

# **AC 2009-480: ATTRACTING MINORITIES TO ENGINEERING CAREERS: ADDRESSING THE CHALLENGES FROM K-12 TO POSTSECONDARY EDUCATION**

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# **ATTRACTING MINORITIES TO ENGINEERING CAREERS: ADDRESSING THE CHALLENGES FROM K-12 TO POST SECONDARY EDUCATION**

## **Abstract**

As minority engineering educators at the undergraduate level, the authors of this paper are acutely in tune to the issues of attracting minority students to and graduating them from engineering curriculums. There is a definite challenge in the recruitment and retention of quality minority students in the engineering disciplines. It is time to address these challenges in truth and offer solutions that help to address the root causes of current problems. This paper looks at the two divisions of a students' academic career that have the most impact upon their undergraduate success; that is their k-12 foundational education and their first two years in college as an undergraduate. These two divisions are not mutually exclusive nor are they unaffected by outside influences.

There are specifically three challenges that need be addressed if we are to seriously make an impact on attracting minorities to engineering careers. The solutions of which must come from a team of agents and processes, acting upon the students' life at decidedly different time intervals and all with a different focus. The first challenge is that of foundational mathematics and science and the critical time frame for the first challenge is that of between 4th and 6th grades. The second challenge is that of instilling a self motivated work ethic towards learning and the critical time frame is ideally 9th grade but no later than the beginning of the 11th grade. The third challenge is that of financial accountability and the critical time frame is from freshman through sophomore years at the undergraduate level. This paper peers into these real challenges of attracting minority students to engineering careers and offers the seeds for implementing solution plans. If a plan is formulated to address these challenges at the correct time frame, then not only will we be able to attract a greater pool of quality minority students to engineering but we will be producing better students overall.

## **Introduction**

There are specifically three challenges that need be addressed if we are to seriously make an impact on attracting minorities to engineering careers. The solutions of which must come from a team of agents and processes, acting upon the students' life at decidedly different time intervals and all with a different focus. The first challenge is that of foundational mathematics and science and the critical time frame for the first challenge is that of between 4th and 6th grades. The second challenge is that of instilling a self motivated work ethic towards learning and the critical time frame is ideally 9th grade but no later than the beginning of the 11th grade. The third challenge is that of financial accountability and the critical time frame is from freshman through sophomore years at the undergraduate level. This paper peers into these real challenges of attracting minority students to engineering careers and offers the seeds for implementing solution plans. If a plan is formulated to address these challenges at the correct time frame, then not only will we be able to attract a greater pool of quality minority students to engineering but we will be producing better students overall.

## **Curriculum, Culture, and Teacher Expectations for Inner City Minority Education in STEM**

There is room for improvement of the mathematics and science curriculum at all K-12 levels. The attrition rate of minority students (born and raised) in the United States, typically from the lower socio-economic level, in Science Technology Engineering and Mathematics (STEM) programs continue to increase as we move into the 21<sup>st</sup> century. Literature and common sense suggests that the stronger the foundation a student possesses in STEM, the greater the likelihood that the student will pursue a career directly in or closely related to STEM. Therefore special efforts to stimulate the interest of minorities for STEM careers needs to be begin as early as 1<sup>st</sup> grade and remain consistent throughout their elementary, middle and high school tenure.

It has been well documented that students have different learning styles<sup>1,2</sup>; some are more visual than others, some learn best through the traditional methods of oral and written instruction, while others learn best through hands on methods and so on. As the corporate, political, economic and social professional industries will probably not adjust their training methods for each student, it is imperative that our students be comfortable with the majority of ways educators can implement knowledge. However, during the critical learning periods where foundations for analysis are formed, it is probably best to adapt a teaching style that accommodates the varied individual learning styles of the student population. Minority students from the lower socio-economic stratus in particular are susceptible to this mismatch between traditional teaching and non-traditional learning styles.<sup>3-5</sup> One viable solution is then to implement a greater number of hands on projects, as well as visual exercises including multimedia, in addition to the traditional oral and written instruction. However, the problem then becomes one of time, as many educators already feel overwhelmed trying to complete the curriculum as defined by the state, satisfying the testing requirements such as the Iowa Test of Basic Skills (ITBS), fulfilling paperwork for No Child Left Behind, parent meetings, managing behavior, monitoring halls and the list goes on and on. These authors suggest that a viable solution to the optimization of the educator's time is to arm them and the students with technology. More assignments can and should be web-based, there are now many trusted websites that offer entire lessons on mathematical and science topics in exciting cartoon forms (eg. NASA, PBS), alternatively multimedia educational DVD's or CD's offer lessons often in innovative ways that will maintain the students attention better than the traditional lecture method. Classrooms dedicated to STEM need to be fully wired to accommodate laptops, file transfers between schools, an inter-school mathematics and scientific network, file transfers to PDA'S etc.; finally most educators are not provided software or equipment that allows them to manage, plan and communicate efficiently to their students or to their administrators. The costs involved for the previous suggestions are most likely beyond the allocated state budget. The lack of diversity in STEM careers may cost the state substantially more in the long term as many scholars forecast that America will struggle to compete in a more global economy in the near future. Additionally, cultural backlashes due to a system where minorities are consistently left out of the professional scientific and technical industry, whether it is on purpose or not, has a strong potential to negatively impact the national economy through more government spending on the penal system, welfare, community health issues etc. Many corporate industries already provide substantial funds towards improving education of minorities through scholarships, fellowships and competitions. These authors suggest that the states work

more closely with corporations who are already making large private donations in order to channel funds towards the purchase of these technological assets as well as any training of educators that might be necessary.

Chatham County is located in Savannah Georgia; the Chatham county system currently has thirty elementary schools, ten middle schools, and seven high schools (2008). The system has a substantial minority population (60%) and the majority of students at the inner city schools are classified as minorities. This school system is therefore an ideal candidate to explore minority learning issues. Prior to developing conclusions and recommendations, it is important to recognize that the performance of minority students in mathematics and science, as well as their attitudes towards these subjects in this county cannot be extended to minority perspectives and performance in general. Any conclusions drawn based on the trends in the attitudes and perspectives for minority students should only directly apply to minority students from similar socio-economic cultures, heritage (eg. born and raised in the inner city in the Southern United States vs. immigrated from Africa or the Caribbean, South America, or raised in the suburbs of Atlanta etc.) and similar parental formal education levels.

Though all schools in the county have to abide by an ‘inclusion’ model, i.e. accommodations are made to incorporate special education students with regular students (this involves having an additional teacher) in the classroom, the inner city schools have substantially more special education students included their regular classrooms. A survey of the high schools in the county indicate that most of the high schools that have majority minority students do not offer AP Physics and AP Calculus consistently, do not compete in more than one annual engineering or mathematics competition and do not utilize multimedia websites to enhance the educational experience. Several teachers were interviewed regarding minority student attitudes to mathematics and science and the same themes kept recurring, these were.

- Lack of knowledge and understanding of parent regarding proper support for child in school
- A family culture that does not value educational excellence
- The being smart is “not cool” mentality
- The common perspective that excellence in STEM is for social misfits or nerds
- Female students not being encouraged or exposed or expected to excel in STEM by their parents and friends

The first theme results in substantial lack of progress for students in STEM as parents do not utilize resources available to them such as free after school tutoring and free in home tutoring. Teachers indicate that the majority of parents of the failing or borderline children are not formally educated beyond high school, or never even graduated high school and often have little knowledge and respect for the power of a good education. The areas that each school serves also seem to influence the performance of the students in STEM. The lowest performing and consequently least recruited students attend a school that services six projects or government assisted apartments.

Some teachers have also reported anonymously that the expectation from the standpoint of the educator is often not there. If a lesson is taught in one way and not understood by a few who may have non-traditional learning styles; the educator will re-teach the concept without

endeavoring to accommodate these varied learning styles or worse, he or she might not repeat the lesson because the student has been labeled by the system as already having a learning deficiency and there is no expectation the child will understand anyway. It has been well documented how important expectation is to the academic development of children.<sup>6-12</sup>

In order to increase minority excellence in STEM, thereby attracting more to STEM careers, a multi-faceted solution must be developed that tackles all the issues outlined above. One common sense solution that has been put in place by the Savannah Chatham school system is the implementation of a “Parent” University. Classes in parenting skills, education involvement and lifestyle issues are provided with no cost to the parents. There is an expectation that parents attending these events will network with other parents, exchange ideas on discipline, child-rearing etc. thereby improving their effectiveness as parents. However, it is difficult to assess the effectiveness of this solution. A method of quantifying and tracking who attends this University and the success of their children in school needs to also be implemented. Various surveys to the parents can be introduced in order to obtain feedback on the effectiveness of the program. This solution also ignores the fact that the majority of parents who need to attend such a program are the high school dropouts, the drug or alcohol addicted parents, mild mental retardation, extremely low IQ’s, continually in and out of the legal system etc. This program will help parents who want to be helped and recognize that they do need help. An assessment of whether this group constitutes the majority or the minority of the parents with children who are performing poorly in mathematics and science needs to also accompany this program and additional measures implemented to accommodate discrepancies. Therefore, the authors propose parental education as a viable solution, however quantitative methods of assessing the effectiveness of the program need to accompany the implementation. Additionally, the system can allocate resources for marketing this program to the non-compliant parental population and providing incentives for their attendance. The cost is of course a significant deterrent for such a program, however this becomes political as tremendous financial resources are used to expand the penal system annually. The authors propose spending the same money to be proactive rather than reactive.

Based on a teacher survey from the seven high schools, there does appear to be a correlation between the lower performing schools in STEM and the number of Learning Disabled (LD) students included in the regular mathematics classes. The school with the largest percentage of minorities also had the largest percentages of LD students included in STEM courses. While it is impossible for each school in the system to have the same number of LD students included in their STEM classes, the authors suggest that the school board review methods to distribute these special students more equitably throughout the system. Additionally, the authors recommend a limit on the amount of projects that any one school may serve regardless of location.

The problem of academics, especially STEM, being a pursuit only for young people with no athletic talent, or those who are not “cool”, “hip” or popular has plagued not only American minority children but many Caucasian American children from all classes. There have been a few attempts to merge academics with rock, pop and hip hop culture. Scholars, educators and administrators, however cannot come to a consensus on whether these pursuits should in fact be integrated.<sup>13, 14</sup> Solutions implemented have again not been scientifically validated. The authors suggest that it is at least worth investigating programs which merge achievements in STEM with

cultural fads (eg. music, video games, fashion) that attract our young students. However, as creative educators with strong leadership skills, we should not necessarily have to follow every single urban cultural nuance in order to stay in step with the youth culture so we can develop STEM programs to attract these young scholars. We can also redefine what is “cool” and “hip” in the schools by nature of how students are recognized and celebrated. Educators only need to follow the blueprint used when schools recognize and celebrate accomplishments in sports or other non-academic pursuits.

## **Improving the Work Ethic of Students**

The development of a strong work ethic for engineering students is a necessary component for success in their undergraduate education and the workforce. Students must be willing and self-motivated to learn in order to establish an appropriate foundation in mathematics and science. Unfortunately, many students are either not familiar with the concept of a strong work ethic or recognize its integral role in facilitating their knowledge, skill growth, and ultimately, their capacity to matriculate and obtain an undergraduate engineering degree. The introduction to work ethic concepts must be presented early enough in a student’s education in order to achieve the challenge of improving their foundational math and science skill at the 4<sup>th</sup>-6<sup>th</sup> grade levels. The inculcation of more detailed work ethic concepts should be continued at the 9<sup>th</sup>-10<sup>th</sup> grade levels as well. In what follows, we will discuss the origins of work ethic, establish a framework for its introduction to middle school students and its subsequent expansion and development for high school students using a self-regulated learning approach.

The simplest definition work ethic is the value an individual places on work. It is society’s view that a “good” or “strong” work ethic is thus characterized by individuals who perceive discipline and hard work as being a positive or beneficial attributes. More formally, work ethic can be described as the set of beliefs, values and principles that prescribe the manner in which individuals interpret and act on their rights and responsibilities at any given time within the context of work <sup>1</sup>. The origin of work ethic can be traced back to Max Weber’s intermingling of Calvinist religious ideology and economics in the early 1900’s. Weber’s philosophy laid the foundation for the development of the term Protestant Work Ethic <sup>2</sup>. Since then, having a strong work ethic has become a widely accepted and desirable trait for students and thus future employees <sup>3</sup> and entrepreneurs to possess.

Within the realm of engineering education the need for a “good” or “strong” work ethic has been often mentioned as a characteristic sought by employers <sup>4, 5</sup>. Cupp, et al. have specifically identified a “good work ethic” as one of five engineering student learning outcomes not currently within the ABET EAC criteria, but frequently cited within the literature as desirable <sup>6</sup>. Unfortunately, the direct teaching of work ethic principles in the classroom is often informal or unintentional (indirect) <sup>2</sup>. For example, many faculty address the need for students to have good work ethic through grading practices and modeling of their own behavior <sup>7</sup>. Adding to the need to explicitly address the importance of work ethic is each generation’s shifting view <sup>8</sup> of “good” work ethic. Many baby boomers now feel that young people associate “good” work ethic with simply showing up for class or work <sup>9</sup>. In light of this, the clear demarcation, and early instillation and inculcation of a strong work ethic are paramount to the short and long term

success of students (e.g., developing foundational math and science skills, becoming motivated life-long learners).

One pathway for students to become life-long learners is through teaching them to become self-regulated learners <sup>10</sup>. Self-regulated learners can be described as those individuals who: 1) Set learning goals/plan what they want to learn; 2) Examine and select the tools (skills) necessary to learn; 3) Monitor their progress towards their learning goals; 4) Maintain motivation to complete tasks towards meeting goals; 5) Understand their strengths and weaknesses. Denzine et al. summarizes self regulated learns as individuals with the “will” and “skill” <sup>11</sup>. They have the will to provide self-motivation and the skill to determine the knowledge they need and currently possess to achieve their goals. Based upon these interpretations of self-regulated learners, we would argue that they have an intrinsically strong work ethic. We hypothesize that by teaching our students to become self-regulated learners, we can improve their work ethic. A significant challenge with this effort will be the maturity of the students (9<sup>th</sup>-10<sup>th</sup> grade level) to perceive and take ownership in their learning. This challenge notwithstanding, the use of self-guided learning principles to foster a strong work ethic will benefit the students in their long-term quest for knowledge acquisition.

### **Plan implementation at the middle school level**

We propose for the middle school students the introduction of work ethic concepts using the Occupational Work Ethic Inventory (OWEI) <sup>12</sup>. This tool provides a brief but accurate measure of an individual’s endorsement of work ethic. Hill and Petty use the OWEI to perform a factor analysis to identify the key attributes of work ethic <sup>13</sup>. They concluded that work ethic is mostly influenced by interpersonal skills, initiative and being dependable. Based on this research, class discussions and student journaling should be employed focused on improving interpersonal skills, initiative and being dependable. Participation in outdoor community service projects may also provide opportunities to nurture these skills in the students. All student results should be tracked and monitored through the 4<sup>th</sup>-6<sup>th</sup> grade levels.

### **Plan implementation at the high school level**

At the 9<sup>th</sup> -10<sup>th</sup> grade levels, work ethic development should be continued and expanded with the inclusion of self-regulated learning concepts. High school freshmen should retake and compare their middle school results of the OWEI. This is followed with group discussion and self-reflection of work ethic concepts. The group discussions can be extended to include role-playing activities and real life scenarios. Hands-on activities such as community service projects can also be employed. Self-reflection activities again consist of journaling.

Tenth grade students will be introduced to self-regulated learning concepts to bolster strong work ethic principles. The first step will be to assess their level of readiness to become self-regulated learners. This will be accomplished using Guglielmino’s Self-directed Learning Readiness Scale (SDLRS) <sup>14</sup>. This tool has been used previously in many studies including work by Litzinger et al. to assess the impact of capstone design courses on students’ readiness for SDL <sup>15</sup>.

Next the students would be guided in the development of learning goals. The level of guidance should be based on their performance on the SDLRS. Class discussions should be given on the differences between performance and learning goals. Performance based goals view learning as a tool in demonstrating competence to others<sup>11</sup>. Learning goals view learning as a means to acquire knowledge for personal competence. Younger students most often exhibit surface learning characteristics<sup>16</sup>, which is associated with performance based goals. Surface learners are extrinsically motivated and tend to focus on the tasks associated with completing a goal using rote learning techniques such as memorization. While mindful of this tendency, performance goals should not be completely discouraged since some competition amongst students could improve their work ethic. Further, Denzine et al. states clearly that performance goals do not harm learning goals<sup>11</sup>.

In the development of learning goals, students should be encouraged to challenge themselves. Students should also be encouraged to use the instructor as a guide and resource, to view errors (in goal execution) as a sign to expend more effort, and to gain an understanding of course material based on overall content<sup>11</sup>. One technique to achieve this understanding is for instructors to explicitly link assignments to content mastery and point out these relationships<sup>10</sup>. Students should have a clear indication of the long term benefits in achieving their learning goals. This will address their need for motivation in achieving these goals. Strategies should be formulated to achieve each goal.

Students should be assisted with self-appraisal and evaluation throughout their efforts in goal achievement. This can be accomplished again using journaling and class discussions on their progress. Students should be able to independently assess the effectiveness of their strategies in achieving their goals. To assess the overall effectiveness of this effort, the 10<sup>th</sup> grade students should be re-tested with the OWEI and the SDLRS at the end of school year. Students should also be informed of these results to provide closure to their self-assessment efforts.

### **Financial Accountability**

Financial resources are an important part of the engineering education of minority students. Students need resources for tuition and fees, books, and living expenses. The proper management of these resources is just as an important component of successful engineering education as the curriculum and work ethic. The components of the financial resources include, personal and family funding, scholarships, work study, federal grants, student loans, and external employment.

For minority students, funding from personal savings and parents constitute a portion of funding towards the students education but more often is only a small portion of the total funding needed for a college education. Many students are first or second generation college students whose parents are not wealthy and cannot afford to pay the tuition and fees. Therefore the student is often times left to find other means of financial resources to help pay for their college education. Scholarships are typically available for minority students in the engineering fields. There are many scholarships specific for minority students and most all scholarships carry some sort of minimum academic standard. This underscores the need for minority students to prepare themselves well academically. Most scholarships carry a minimum GPA requirement of a 3.0.



Students need to be educated on the importance of applying themselves towards their academics to the best of their ability so that they can maintain a good GPA and qualify for the many scholarships that are available to minority students. It is not ironic that the work ethic and financial accountability are inextricably tied together; one feeds the other. Students need to work hard and obtain better than average grades in order to have access to increased financial sources. Many institutions offer minority students the opportunity to earn funds for college expenses by participating in college work study programs. These programs allow a student to work on campus and earn additional funding. There are positive benefits to this type of employment. The benefits include that the student works on campus sometimes in their own department and are not working off campus jobs. Many of these work study programs are needs based and are given to those students who qualify as not having enough funds to pay for their college education. They are also usually restricted in the maximum number of hours that a student can work. This at least assures that the student is not putting too much emphasis on the work and not the study. Student work study and federal grants are good sources of finances for minority students and should continue to be utilized.

Student loans can be a good financial resource to assist minority students to pay for their college education. However, this is one component of the financial resources picture that can be misused or abused to the detriment of the student. Student loan terms are often favorable; allowing the student to begin paying back the loan upon graduation and typically at decent interest rates. These loans can sometimes be the lifeline that students need to stay in college and complete their engineering degrees. However, students sometimes abuse the student loan program not understanding the downstream consequences. Students often times apply for loans above and beyond what is needed to complete payment of college tuition, fees, housing, books and other necessities. Minority students will often times max out on their loan capabilities to pay for sometimes unnecessary items including automobiles. The problem here is that minority students do not understand that they are racking up obligations that are not necessary, that must be eventually paid back and that will ultimately impact their credit and buying power once they complete college and enter the working world. These forms of financial assistance should be used as a means to complete the engineering degree but only when absolutely necessary.

Finally, a trend that has seemed to consistently increase is that of students working off campus jobs. Many minority students have taken on part time and in some cases full time jobs to help pay for their engineering degree. However, here is another element of the formula that is sometimes abused and often to the detriment of the student. The problem is that students are taking on part time or full time work mainly to earn extra money to feed needs outside of those necessary for college; including automobile and related expenses, expensive clothing, cell phones, electronic gadgets, apartments etc. The consequence is that the students grades suffer. More often than not, when a student works a part time job off campus, they are not going to be able to give the proper amount of time necessary to their engineering studies. Most often grades will begin to suffer and they student eventually ends up performing below their capabilities. There should be some regulations for minority students being able to work off campus jobs. Students should first be in good academic standing, work no more than 15 to 20 hours per week, work very close to campus if not on, and it should be needs based. Students should be discouraged from working off campus jobs mainly to obtain funds for needs not directly connected to their education.

## Conclusion

In conclusion there are three primary challenges that are integral to attracting and retaining minority students in the engineering disciplines. Those challenges include curriculum and culture at the k-12 level, student work ethic, and financial accountability. Much like a three legged stool, with the improper management of one, staying balanced on just the other two is a very difficult task.

There is room for improvement of the mathematics and science curriculum at all K-12 levels. The attrition rate of minority students (born and raised) in the United States, typically from the lower socio-economic level, in Science Technology Engineering and Mathematics (STEM) programs continue to increase as we move into the 21st century. Literature and common sense suggests that the stronger the foundation a student possesses in STEM, the greater the likelihood that the student will pursue a career directly in or closely related to STEM. Therefore special efforts to stimulate the interest of minorities for STEM careers needs to be begin as early as 1st grade and remain consistent throughout their elementary, middle and high school tenure.

The development of a strong work ethic for engineering students is a necessary component for success in their undergraduate education and the workforce. Students must be willing and self-motivated to learn in order to establish an appropriate foundation in mathematics and science. Unfortunately, many students are either not familiar with the concept of a strong work ethic or recognize its integral role in facilitating their knowledge, skill growth, and ultimately, their capacity to matriculate and obtain an undergraduate engineering degree. The introduction to work ethic concepts must be presented early enough in a student's education in order to achieve the challenge of improving their foundational math and science skill at the 4th-6th grade levels. The inculcation of more detailed work ethic concepts should be continued at the 9th-10th grade levels as well.

Minority students have to be educated on the financial accountability of pursuing a STEM degree and the pros and cons of each. Federal grants, personal saved funds from the student and family, and college work study are components that can continue to be utilized in a positive manner to help pay for a college education. Student loans and off campus employment should be utilized only when absolutely necessary as they both have consequences affecting the students financial obligations downstream or their academics respectively.

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