



## **Completing the K-12 Engineering Pipeline by Creating College Pathways (Work in Progress)**

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# Completing the K-12 Engineering Pipeline by Creating College Pathways: Work in Progress

## Abstract

One of the largest school districts in the State of Colorado, Denver Public Schools, has partnered with a university of science and engineering, Colorado School of Mines, to improve the education that precollege students receive in science, technology, engineering and mathematics (STEM). This partnership spans the kindergarten through twelfth grade STEM pipeline. The manner in which students and teachers learn STEM, at all levels, is being challenged and changed. Additionally, graduate students are learning communication skills and the importance of recruiting the next generation of scientists and engineers. This article describes a work in progress that is designed to include the entire kindergarten through twelfth grade pipeline within one school district in STEM learning.

## Introduction

The importance of improving education in science, technology, engineering and mathematics (STEM) has been repeatedly argued in high profile publications in the United States, e.g., “Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics” [1], “Rising Above the Gathering Storm” [2], “Before It’s Too Late” [3], and “A Nation at Risk” [4]. By 2018, 35% of all STEM jobs will require training beyond high school [5]. Yet, only 14% of current college degrees are awarded in STEM fields [6]. In 2012, the President’s Council of Advisors on Science and Technology (PCAST) submitted a report [1] which emphasizes the need to prepare high school students to pursue degrees in STEM. An NSF report [7], argued, “To succeed in this new information-based and highly technological society, all students need to develop their capabilities in science, technology, engineering, and mathematics (STEM) to levels much beyond what was considered acceptable in the past.”

To meet the future STEM needs of our nation, all students need to master STEM content. Unfortunately, minority and low-income students often struggle in STEM content areas. The Hispanic population currently comprises approximately 16.3% of the total U.S. population [8]. In Colorado, this group comprises 20.7% of the population. Growth in the Hispanic population throughout the U.S. is four times the rate for that of the general population, resulting in Hispanic’s comprising the majority of the working population in the U.S. by 2042 [9, 10]. Minority student populations in our state display a 13.4% achievement gap in mathematics compared to the broader student population [5]; minority achievement gaps have been witnessed across the U.S. [11]. An achievement gap also exists for low-income students when compared to their peers [11]. Only 18% of high school students who receive free or reduced cost lunches in Colorado are at or above a state defined proficiency level in mathematics while 35.8% of the general student population reaches this level of attainment [5]. Minority and low-income students require the same preparation and deserve the same opportunities in STEM as their peers. Reaching this subset of students can be a challenge. This article describes a partnership between the Colorado School of Mines, a college of science and engineering, and Denver Public Schools, a kindergarten through twelfth grade (K-12), largely minority, school district.

A unique feature of this partnership is the inclusion of all grade levels in DPS, K-12, in our outreach programs. STEM outreach is defined here as educational activities that are designed to support the improvement of instruction of K-12 STEM education provided by STEM content experts that are not attending or instructing in a School of Education. All of our university participants are drawn from STEM departments. These programs are designed to stimulate students' interests in STEM and to strengthen the instruction that these students receive in these areas. These programs are also designed to solicit long-term commitments and participation from K-12 teachers of up to two years.

## **Partners**

The efforts described in this article reflect a collaborative partnership between a large public school district, DPS, and a university, CSM. The demographics of the participants are described in the subsections that follow.

### ***Public School District***

DPS is approximately 58% Latino and 14% African American. Seventy-two percent of students within the district qualify for free or reduced cost lunch. The district serves over 85,000 students in grades K-12 with an overall graduation rate of 61.3% and a dropout rate of 5% per academic year.

### ***University***

CSM is a public university specializing in applied science and engineering. There are over 4200 undergraduate students enrolled, 73% of which are male and 13% who are underrepresented minorities. The university, which boasts the highest admission standards of public institutions in the state, has a desire to increase the diversity of its student population by recruiting a larger percentage of underrepresented groups to STEM.

## **Description of Partnership**

This section is subdivided into two subsections. The first section describes one of the CSM's outreach programs. This program was in place before this partnership began but was originally implemented with a different school district partner. The current program builds from this prior effort. The second subsection describes the expansion of this prior program to include the current partner district and their high school classrooms.

### ***Kindergarten through Eighth***

CSM has had an established outreach program for kindergarten through eighth grade for over ten years [12, 13, 14, 15]. These prior efforts were completed with a different school district and the resultant model is being transferred and tested here. DPS has been involved in this collaboration since the summer of 2013.

Recruitment of teachers and of graduate student participants to this program occurs in the spring of each year. Contacts are made with teachers through the school partner district liaisons, e.g., principals, special project coordinator, parent-teacher organizations, etc. Once an interested teacher has been identified, follow-up emails or phone calls are completed by the university staff. Teachers who wish to participate are encouraged to invite their colleagues as well. Preference is given to applications that include all of the elementary and middle school grade levels, viz. a teacher representing each grade, K-8. Graduate students are recruited through direct mailings to STEM faculty members who are invited to refer students. The participation of female and minority students is encouraged. Although there is a desire to recruit minority role models, the enrollment pool of minorities at a graduate level within the university is limited. Of seven participating graduate students in 2014-2015, one is a minority and two others are female.

Six elementary and one middle school teacher from the partner district attended 2014 summer workshop. Participating teachers receive a modest stipend of \$1000 per year. This stipend was paid in three equal amounts, one at the end of the summer, one in the middle of the academic year and one at the end of the academic year. Graduate students complete this experience in place of a graduate student research assignment and receive compensation through the payment of tuition, stipend and fees.

Each summer following recruitment, the participating university offers a two-week summer workshop to K-8 teachers. Funding for this offering and the broader program has been secured from various companies and foundations, including the Bechtel Foundation, National Science Foundation and the Saey Foundation. Summer workshops are presented by the university faculty as part of the broader impact component of research grants and funding for faculty participation is through research grants secured by research groups and individual faculty members (e.g., NSF, DMR-0820518; NSF, ERC-1028968). Each workshop presentation is hands-on and reflects current research that is underway in STEM. Additionally, most of the workshop presentations have been refined over several years with the advice of externally hired K-8 pedagogical experts and feedback from workshop participants. Newly developed presentations or presentations that have not yet been presented to K-8 teachers, receive guidance from an external pedagogical K-8 expert. Each lesson is designed such that it can be immediately implemented in a K-8 classroom. Neither the graduate students nor the university faculty participating in this program necessarily have a background in K-8 pedagogy or education. The participating graduate students are completing their degrees in STEM not in education. The graduate students in this program are training for a content master's or Ph.D. in a STEM field. The usability of the instructional modules relies on the knowledge of our external STEM experts and our teachers who evaluate and refine lessons in a manner that is appropriate to the K-8 classroom.

In order to support teachers as they implement hands-on science and engineering in their classroom, graduate students from the participating university provide classroom-based support for 15 hours each week at the participating school. This component of the program is modeled after a successful program which was developed at the start of this millennium as part of the National Science Foundations' GK-12 program (NSF, DGE-0231611; NSF, DGE-0638719). The original program was developed and implemented in partnership with a different school district and is now being developed and tested in the new setting. STEM graduate students act as content experts; participating teachers are the pedagogical experts.

Elementary teachers typically instruct science and mathematics for, at most, one hour per day. Middle school teachers instruct different groups of students in science and mathematics throughout the day. Graduate students who support elementary level teachers are assigned to support up to three teachers throughout the academic year while graduate students who are assigned to support middle school are assigned up to two teachers per academic year. The level of support (5 versus 7.5 hours per week per teacher) is determined based on the specialization of the teacher with whom the graduate student works and the amount of classroom time dedicated to science and/or mathematics. Graduate students support the participating teachers by identifying or developing appropriate instructional science and engineering lesson plans, assisting the teachers with scientific or in-class engineering experiments, and leading hands-on laboratories experiments. All of this is completed under the direction of the participating teacher who is the classroom pedagogical expert. This program directly impacts the content knowledge of the participating teachers (through the summer workshop) and the science and engineering experiences of the participating students (through academic year support).

### ***High School***

In 2014, DPS approached the CSM and requested the expansion of the K-8 program to include high school teachers and their students. Although CSM was enthusiastic to join this effort, they could not do so without additional funding. DPS raised the funds by receiving a Youth CareerConnect grant, sponsored jointly by the Department of Labor and the Department of Education. In 2014-2015, an additional graduate student was hired to support the high school effort. This graduate student directly assists two high school science instructors for up to 19 hours each week. One of the participating teachers attended the summer workshop; the second teacher did not join the school district until after the workshop concluded. The inclusion of high school teachers is expected to expand to six teachers and three graduate students in 2015-2016, supported partially by funds raised by the district. All participating teachers will attend the summer workshop. This workshop is being redesigned to include hands-on high school science and mathematics activities, which are illustrative of various faculty member's research. The participating school district is responsible for identifying which high school teachers will participate; the university recruits graduate student applications through faculty advisors (as described in previous section), and the school district and university partners jointly select the graduate students that will assist the high school classrooms. Funding for this component of the project has been secured by the school district.

In addition to the expansion of the above described outreach program to include high school, several other programs are being planned for implementation. For example, faculty from the participating university have joined the curriculum advisory board for the partner K-12 district. The purpose of this committee is to reform the current high school offerings in a manner that better prepares students for college attendance and future careers in science and engineering. As our partnership strengthens over the next several years, we anticipate the conceptualization and implementation of additional programs, at all levels, well beyond that which is describe in through this work-in-progress paper. Although we anticipate a minimum of a ten-year collaboration, this will be determined by the success of the program and the funds we

successfully secure for long-term implementation. Currently, funds have been secured to support the K-12 efforts through the academic year 2016-2017.

## **Benefits**

This section describes the anticipated benefits of our partnership for K-12 students and teachers and for graduate students and college level faculty.

### ***K-12 Students and Teachers***

An anticipated benefit of the program described here is to increase the interest, success, and college enrollment of students who are attending the partner high school with respect to science and mathematics. This partnership seeks to support students in becoming college ready upon high school graduation.

Many students lose interest in science and mathematics before they enter middle school. Given this, our efforts begin at the elementary level. This partnership seeks to stimulate the natural curiosity that young students have in their world and strengthen this interest before they enter the middle grades. Outreach in middle school and high school is designed to intensify that interest, allowing students to experience the excitement of scientific discovery. By high school, the students that participate in each level of this program will recognize the benefits of science and mathematics and will understand the importance of working hard to learn these subjects. Role models, in the form of graduate students, will be regular members of the elementary, middle school and high school instructional team. In summary, the benefits to the pre-college students are apparent—to increase their knowledge, understanding and appreciation of science and mathematics and to provide an incentive in the form of future opportunities once they have mastered these subjects.

Participating teachers also have the opportunity to benefit from this program by increasing their knowledge and understanding of content that they teach. Additionally, they are provided with a classroom assistant, in the form of a graduate student, throughout the academic year. On a monetary level, they receive a \$1000 stipend for project participation, divided into three equal payments during the academic year. The teachers who participate in this program are respected professionals, both knowledgeable in their content area and compensated for their professional development efforts.

### ***Graduate Students and College Faculty***

Graduate students receive their tuition, stipend and fees in compensation for their efforts in this program. Many graduate students select to participate in this program rather than complete a campus based research assistantship. Through this program, graduate students learn to communicate mathematics and science to elementary, middle and high school students. This benefit is particularly important since scientists and engineers are frequently criticized for lacking the capability to communicate their research results to the non-scientific population. Participating graduate students, many who will eventually become professors, also learn about

instructional pedagogy, an important construct for future professors, which is infrequently taught in STEM graduate studies.

Faculty also benefit from participation in this partnership. The National Science Foundation (NSF) has two merit review criteria that are common across research competitions: i) Intellectual Merit and ii) Broader Impacts. Most researchers have little difficulty justifying the intellectual merit of their research efforts. As graduate students, faculty members learn to embed their work into the prior work of others, justifying the technical qualities and importance of their research from an intellectual perspective. Justifying broader impacts require researchers to think about their research and justify how their research benefits society. Few researchers have had the opportunity to evaluate their efforts from the perspective of an outsider. Faculty members who participate in K-12 outreach are frequently challenged by students' questions, bringing a naïve perspective to the researcher. This creates a challenge and may result in the contemplation of societal benefits. Improved education and the recruitment of underrepresented populations to science and engineering is in-and-of itself a potential broader impact of this research process. The effort described here leverages the efforts of individual researchers with respect to broader impacts into an impactful program that serves societal needs. Additionally, there is a central point of contact at the university who organizes the broader effort, which spans multiple research projects. Such an effort could not be undertaken without a central university contact.

### **Needs Assessment with Preliminary Data**

The proposed plan for this project is to systematically work with each school, e.g. elementary, middle and high school, within the partner district for a two-year period. This will allow the teachers in the school to strengthen and practice their STEM knowledge. Participating schools are first identified by which high school will participate. High schools are selected based on performance needs, with the highest needs or the lowest proficiency rates for students in mathematics entering the project first. Elementary and middle schools are then selected to participate because they feed into the given high school. Once all schools have participated in this program for two-year period, this partnership program will be offered to “new” teachers or teachers who have entered the district after this project was implemented in their school.

In preparation for this partnership, a needs assessment was completed using available district data. Based on the ten-year period from 2000 to 2010, the participating school district has had an increase in the percentage of K-12 students who are living in the district and who select to attend the district's schools. This percentage rose from 76% to 81%, respectively. Although this is positive trend, these enrollment percentages lie below all other districts within Colorado. This project is gathering comparable data from 2010, 2015 and 2020. The data from 2010 to 2015 will be used to determine whether there is an increase in district students who enroll in district schools. A trend line will be fitted for 2010 to 2015 and compared to a trend line for 2015 to 2020 (as well as the earlier trend lines). We anticipate that the 2015 to 2020 trend line will have a steeper slope than the previous trend lines. Additionally, enrollment within the schools that participate in this project will be compared in 2020 to the broader district averages. We anticipate that the participating schools will have a greater increase in enrollment than the other schools within the district.

Mathematics performance on the state assessment program indicates that as students' progress from kindergarten to twelfth grade, the percentage of students within the district that attain proficiency decreases. For example, in 2011, 53%, 46% and 18% of attending 4<sup>th</sup>, 8<sup>th</sup> and 10<sup>th</sup> grade students, respectively, attained proficiency in mathematics. There was also a witnessed gap with a minimum of 20% difference between high and low-income students in terms of proficiency in mathematics. As of 2015, a new state assessment is being implemented. This will render comparisons from before 2015 and after 2015 inappropriate. However, the method of comparison used here, beginning in 2015, will be completed using the new state assessment data. We anticipate that there will be a five-year increase in proficiency levels for all economic groups, with a greater slope on the trend line for low-income students. Given the new assessment, we will not be able to make comparisons with historical data. Schools that participate in this project will also be isolated and compared to the broader district performance. We anticipate at least a ten percentage point increase in the number of students who reach proficiency by the tenth grade within the district over the course of this project. We further anticipate that most of that growth will occur within the schools in which we implement this program.

Only 67% of the districts graduating students immediately entered college following graduation in 2011. Of this percentage, 59% required some type of remediation. Only 2% of students from this district who applied to the partner university were admitted over a ten-year period. For these percentages, we have established targets. By 2020, we seek to increase successful college enrollment to 80% with a reduced remediation rate of 20%. At the partner university, we seek to increase the acceptance rate without a reduction in entrance requirements to 10%.

## **Conclusions**

This article describes a work in progress for engineering programs that are currently being developed and implemented through a K-12/university partnership. Components of this effort include science and mathematics teachers and their students, and university faculty and their graduate students. Kindergarten through twelfth grade teachers have the opportunity to expand their scientific and mathematical knowledge by attending a sequence of two week summer workshops which are taught by research scientists and engineers. The focus of these workshops are content, not pedagogy, as the participating teachers are the recognized K-12 pedagogical experts. Graduate students are assigned to assist the participating teachers in their classrooms throughout the academic year, significantly improving K-12 students exposure to scientific and engineering concepts. At the middle and high school level, summer programs are being developed that expose students to college campuses and advanced scientific and mathematical understanding. Pathways or engineering programs are also being created and implemented to seamlessly transition high school students into rigorous university environment.

This unique and intensive program addresses all levels of the K-12 pipeline. Students learn to enjoy science and mathematics at a young age and receive the instruction and support that is necessary to encourage and develop that interest until they enter college. The participating school district serves a large proportion of students who have traditionally been underserved in STEM. This primarily includes a large Latino population and students from low-income families. We anticipate the expansion of this work-in-progress to include additional programs and measures in



the near future. The data presented in this work-in-progress is preliminary in nature, describing the participating school district before the intervention. We invite the interested reader to follow our efforts and future publications.

## References

1. President's Council of Advisors on Science and Technology. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. Retrieved from [http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final\\_feb.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf).
2. Committee on Prospering in the Global Economy of the 21<sup>st</sup> Century. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.
3. National Commission on Mathematics and Science. (2000). *Before it's too late: A report to the nation from the National Commission on Mathematics and Science Teaching for the 21st century* [4] National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform*. Retrieved from [http://datacenter.spps.org/uploads/sotw\\_a\\_nation\\_at\\_risk\\_1983.pdf](http://datacenter.spps.org/uploads/sotw_a_nation_at_risk_1983.pdf).
4. National commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform*. Retrieved from [http://datacenter.spps.org/uploads/sotw\\_a\\_nation\\_at\\_risk\\_1983.pdf](http://datacenter.spps.org/uploads/sotw_a_nation_at_risk_1983.pdf).
5. Garcia, V. (2012). *STEM needs and assets*. Colorado Department of Education.
6. Dobbs, R., Madgavkar, A., Barton, D., Labaye, E., Manyika, J., Roxburgh, C., ... Madhav, S. (2012). *The world at work : Jobs, pay, and skills for 3.5 billion people*. Retrieved from [http://www.madrimasd.org/empleo/documentos/doc/MGI-Global\\_labor\\_Full\\_Report\\_June\\_2012.pdf](http://www.madrimasd.org/empleo/documentos/doc/MGI-Global_labor_Full_Report_June_2012.pdf)
7. National Science Foundation. (2007). *A national action plan for addressing the critical needs of the U.S. science, technology, engineering, and mathematics education system*. Retrieved from [http://www.nsf.gov/nsb/edu\\_com/draft\\_stem\\_rep](http://www.nsf.gov/nsb/edu_com/draft_stem_rep).
8. U.S. Census Bureau. (2011). *The Hispanic population: 2010*. Retrieved from <http://www.census.gov/prod/cen2010/briefs/c2010br-04.pdf>.
9. BBC News. (2008, August 14). Minorities set to be US majority. *BBC News*. Retrieved from <http://news.bbc.co.uk/2/hi/americas/7559996.stm>.
10. Crisp, G., & Nora, A. (2012). *Overview of Hispanics in science, mathematics, engineering and technology (STEM): K-16 representation, preparation and participation*. Retrieved from [http://www.hacu.net/images/hacu/OPAI/H3ERC/2012\\_papers/Crisp%20nora%20-%20hispanics%20in%20stem%20-%20updated%202012.pdf](http://www.hacu.net/images/hacu/OPAI/H3ERC/2012_papers/Crisp%20nora%20-%20hispanics%20in%20stem%20-%20updated%202012.pdf).
11. Reardon, S. F., & Galindo, C. (2009). The Hispanic-White achievement gap in math and reading in the elementary grades. *American Education Research Journal*, 46(3), 853-891.
12. Moskal, B. & Skokan, C. (2011). "Supporting the K-12 classroom through university outreach," *Journal of Higher Education Outreach and Engagement*, 15 (1), 53-75. Available at: <http://openjournals.libs.uga.edu/index.php/jheoe/issue/view/52>.
13. Moskal, B., Skokan, C., Kosbar, L., Dean, A., Westland, C., Barker, H., Nguyen, Q. & Tafoya, J. (2007). "K-12 outreach: Identifying the broader impacts of four outreach projects." *Journal of Engineering Education*, 96 (2), 173-189.
14. Tafoya, J., Nguyen, Q., Skokan, C. & Moskal, B. (2005). "K-12 outreach in an engineering intensive university." Paper in the Proceedings of the annual meeting of the American Society for Engineering Education, Portland, Oregon (11 pages). REPRINT: Proceedings of 4<sup>th</sup> ASEE/AaeE Global Colloquium on Engineering Education, Sydney, Australia, September, 2005.
15. Moskal, B., Skokan, C. & Duffield, J. (2004). "GK-12 learning partnership: An outreach program in engineering education." Paper in the Proceedings of the International Conference on Engineering Education, Gainesville, Florida (9 pages).