addition, taking more science classes in high school was associated with actual enrollment in manufacturing fields instead of other STEM fields, but not with aspiration to enroll in manufacturing. Similar findings were documented by Dick and Rallis (1991), where based on survey data collected from about 2,000 high school seniors, the authors examined the relationship between career choice and course-taking behavior. Results indicate that taking both calculus and physics classes does not seem to promote aspirations to enter science or engineering careers, especially among female students, which was echoed in this study that shows that math and science credits were not significant predictors in the model of aspiration. However, as Trusty (2002) found in his study using NELS:88 database with four-year college enrollees, the effects of high school math and science courses on choice of major in college differ. In particular, the author argued that for girls but not for boys, taking most academically intensive courses (e.g., trigonometry and pre-calculus) had a strong relationship with majoring in science and math fields later in four-year colleges.

While previous research focused primarily on math and science fields in general, in the current study, similar relationship was found between taking AP math courses and aspiration to and enrollment in manufacturing field for both genders. Therefore, to motivate high school students to aspire to manufacturing-related fields, high school teachers should encourage students to take more challenging math courses. These courses may not only prepare students for college-level courses, but also inspire students' interest in related fields.

Finally, students who aspired to or enrolled in manufacturing in the ELS:2002 sample tended to be more academically-oriented, based on their high school tracks. These patterns echo the significant role played by academic preparation in math and science in shaping the possibility of aspiring to manufacturing and the probability of enrolling in these fields, as well as individual's college and career options in general (U.S. Department of Education, 2008). Nonetheless, taking the occupational track in addition to academic track during high school was actually the key to enrollment in manufacturing majors. Given that more than 65% of students in ELS:2002 were categorized as in Other Track by 12th grade (i.e., they did not take enough credits to be labeled as in either Academic or Occupational Track), the small group of students in Both Track (2.0% of the entire analytical sample in this study) may be more academically prepared. Furthermore, they may have started early to explore different career options so that they were able to complete at least three credits in one specific labor market program. Thus, merely taking the occupational or academic track during high school may not be sufficient to motivate students to eventually enroll in manufacturing fields; rather, it is possible that students' preparation in both academically and occupationally oriented coursework together helps shape their pathways to manufacturing versus other STEM fields eventually. In other words, students have to be both academically proficient and occupationally "savvy" upon high school graduation to ensure success in postsecondary education (U.S. Department of Education, 2008). The characteristics of this group of students are worth further investigation. It is also likely that the model of enrollment could be better specified if these characteristics could be modeled in the future.

Somewhat surprisingly, students' postsecondary education experiences, measured by the frequency of their interactions with faculty and academic advisors, were not associated with their aspirations to and enrollment in manufacturing fields. In general, research evidence on student engagement in two-year and four-year colleges suggests that faculty-student interaction and student support services are key factors in retaining and engaging college students (e.g., Chang, Sharkness, Newman, & Hurtado, 2010). Taking other salient factors into account, it is likely that students' high school academic preparation still plays a major role, so the importance of the relationship of interacting with faculty and academic advisors with aspirations and enrollment in manufacturing fields was attenuated. Other unmeasured factors and influences, including the multiple options for delivering instruction, could also affect aspirations and enrollment commitments. As Washbon (2012) pointed out, as the use of videoconferencing and other instructional technologies become more commonplace, learners have more flexibility and autonomy (e.g., being able to self-pace, weekend learning options). In this context, teaching and learning experiences are being rapidly transformed. The frequency and opportunities of in-person interaction with faculty and academic advisors may be greatly influenced, too. Given the multiple missions of two-year colleges, instructors and academic advisors may take a more proactive stance, intervening in students' learning process when students seem to struggle with math and science in particular, or when students' course plans do not reflect a particular interest in a specific area. The rapidly changing instructional technologies – combined with several other un-examined factors such as dual credit course enrollment (e.g., Hoffman, Vargas, & Santos, 2009), student mobility, and access to financial aid – make the search for definitive and influential predictors of aspiration and initial enrollment very complex and challenging.

In summary, for public two-year college students, our hypotheses were confirmed that high school academic experiences play a pivotal role in developing aspirations to enroll and actually enrolling in manufacturing fields versus other STEM majors. In particular, students' academic preparation in math and science seems to be the crucial precursors; therefore, two-year colleges should strive to reach out to high schools, working together to ensure that students acquire adequate math and science proficiency so that they may have a higher likelihood of enrolling in manufacturing programs. For example, providing more effective basic skills on math and science would greatly help students to be more academically prepared (Crisp, Nora, & Taggart, 2009). It is thus likely that their improved math and science proficiency may motivate them to consider manufacturing as a field of study. Further, two-year college leaders could work closely with local high schools to advocate the importance of math and science if students are interested in pursuing a career in manufacturing. Moreover, high school students should be aware of the benefit of completing both academic and occupational track to maximize their options and opportunities in the manufacturing career pathway. Since important indicators of academic achievement (e.g., high school GPA and math standardized test score) were not significantly correlated in this study, students' holistic high school educational experience deserves more attention, as reflected in the association with completion of both high school tracks – academic and occupational – and students' interest and enrollment in manufacturing in two-year colleges. For all high school students, a seamless academic and career pipeline emphasizing the importance of academic preparation and college level success would be helpful.

Endnotes

[1] The high school track variable was derived from high school transcript data. To be in the academic track, students had to accumulate: a) at least four credits of English, b) one math credit higher than Algebra II Advanced I, II, III in the math pipeline and any two other credits in math, c) one science credit higher than Biology 5, 6, 7, 8 in the science pipeline and any two other credits in science, d) one credit of social studies in US or world history and any two other credits in social studies, and e) at least two credits in a single foreign language (e.g. two credits in Spanish, as opposed to one credit in Spanish and one credit in Latin). Students in the occupational track had to accumulate at least three credits in a single Specific Labor Market Program (SLMP) vocational area. SLMP areas included: a) agriculture and renewable resources, b) business, c) marketing and distribution, d) health care, e) protective and public services, f) trade and industry, g) technology and communication, h) personal and other services, i) food service and hospitality, and j) child care and education. Students who met only the requirement of academic or occupational track were coded as “Academic Track” and “Occupational Track,” respectively. Students who met both requirements were coded as “Both Track,” whereas those who met neither requirement were coded as “Other Track.”

[2] In addition to model estimation, it is of interest to understand if proper predictors are selected, if there are redundant or unnecessary predictors in the models, and how well the models can correctly classify individuals, based on the predictors and covariates, into the academic aspiration or enrollment group of their choice. In the model of aspiration, link test of model specification was conducted. Consequently, this model was properly specified (coefficient=-3.55, SE=4.01, p=.38), meaning that predictors included in this model were appropriately selected. Multi-collinearity test was performed to investigate if there were redundant predictors in this model, and the VIF and tolerance statistics indicated that there were no suspicious collinear relationships among the predictors. In other words, these predictors effectively explained the variance in the outcome variable. Note that since the model of aspiration and the model of enrollment shared the same set of predictors, their multi-collinearity test results were the same. An approximate measure of Hosmer-Lemeshow χ^2 test was conducted to see how well the model fitted the data while simultaneously taking the clustered data structure and sampling weight into account. The result showed that the model fitted the data fairly well ($F_{(9,45)}$=.54, p=.84). Finally, the sensitivity of this model was 48.39%, indicating that 48.39% of manufacturing aspirants were correctly predicted to be aspirants by the model. The specificity was 82.88%, so 82.88% of non-manufacturing aspirants were properly specified as such. In sum, 69.46% were correctly classified.

[3] In the enrollment model (without aspiration to enroll as a predictor), link test was conducted and showed that this model was properly specified (coefficient=-4.43, SE=5.19, p=.40). An approximate measure of Hosmer-Lemeshow χ^2 test showed that the model did not fit the data well ($F_{(9,26)}$=4.62, p<.05). The model sensitivity was 36.73%, indicating that 36.73% of manufacturing majors were correctly predicted. The model specificity was 83.84%, so 83.84% of non-manufacturing majors were properly specified as such. In sum, 68.24% were correctly classified.

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