Efficacy of STEM and Engineering School Model Programs in the Los Angeles, California Area

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Abstract
California is famous as the home of technology companies like Apple Computers, Space-X, Tesla, Google, and many more. But are California schools doing enough to supply a workforce capable of working in these companies? To address this, the California government and K -12 school districts have devised many different STEM school models. Some students start in Kindergarten STEM programs. STEM charter, magnet, and schools within school academies have been created at all levels, with many different versions and program details. But do these programs actually generate more engineers, programmers and designers? Collecting data involved a combination of online research, and direct contact with a variety of schools. However, the program details, demographics, how they operated were ultimately so disparate, that the scope of the research was narrowed to focus compare three different high schools, each representative of the three main school types – school within a school academy, a charter and a magnet school. The first was a school within a school model, which students could select into regardless of academic qualifications. The next was an independent charter school. The last was a STEM academy which had high academic entrance requirements. All of these schools had faculty which included at least one professional engineer. The results showed that although the student populations were similar, many students did opt to matriculate into STEM career pathways at university and apprenticeship levels. Not all students did so, with female students often opting for other non-STEM career pathways upon high school graduation.

Keywords: STEM, Charter Schools, Magnet Schools, Academies

Introduction

California is home to many tech start-ups and companies, that have changed the world. Most of their founders were products of the American, or more specifically the California public educational system. A climate exists in Silicon Valley which is highly conducive and friendly to starting technology businesses – there is "venture capital" seed money available. Entrepreneurial expertise and support are abundant. But are California public schools currently producing a workforce capable of working in such businesses? And, will their graduates go on to also be STEM professionals and even entrepreneurial? To address this issue, the California state government has implemented many educational mandates to address this issue. A wide variety of Science Technology Engineering and Math (STEM) school types have formed, which serve many different kinds of demographics and communities. But the question remains: are these schools actually producing students who pursue university level courses, which will result in more engineers, scientists, programmers and designers?

This paper addresses some of the history of how and why STEM schools evolved. It covers some of the different types of STEM school models in the Los Angeles California area. Finally, the research was narrowed down to focus on three basic types of high school STEM programs. It looks at how likely their respective graduates were to enter these fields and why. What features of each of these schools made them more or less conducive to the stated goal?

To answer these questions, data was collected from online and other sources. However, it was deemed necessary to interview as many graduates of these programs as possible to really hone in on the specifics of their respective experiences. The results section provides data in the form of charts and tables. From this information some recommendations are made about what works well and what does not. Also, although the student populations of these schools have similar demographics and numbers of male and female students (with some exceptions), the students opting to pursue STEM careers upon graduation were predominantly male. Some reflections on why this happened is provided, which may be controversial or even surprising. This information is summarised in the conclusion section.

Historical Background

Before detailing how and why STEM programs have become so important in Los Angeles public schools, and why that is potentially important to the California business community, some historical background is useful. The current climate of STEM education innovation is the result of some important swings of the educational pendulum. A free public education for all American children is provided by the United States Constitution and Bill of Rights and subsequent case law. The details of that education are left to the individual fifty states. In general, most states are divided into "school districts" which are loosely organized around geographical areas. For instance, in the Los Angeles, California area, there is one large school district known as the Los Angeles Unified School District (LAUSD). It is second in size only to that of New York Public Schools. But not all cities in the Los Angeles area belong to it. An example would be the Beverly Hills Unified School District. Each of these districts is mandated to direct educational policy subject to state and federal law, but the exact manner and form of how they do this is left to the districts to decide. A locally elected school board must decide what is best for the children and families of any given district. For this reason, there is a very broad diversity of programs of various sorts not only in California and Los Angeles in particular, but across all of the USA.

Prior to the early 2000's in California schools, school districts had their own interpretations of California's standards for Math, Science and other areas of study. Although there was some state testing at the end of each school year for these subjects, there were no particular negative consequences for students performing poorly. As part of President Lynden Johnson's "War on Poverty," various Federal programs were enacted which entitled low performing school district to get large sums of money with which to improve. In fact, a district could get substantially more Federal "entitlement" funding if school districts' students were doing poorly. No incentives were tied to the money which would require improving student performance or outcomes. So, low income neighborhood school districts might be very wealthy, getting large amounts of federal money, while their students' outcomes were not good and few efforts were made to improve them. Some suggested this was the "Poverty Pays," educational funding scheme. In some cases, district coffers contained millions of dollars while money allocated for new textbooks and supplies went unspent.

This changed when President George Bush was elected in 2000. With Microsoft founder Bill Gates and others, the "No Child Left Behind" (NCLB) movement was legislated. It literally meant that all students should be prepared as if they were all going to university. With it came mandates for state standards for all subject areas, plus "high stakes" testing to determine if school districts were making progress at improving student outcomes. If they did not, school districts could be taken over, loose funding or worse. Schools scrambled to improve their curricula and great pressure was put on teachers to "teach to the test," and even more pressure was placed upon students to perform well on them. And with NCLB, schools reduced or eliminated their "vocational education" which was aimed at conferring marketable skills to students who were not university bound. "Teachable moments" for discussion and relationship building in classrooms also disappeared. Mr. Gates was also intent on identifying and ridding the system of "bad teachers." If schools could just eliminate bad teachers then education would be excellent and 100% of students would qualify as proficient. There would be no below grade level students anymore, was the hoped for result. As statistically unlikely as this was, the enormous ship of education had been steered in a new direction and vast resources were committed to seeing it through. As part of this effort, power and individual initiative was stripped from individual teachers in many places. In some cases, they were given teaching scripts to follow. If not actual scripts, rigid pacing guides were put in place. Administrators anxious to improve test scores checked carefully on teachers to make sure they were adhering rigidly to their scripts or pacing plans. The results of this were predictable. Test scores went up somewhat, but critical thinking skills plummeted.

It soon became apparent to business and university leaders that the graduates from this NCLB education were lacking in self initiative and the ability to think for themselves. They might be able to find the right Algebra answer, but the ability to apply their Mathematics knowledge to a real life problem was not so strong. It was finally determined that this approach was not yielding the results expected. Along the way, even Bill Gates finally had to admit, that he did not know how to fix education and that not all kids were in fact headed to university. The scripts were abolished but teacher and classroom micro-managing were here to stay. The lack of "common sense" problem was still acute.

To remedy this at the national level, a consortium of industry and education leaders and state governors came up with an attempt at national standards, something known as the "Common Core Standards" (CCS) and the Next Generation Science Standards (NGSS). Not all U.S. states have adopted these to this day. A mandate for national standards violates "States' Rights" and many states resented the intrusion into their affairs. Some states believe that their own state

educational standards are far superior to the new ones. But with them comes a stronger focus on critical thinking and STEM education. California adopted CCS and NGSS in 2013.

For California, ever concerned about fulfilling the needs of the Tech community businesses and industries for a tech capable workforce, this shift to STEM education meant a rush to implement STEM school programs. There was a great deal of innovation and many different types arose. Options became available for children as young as five years old to enroll in STEM focused schools. From Kindergarten through the end of high school, STEM programs proliferated. These were aimed at producing more students who wanted to become engineers and scientists. Within comprehensive high schools, and in separate schools, STEM education proliferated. One could almost say that it was like the Wild West, as there were few rules and lots of imaginative STEM programs were conceived of. Charter and magnet schools formed, as well as school within a school academies were birthed which gave STEM unprecedented visibility. School textbook publishers and others came up with many different packages of STEM curricula with kits of STEM laboratory equipment, replete with all the widgets necessary for doing engineering education.

Some STEM Charter schools formed which were loosely affiliated with school districts. Then different school districts formed their own charter schools. A charter school has no academic or behavior standards for applicants to meet. Any child can apply to attend a charter and its students are chosen in a public lottery. Students who do not make the list are placed on a waiting list. Still others formed STEM magnet schools, which were schools of choice with a STEM focus. They had to be applied to, and had academic and behavior standards to be met by prospective students. They had rules about mandated parent participation and student behavior.

In school districts, there are schools that can be attended solely by reason of geography and address. If a child's address was within a certain area, then they were entitled to attend certain schools without any sort of application. Not to be outdone by the smaller and more nimble charter and magnet programs, these "comprehensive" schools set up their own schools within schools or academies within the main school. These mini-schools could be selected into by the students themselves without any requirements for academic performance, solely based on student interest. These schools within schools embraced all comers. Today, most California high schools have some sort of program specifically aimed at encouraging STEM interest and participation. School districts rearranged and reformed themselves, a process which continues to this day.

Methods

The objective of this project was to determine which kinds of programs were most effective at getting students interested in STEM such that they would pursue a STEM career, such as engineering or computer programming. Because the Los Angeles Unified School District (LAUSD) is so large and has so many innovative programs, research began there. This is the second largest school district in the nation and encompasses only part of the L.A. metropolitan area. It was therefore assumed that finding data would be easy since there should be so much of it. There are many districts surrounding and distinct from LAUSD, but with fewer programs and so not as much diversity in program designs. Using online resources, as much information about the various STEM programs within LAUSD was collected first. Data was easily compiled on student and family demographics, age level of students and the like. Less transparent were the details of each school's particular programs. Some schools had lots of technology – computers, and other equipment available to use. Some schools had adopted "off

the shelf" engineering education programs available in the USA such as "Project Lead the Way," (PLTW), or "Project Based Learning," (PBL) or "Teach Engineering" or a variety of other programs. However, from each school's webpage or the school districts' own descriptions, it was almost impossible to tell which they had adopted, or if they had concocted their own. It was virtually impossible to determine if they had an actual engineer working in their program as well. The latter was the case for many, but again it was not necessarily publicized. A call had to be made to each school to inquire about their program model. In many cases, they did not want to disclose this information. Qualifications of the school faculty members to teach an engineering curriculum were undisclosed and guarded. While some schools had hired actual engineers, while others simply used Math or Science teachers to teach engineering.

At the big comprehensive LAUSD high schools, many had STEM programs in a school within a school configuration. It was assumed for purposes of this project, rightly or wrongly that if students had an interest in STEM career pathways, they would have selected into these programs. However, the exact program details that could be obtained showed a great of variation. Many details were unknown to the persons answering calls, and in many cases they did not know where exactly to direct the calls. Or so they claimed.

After many attempts to glean information but not obtain what was hoped for, it seemed more logical to focus on the three main STEM school types described above, and to select representative schools from which information could be more easily collected. Three schools within a certain geographical area were selected. These schools had somewhat similar demographics. For instance, all three qualified as inner city, were ethnically diverse, and most students qualified for the "Free or Reduced Price Lunch Program" which is a federal program, which is often used as a measure of poverty and low income level. The information sought from them was 1- Type of curriculum 2- Results of four years of participation in the program in terms of university attendance and program selection, 3- Was program student versus mentor centric, 4- Qualifications of the instructors (i.e. did they have an engineer teaching engineering or a Math or Science teacher teaching it instead), 5- Equipment and technology available for students to use. 6- General and miscellaneous information.

The three schools selected represented each basic type - a STEM charter, a STEM magnet and a school within a school.

Discussion and Findings

Overview of LAUSD school types, as background is shown in Figure 1. As can be seen from the table, the specific kinds of magnet or charter schools are not delineated. Approximately twenty percent of K-12 LAUSD schools were found to be specifically STEM focused from other available information. This included magnet, charter and school within a school program formats. STEM focused schools and curricula varied widely across Los Angeles area schools and districts as already mentioned. The Beverly Hills Unified School District (unified means it has high schools, without that designation it would just have K-8 or Kindergarten through middle schools, and would be called a school district) includes STEM education for all its students. All of them must take and pass coding courses. They were the exception. For most school districts, coding and STEM were offered to those interested in it and not to all students. For instance, some schools within LAUSD were performing arts charter or magnet schools, and did not offer coding. That tended to be a common approach from available information.

Computer equipment was generally available to all students, although the age and quality of that equipment varied.

To satisfy the project objective, the three focus schools were chosen- the Lennox Math Science and Technology Academy (LMSTA), a charter school, the California Academy of Math and Science (CAMS), a magnet school and the Hawthorne High School – Manufacturing Engineering School (HHS-MES) the school within a school. The schools were in a similar geographic area. Students who were at any one of these schools could have attended any of the other three under the right circumstances. All three were in an inner-city, mostly low income, ethnically diverse area. All of these schools included the option for their students to take university preparation courses, something in California known as U.C. courses (courses eligible to be considered for acceptance to University of California, at any of their campuses). LMSTA and CAMS are explicitly college preparation programs, while HHS-MES had such programs as options for interested youth. Since HHS-MES had an open "opt in" design, many students chose it because they wanted to build and make stuff, rather than get into college. All three schools had Advanced Placement (AP) courses available in many different subjects. All three also had options for students to take actual college classes either through a community college or on a university campus. Engineering was treated as an elective, except at CAMS where it was integrated into all curricula. All of these schools had computer equipment available for students to use. At LMSTA and HHS-MES students were assigned a Google Chromebook, which they were able to carry and use at home.

All of these schools had students in cohort groups which stayed together throughout all four years of high school. This "familia" or camaraderie approach was deemed critical to the success of students in all these programs. Parent and family participation was encouraged at all three schools.

All three schools had engineers who had degrees in engineering and industrial work experience, prior to teaching in their respective programs. All of the other teachers were fully credentialed by the state of California to teach in their content area. CAMS had teachers who were also professors at Cal State University – Dominguez Hills.

Some differences between programs were how their student body was formed. For the charter school, LMSTA, any child could apply and the first 150 students were chosen in a public lottery. For CAMS, since it was a magnet school, students were recruited and had to apply and meet high academic and behavior standards. They could be highly selective about who the students were in their program, balancing for ethnicity, gender and other attributes. HHS-MES on the other hand, had no academic or other requirements for their students. If a student could attend Hawthorne High School by virtue of his or her geographic address, they were entitled to opt into the Engineering School as well.

Other differences between the programs were in student versus mentor centricity. In other words, students at CAMS and LMSTA were in rigorous academic college preparatory programs, with teacher or mentor delineated projects. Students were advised, counseled and taught with the goal of college preparation. Contrast that with HHS-MES which was very student centric. Older students were trained to use, maintain and trouble shoot many highly technical pieces of equipment, after which they would mentor younger students. There was a great deal of flexibility in type and scope of engineering projects and coursework students could engage in. For instance, all students had to learn 3D modeling at all three schools. But some students at HHS-MES preferred to do this above other things and were free to develop

their skills in this area. Indeed, some students from this program were so skilled in this area that they could graduate from the program and go immediately to work in a professional capacity doing 3D modeling. So this program was more flexible and amenable to student choice than the other two.

All three programs demonstrated excellence, but in different ways. All met or exceeded student and community expectations.

Data

In determining if these STEM programs actually produce more STEM professionals, general data and specific data can be compared. To answer the general question of whether or not STEM programs in California are generating more STEM professionals, we can utilize general data from the University of California (UC) system. In Figure 2, one can see that from 2010 to 2020, the period when most of these STEM programs were implemented, the number of students enrolled in Engineering went from 70,000 to over 100,000, representing a 43% increase. In trying to determine whether this increase is due to California's educational STEM program innovations, it is not so easily done. Students in California are not limited to attendance at universities solely in California, nor do universities and colleges in California draw exclusively on students of Californian origin. However, the Next Generation Science Standards, which have a strong STEM focus debuted in many of the United States around 2010, so it could be inferred that STEM interest increased in part because of this.

For the three STEM focus schools, interest in STEM was evident from their respective programs. Although it might have been optimum to do a double-blind study, to have a control group from a non-STEM program contrasted with these three focus groups, it would have been virtually impossible. Even in regular public schools, the NGSS mandates STEM awareness and activities, so all students have STEM exposure through their Science classes which all students must take. However, looking at the number of students opting to matriculate into STEM university majors from each of the three focus schools, shows that their programs certainly did not kill interest in STEM careers. See Figure 3. Looking at the percentages alone can be a bit deceptive though.

For LMSTA, there is a fairly high acceptance rate to four year colleges and universities of sixty percent. This is in spite of the fact that members of their incoming freshman class had only to apply and be accepted to the school through a lottery. In other words, they did not have to have demonstrated any particular level of academic achievement prior to enrolling. In this particular community, there had been a history of many students not even completing high school. So to have over sixty percent going to four year colleges and universities represents a significant achievement. Of the forty percent not going to university, many are most likely going to community college. In the USA, community colleges are two year post high school colleges. Anyone can take courses at these schools including adults. As much as two full years of university credit can be accomplished there. Then those students can apply to transfer to a four year university program, such as engineering with all of their prerequisite coursework satisfied. The transfer rate from community college to the U.C. system is actually quite high. So students who could not initially get into a four year program always have this "side door" way of accessing their desired degree. LMSTA faculty members also expressed surprise that so many of their students were choosing careers with a community service aspect. For instance, of the sixty percent going to university, many said they wanted to become teachers or lawyers or health care professionals, and only half of those wanted to go into STEM careers.

It is worth noting however, that teachers in the three schools specifically interviewed, noted that many of their students could not get accepted into the STEM programs they applied to. For instance, California Polytechnic University at San Luis Obispo had a 28% acceptance rate. This includes all majors. When narrowed down to specific majors, such as Engineering, the acceptance rate was 31%. But for inner city, ethnically diverse students that amounts to seven out of ten being rejected or perhaps more, since these students have additional academic challenges. Many are English language learners and began Kindergarten as much as three years behind academically, due to complications from impoverished circumstances. As well, students who were of the first generation to attend university often did not have family support or understand how to get financial aid. Some schools had excellent counseling staffs to help with this, although not all were so good. Teachers also noted a "fear of failure" amongst their students. Students had a preconceived notion that if they were not "A" students, then they were failures. Instructors at these schools noted that "failure education" should be explicitly taught, since many times success is the result of a series of improvements upon failed trials. This is borne out by research.

Most of the CAMS students were university bound. That was anticipated due to the high academic achievement level of students coming into their program. They also had a high level of students going into STEM majors upon matriculation at four year colleges and universities. However, many of their female students opted not to go into STEM careers. These students cited male attitudes towards them which could be interpreted as sexist. Some stated for instance that on four person robotics teams, they were frequently relegated to the less interesting or fun role on the team. On most of these teams the roles are programmer, maker-builder, operator and recorder. The recorder writes and keeps the lab notebook, takes pictures, keeps the budget, etc, which sounds a lot like the job of a secretary. Girls said they wanted one of the other roles, but their male counterparts would tell them that they could not have those jobs. Many girls from this program chose to major in nursing. When asked why they did not want to go to medical school instead, they said they wanted a program with more women, since members of their own gender were "easier to work with."

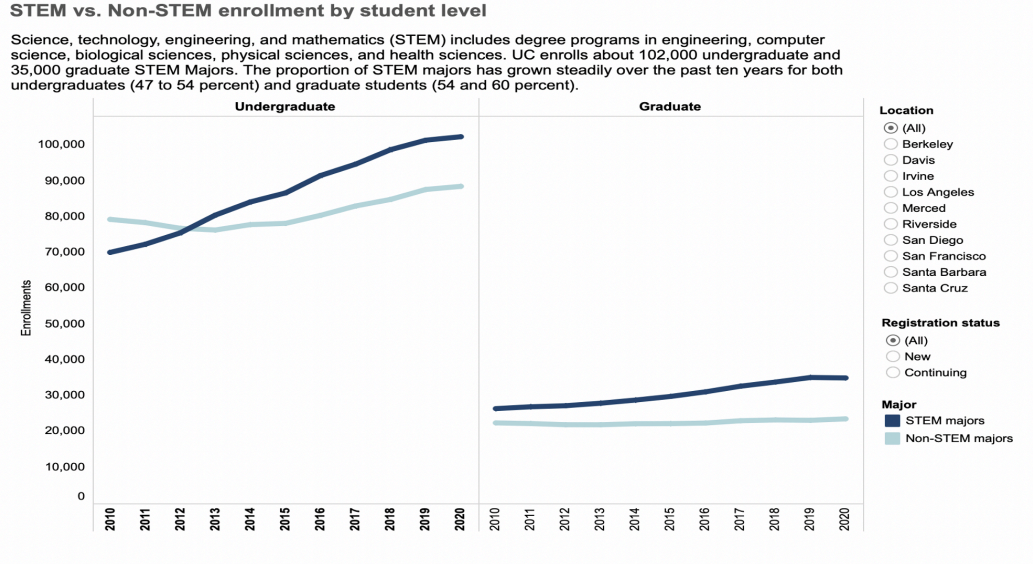
The students from the HHS-MES program did not show as high of a rate of acceptance to four year colleges and universities. This was expected due to the nature of the incoming freshman class who classified as being part college preparatory and part vocationally education oriented. However, their engineering instructor thought more of them probably went via the community college route. Also, they had a higher rate of STEM career pursuit than the others. Because this program functioned as both a college preparatory and vocational education hybrid school, there were many students who opted to go straight to work upon graduation. Many were hired by local tech companies because they were already so skilled in programming, 3D modeling and robotics. Because of the flexibility of the community college and American university system, students can always go back to pick up a university degree later.

Figure 1: Los Angeles Unified School District – Roster of Types of Schools

Primary School Centers	18
Elementary Schools	439
Middle Schools	77
Senior High Schools	88
Option Schools	54
Magnet Schools	65
Multi-level Schools	28
Special Education Schools	12
Home/Hospital	2
K-12 Magnet Centers (on regular campuses)	245
Independent Charter Schools	231
Other Schools and Centers	154
Grand Total	**1,413**

(Graphic source: https://home.lausd.net/apps/news/article/457182)

Figure 2: STEM versus Non- STEM Majors within the University of California System



https://www.universityofcalifornia.edu/infocenter/uc-stem-degree-pipeline

Figure 3: Comparison of the Three Focus Schools

	LMSTA – Charter	CAMS - Magnet	HHS-ES: School within a School
Engineer on Faculty	√	√	√
Student Cohorts	√	√	√
Qualify to Apply?	No	Yes	No
Integrated or Standard Curriculum	Standard w. Engr. Elective	Integrated	Standard w. Engr. Elective
Student or Mentor Centered	Mentor	Mentor	Student
Students going to 4yr University	60%	95%	35%
Students going into STEM Career Fields	30%	72%	89%
Males to STEM	25%	62%	85%
Females to STEM	5%	10%	4%

Conclusion

It is evident that there is more interest in students pursuing STEM careers. If students would never have considered going into an engineering or programming career twenty years ago because they were unaware of what those were, now they know better. The STEM focus in Science classes in California schools has highlighted STEM possible career pathways. But in the three focus schools, it was clear that students had many hands-on opportunities to experience engineering and programming first hand. All three schools provided students with multiple opportunities to get excellent academic college preparation, and earn university credit at the same time. Even though not one hundred percent of these students wanted to go on to STEM careers, it is clear that such STEM focused schools gave them a realistic representation thereof. It is also clear that more students are graduating from these Los Angeles schools with a solid educational background for pursuing STEM careers if they choose to go that way.

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