New Mexico PREP Academy from 2016-2019 (Evaluation)

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Patricia A. Sullivan serves as Associate Dean for Outreach and Recruitment in the College of Engineering at New Mexico State University. She received her PhD in industrial engineering and has over 35 years' experience directing statewide engineering outreach services that include technical engineering business assistance, professional development, and educational outreach programs. She is co-PI for a National Science Foundation (NSF) INCLUDES pilot grant, co-PI for a NSF grant to broaden participation in STEM, and is a PI for an i6 Challenge grant through the U.S. Economic Development Administration (EDA). She served as institutional integrator for the Partnership for the Advancement of Engineering Education (PACE) at NMSU, was University Affiliate Director for the NM ans was co-lead for a NSF funded Pathways to Innovation cohort at NMSU. Currently, Patricia serves on the Western Interstate Commission for Higher Education (WICHE), and a member of the board of directors for Enchantment Land Certified Development Company (a program that certifies SBA 504 loans that foster economic development.) She has extensive experience in economic development particularly efforts that build on collaborative partnerships with business and industry, government agencies, and other stake-holders to enhance employment opportunities for engineering students.

Dr. Steven J Stochaj, New Mexico State University

Steve Stochaj - Distinguished Professor, Klipsch School of Electrical and Computer Engineering - New Mexico State University: Steve has participated in a number of curricular activities aimed at increasing minority participation in STEM fields. These include the development of the freshman year experience (ENGR 100), and the NSF INCLUDES: Enhancing the New Mexico STEM Pipeline - Design and Development Launch Pilot program.

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Background

The New Mexico PREP Middle and High School Academies (NM PREP[1]) are two-week residential summer STEM programs that were offered once a year from 2016 to 2019 at a southwestern university. This program aimed to expose its students, those in grades 6 through 12, to the field of engineering and provide them with a basic foundation of knowledge that would be useful to them should they pursue a collegiate degree in engineering. Participating in this program also allows students the opportunity to experience life on a university campus, gain self-confidence, refine their self-identity, collaborate with like-minded individuals, and increase their knowledge of engineering. In order to do so, NM PREP utilized hands-on activities, field trips, opportunities for group work, and lectures that revolved around a variety of engineering disciplines including Aerospace, Chemical, Civil, Electrical, Geomatics/Survey, Industrial, and Mechanical Engineering as well as Engineering Technology and Information Engineering Technology. While the disciplines covered have not changed, there have been changes to the content of the program itself as well as the evaluation methods. These changes have been based on a variety of factors including results from the program's evaluation, changes within university's engineering department, changes in mentorship, and changes within the disciplines themselves. For example, one of the aims for the 2017 and 2018 Academies was to help students understand the engineering design process. However, this was not an aim of the 2016 and 2019 Academies.

Students

Throughout the four NM PREP Academies offered, there were a total of 665 students (20.6% Middle School students, 26.3% High School students, and 53.1% unspecified students) between the ages of 11 and 18 years old. Of those students, 27.0% identified as male and 20.7% identified as female (the remaining 52.5% did not disclose their gender). Overall, 26.9% identified themselves as Hispanic, 11.3% as Caucasian, 4.0% as Asian/Pacific Islander, 2.4% as Native American/ American Indian, 1.4% as African American, and 1.1% as other (the remaining 53.1% did not disclose their ethnicity).

Program Evaluation

In order to assess program outcomes and effectiveness, students were asked to complete pre-post surveys and pre-post content assessments for a total of four evaluation measures. Due to changes within the program's curriculum[1] and research team, the evaluation measures were altered every

[1] The challenge of increasing diversity in STEM has been with us for more than two decades. Despite effort and time, little has been achieved in changing the representation in STEM. The paradigm that exposure to STEM generates STEM degrees and drives the STEM workforce does not appear to work. Exposure to STEM is necessary, but it is not sufficient to diversify the STEM workforce. The PREP program focuses on activities that will increase STEM self-efficacy, STEM career awareness, and grit. This was accomplished by including activities led by

year. The modality of collecting data also changed throughout the years (paper and pencil, SurveyMonkey, Google Forms, and REDCap[7,8]) As such, it should be noted the remainder of this paper focuses on aspects of the evaluation measures that remained consistent across all years of program information (see Table 1). Given changes within the scales themselves (e.g., changing Likert values/descriptions, item wording, and number of items), the analyses described below were conducted using standardized z-scores. Difference scores (post score – pre score) were then calculated as a means of analyzing and interpreting the data. It should also be noted the evaluation measures were designed by members of the NM PREP team based on the aims of the program and guided by research regarding methods for assessing those aims.

The goal of the survey was two-fold: (1) obtain an understanding of students' experience in NM PREP and (2) assess whether NM PREP led to changes within the students themselves. For the survey, students were asked a variety qualitative (using a short answer format) and quantitative (using Likert scale and multiple choice formats) questions. These questions focused on students' self-efficacy (e.g., how confident are you with engineering, how confident are you in your ability to build something from a drawing, etc.), personal identity (e.g., I think of myself as a STEM professional, I am excited by discovering something new, etc.), mindset (e.g., intelligence is something you are born with, you can change even your basic intelligence level considerably), grit (e.g., I am a hard worker, I finish whatever I begin, etc.), and interest in engineering careers (e.g., Aerospace Engineering, Electrical Engineering, etc.). The pre-surveys contained additional questions regarding student backgrounds (e.g., prior STEM experiences, classes taken in school, etc.) while the post-surveys contained additional questions asking students to rate and/or describe their experience in NM PREP (e.g., how would you rate the Robot unit, what was your favorite part of NM PREP, etc.).

The goal of the content assessment was also two-fold: (1) assess students' knowledge of engineering prior to NM PREP and (2) assess whether that knowledge increased as a result of NM PREP. For the content assessment, students were asked to define a variety of engineering related words (e.g., friction, torque, error, precision, etc.) and answer a series of general knowledge questions (e.g., which of the following is not a form of energy, which of the following is not an example of a vector, etc.) using a multiple choice or fill in the blank question format. The content assessment was treated as a quiz in that students would earn one point for every question they answered correctly.

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companies and labs and using materials developed by faculty-presenters as part of the broader impact portion of their NSF funded grants. The program provided diversity training for the PREP staff, including the student mentors. The students were required to undertake a research project that culminated in a poster session modeled after a professional conference

Table 1.
Constructs assessed during each year of the NM PREP Academy

	Construct	2016	2017	2018	2019
Pre-Post Survey	Demographics			x	x
	Relevant Background Information		x	x	x
	Self-Efficacy (Subjects & Tasks)	x	x	x	x
	Personal Identity	x	x	x	x
	Mindset			x	x
	Grit			x	x
	Engineering Knowledge (Perceived & Actual)	x	x	x	x
	Engineering Career Interest	x	x	x	x
	College Student Inventory			x	x
	Program Experience	x	x	x	x
	Future Plans			x	x
Pre-Post Content Assessment	Demographics				x
	Vocabulary	x	x	x	x
	General Knowledge	x	x	x	x
	Measurement	x	x	x	x
	Applied Knowledge	x	x	x	x

Survey Results

A series of independent sample t-tests were conducted using the difference in standardized z-scores to assess for changes within students after participating in NM PREP. Our hypotheses were as follows:

1. Participating in the NM PREP Academy will lead to improvements in student's self-efficacy regarding engineering-related subjects (e.g., how confident are you with Algebra, Computer Science, Engineering, etc.?).
2. Participating in the NM PREP Academy will lead to improvements in student's self-efficacy regarding engineering-related tasks (e.g., how confident are you with building something from a drawing, generating a research question to answer, using the Engineering Design Process, etc.?).
3. Participating in the NM PREP Academy will lead to improvements in student's personal engineering identity (e.g., how much do you agree with the following: I am excited by discovering something new, I feel like I belong in the field of engineering, I think of myself as a STEM professional, etc.).
4. Participating in the NM PREP Academy will lead to improvements in student's perceived knowledge of engineering disciplines (e.g., how familiar are you with what aerospace engineers, electrical engineers, mechanical engineers, etc. do for a living?).
5. Participating in the NM PREP Academy will lead to improvements in student's interest in engineering careers (e.g., what is your current level of interest in chemical engineering, survey engineering, industrial engineering, etc. careers?).

Results from these analyses (see Table 2) indicate, across all years and both programs, participating in NM PREP did not have a significant impact on students' self-efficacy, personal engineering identity, perceived knowledge of engineering disciplines, or interest in engineering careers. However, in comparing results between years, participating in NM PREP 2019 led to significant decreases in student's subject-related self-efficacy (M_{pre} = 0.12, M_{post} = -0.08), perceived knowledge (M_{pre} = -0.02, M_{post} = -0.39), and career interest (M_{pre} = -0.10, M_{post} = -0.23). Furthermore, in comparing results between years and programs, participating in the 2016 NM PREP Middle School Academies led to a significant increase in students' subject-related self-efficacy (M_{pre} = -0.37, M_{post} = -0.10) while participating in the 2018 NM PREP Middle School Academies led to a significant decrease in students' subject-related self-efficacy (M_{pre} = 0.55, M_{post} = 0.11). Additionally, participating in the 2019 NM PREP Middle School Academy led to a significant decreases in students' task-related self-efficacy (M_{pre} = -0.22, M_{post} = -0.57), personal engineering identity (M_{pre} = -0.18, M_{post} = -0.37), perceived knowledge (M_{pre} = -0.60, M_{post} = -1.19), and interest in engineering careers (M_{pre} = -0.55, M_{post} = -0.86). Similarly, participating in the 2019 NM PREP High School Academy led to a significant decrease in students' perceived knowledge (M_{pre} = -0.02, M_{post} = -0.39). Nonetheless, in examining the pattern of results (see Figures 1 – 5), it seems that participation in NM PREP led to several, non-significant improvements in students' subject-related self-efficacy (2017), task-related self-efficacy (2016, 2017, and 2018), personal identity (2016 and 2018), perceived knowledge (2016 and 2018), and career interest (2016, 2017, and 2018).

In examining the qualitative data, it seems several students enjoyed their experience in NM PREP. They particularly enjoyed the exploratory activities (e.g., building a robot, etc.), field trips (e.g., White Sands National Monument), and guest speakers. Students also indicated they would recommend NM PREP to a friend because they felt it provided a good education both academically (i.e., learning about engineering, math, and science) and personally (i.e., learning about teamwork, whether they are truly interested in engineering, and having the opportunity to stay in dormitories). Several students also felt NM PREP helped prepare them for their future. Additionally, many students indicated they would like to participate in STEM based extra-curricular activities during their next school year as a means of continuing their education, obtaining more STEM-related experience, and preparing themselves for the future.

While our hypotheses were generally not supported, the results of this evaluation may suggest NM PREP is an effective means of helping students identify whether they are interested in further pursuing engineering-related activities. It is possible these results reflect the nature of the program in that students' may feel overwhelmed with the amount of information they are given in a period of two weeks. It is also possible the lack of significant results is related to changes in the evaluation procedures throughout the program's implementation.

Table 2.

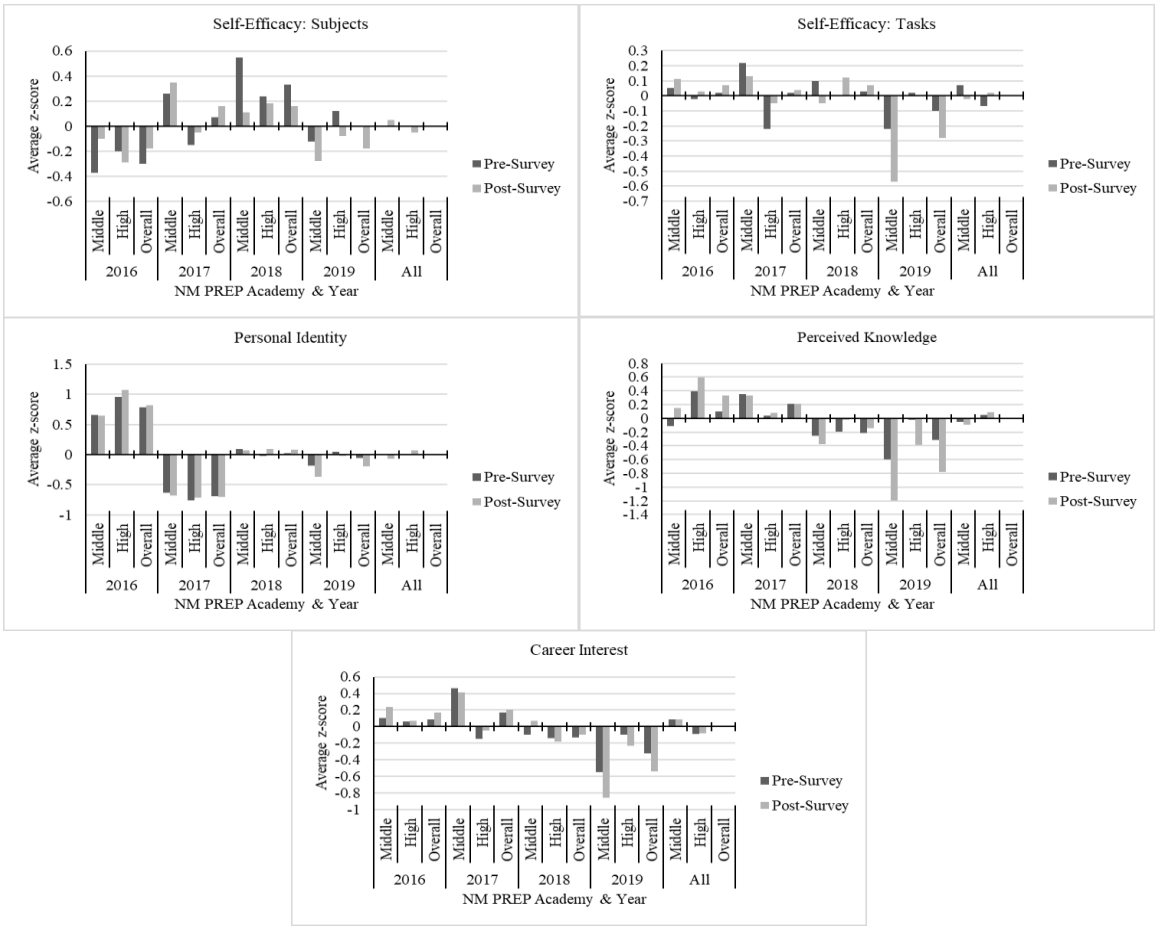
Independent Samples t-Test Survey Results

		Self-Efficacy: Subjects		Self-Efficacy: Tasks		Personal Identity		Perceived Knowledge		Career Interest	
Year	Academy	df	*t*	df	*t*	df	*t*	df	*t*	df	*t*
2016	Middle	47	1.94*	47	0.57	47	-0.16	46	1.68	46	0.95
	High	32	-0.62	33	0.28	33	0.97	33	1.06	33	0.06
	Overall	80	1.16	81	0.59	81	0.52	80	1.97	80	0.74
2017	Middle	47	0.62	47	-0.70	47	-0.58	47	-0.12	47	-0.41
	High	41	0.90	41	1.41	41	0.43	41	0.26	41	0.80
	Overall	89	1.04	89	0.33	89	-0.10	89	0.07	89	0.25
2018	Middle	15	-2.45**	15	-0.77	17	-0.18	17	-0.48	15	0.98
	High	36	-0.54	36	1.46	37	1.32	37	0.99	36	-0.24
	Overall	52	-1.72	52	0.47	55	0.95	55	0.52	52	0.24
2019	Middle	23	-1.43	23	-2.98**	23	-2.20**	23	-3.58**	23	-2.24**
	High	24	-1.53	24	-0.14	24	-0.66	24	-1.98*	23	0.72
	Overall	48	-2.11**	48	-1.85	48	-1.89	48	-3.84**	47	-1.96*
All	Middle	135	0.60	135	-1.37	1379	-1.17	136	-0.45	134	-0.04
	High	136	-0.69	137	1.39	138	1.15	138	0.47	136	0.04
	Overall	272	0.00	273	0.00	276	0.00	275	0.00	271	0.00

Note. *denotes marginal significance ($p < .06$); **denotes significance ($p < .05$)

Figures 1-5.

Average scale scores



Content Assessment Results

A series of independent sample t-tests were conducted using the difference in standardized z-scores to assess for changes in students' knowledge of engineering after participating in NM PREP. We hypothesized that participating in the NM PREP Academy would lead to improvements in student's knowledge of engineering.

Results from these analyses (see Table 3) indicate, across all years and both programs, participation in NM PREP did not have a significant impact on students' knowledge of engineering. However, in comparing results between years, participating in the NM PREP 2018 (M_{pre} = -0.53, M_{post} = -0.60) and 2019 (M_{pre} = -0.43, M_{post} = -0.53) Academies led to a significant increases in students' knowledge of engineering. Furthermore, in comparing results between years and programs, participating in the 2017 NM PREP Middle School (M_{pre} = -0.47, M_{post} = -0.35) led to a significant increase in students' knowledge of engineering. Similarly, participating in the 2018 (M_{pre} = -0.31, M_{post} = -0.46) and 2019 (M_{pre} = -0.29, M_{post} = -0.51) NM PREP High School Academies led to a significant increase in students' knowledge of engineering. Nonetheless, in examining the pattern of results (see Figure 6), it seems that participation in NM PREP led to several, non-significant improvements in students' knowledge of engineering (2016 and 2017).

While our hypothesis was generally not supported, the results of this evaluation may suggest NM PREP has the potential increase students' knowledge of engineering. While items on the content assessment were modified each year to reflect changes in NM PREP's curriculum, it possible these results reflect a lack of convergence between the curriculum and content assessment. Like the survey, it is also possible the lack of significant results reflect the nature of the program in that students' may feel overwhelmed with the amount of information they are given in a period of two weeks. Similarly, it is possible students' did not have enough time to develop a deeper understanding of the concepts addressed in the content assessment.

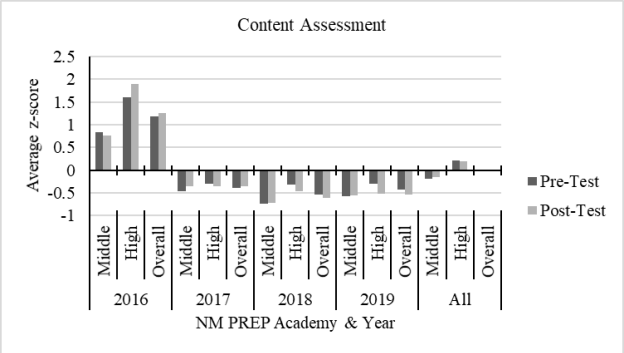
Table 3.
Independent Samples t-Test Content Assessment Results

Year	Academy	df	*t*
2016	Middle	45	-0.69
	High	36	1.93
	Overall	82	0.90
2017	Middle	48	3.06**
	High	38	-1.52
	Overall	87	1.25
2018	Middle	41	0.10
	High	37	-3.81**
	Overall	79	-2.17**
2019	Middle	23	0.47
	High	23	-5.19**
	Overall	47	-3.03**

All	Middle	160	0.45
	High	137	-0.43
	Overall	298	0.00

Note. **denotes significance ($p < .05$)

Figure 6.



Conclusion

Overall, participation in the NM PREP Academy had little effect on students' self-efficacy, personal engineering identity, perceived engineering knowledge, actual engineering knowledge, and interest in engineering careers when considering the program as a whole. While not mentioned above, the lack of significant results overall may be a result of changes in the program each year including different instructors/mentors, modified curriculums, and fluid evaluation measures. However, in making intra-program comparisons, it seems that participation in NM PREP has the potential to alter students' subject- and task-related self-efficacy, personal engineering identity, perceived engineering knowledge, actual engineering knowledge, and interest in engineering careers[2,3,4,5,6,9,10]. Although this lends support to the notion that changes in the NM PREP Academy program itself attributes, at least in part, to the lack of significant results overall, it also provides us with the hope that further modifications will increase NM PREP's overall effectiveness. In looking forward to the 2020 NM PREP Academy, the program's team working to further solidify the curriculum and evaluation measures while increasing the consistency between instructors/mentors by assessing previous implementations of the program and providing its staff with appropriate trainings.

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