A Ten Year Assessment of the Pre-Engineering Program for Under-Represented, Low Income and/or First Generation College Students at The University of Akron

Paul C. Lam, Tirumalai Srivatsan, Dennis Doverspike, John Vesalo and P. Ruby Mawasha
The University of Akron

ABSTRACT

This paper summarizes the findings of a ten year study on a Pre-Engineering program aimed at dramatically improving both the recruitment and retention of under-represented students pursuing careers in Science, Technology, Engineering and Mathematics (STEM) at The University of Akron. The primary goal of this study was to evaluate The University of Akron's operation of the special High School Upward Bound, Upward Bound Math Science, Educational Talent Search and Pre-Engineering Academic Achievement Programs with the primary objective of increasing the number of under-represented students in STEM. The programs are offered in collaboration with the College of Engineering Minority Engineering program, **I**ncreasing **D**iversity in **E**ngineering **A**cademic**s** (**IDEAs**). The net effectiveness of the programs was measured using the following parameters: (a) average high school grade point average both before and after participating in Pre-Engineering programs, (b) high school math and science achievements, (c) retention rate for students returning from previous year, (d) students enrolling in colleges and (e) percentage of students committed to STEM upon graduation. The most noteworthy result stemming from the use of these strategies is that the targeted students, who have expressed an enthusiastic interest in pursuing mathematics and science, are highly motivated, ambitious and excited about exploring STEM.

INTRODUCTION

Several colleges spread through the United States now offer a variety of pre-engineering math/science programs in a sincere effort to promote the pursuit of undergraduate Science, Technology, Engineering and Mathematics (STEM) education among under-represented high school students. The primary purpose of such programs is to facilitate an increase in enrollment with concurrent retention of under-represented STEM students, defined here to include the following: (a) African American, (b) Hispanics, (c) Native American and possibly (d) Asian-Pacific. Further, those students who meet the federal income and/or first-generation college criteria (neither parent having earned a bachelor's degree) can participate in these pre-engineering math/science programs. Other noteworthy goals of such projects include the following: (1) to reinforce the self-confidence of under-represented high school students; (2) to enhance their problem solving skills by using a hands-on learning approach; (3) to increase the overall awareness of the student of viable career options in STEM; (4) to provide diagnostic testing for high school students in mathematics so as to determine their deficiencies prior to their enrollment in college; and (5) to provide students with opportunities to use computers and become intimately familiar with the usage of word processing, spreadsheets, math software packages, and the Internet. The projects thus address the significant shortage of under-represented or disadvantaged and low-income students in STEM and careers by targeting potentially interested and talented high school students.

Based on documentation in the published (open) literature about careers, African American career development, and minorities in engineering (Carter & Wilson, 1992; Landis, 1991, National Science Foundation, 1992), we have developed a general framework for understanding the success in STEM among under-represented students. Our concept of success relies on the following parameters (Lam, 1997): (a) math and science knowledge, (b) career orientation, and a commitment to STEM as a career; (c) educational and occupational values and beliefs, (d) social support, which includes role models, support from peer faculty and support from family, and (e) self-efficacy or competency. These parameters were intended to serve as a general guide in the design of our various STEM programs.

At The University of Akron, the Academic Achievement Programs (Upward Bound, Math/Science, Educational Talent Search and Pre-Engineering) were established in 1988, and the engineering program for minorities was initiated in the Spring semester of 1990. In 1993, the College of Engineering began to collaborate with the Department of Academic Achievement Programs in order to coordinate and improve the running of outreach programs aimed at enhancing the possibility of academic success among under-represented high school students. An initial conceptualization of the program relied heavily upon the works of Landis (1991, 1995). These efforts have provided the desired pipeline for admitting students to the STEM programs. In particular, for the past ten years, the programs in Academic Achievement, in cooperation with the minority-engineering program [Increasing Diversity in Engineering Academics (IDEAs)] at The University of Akron have conducted a six-week summer residential program. This program consists of an integrated curriculum in (a) Mathematics, (b) Sciences, (c) Language Arts, (d) Technical Writing, and (e) Computer Science coupled with practical hands-on experience in engineering design practice. The knowledge that the students gain during the summer program has provided the needful direction toward careful consideration for pursuing future courses in STEM during their academic years in high school. In addition to the summer curricula, the project includes an academic year tutorial component and summer transition activities, which essentially include: (a) diagnostic testing, (b) orientation, (c) peer mentoring, (d) study skill and group dynamic workshops, (e) bridge-up classes, and (f) academic advising.

The purpose of this paper is to describe and analyze the results for this unique and innovative pre-college curriculum plan that attempts to improve the STEM educational process for 9th to 12th grade students. In order to assess the performance of the program, data has been collected over the past ten years. Further, it provides a summary of a recruitment and retention program that will help to attract under-represented students to the STEM field of study in college. The assessment of the program is evaluated using the: (1) average high school grade point average both before and after participating in Pre-Engineering programs, (2) high school math and science achievements, (3) retention rate for students returning from the previous year, and (4) percentage of students committed to STEM upon graduation.

Year	Total # of Students	Freshmen	Sophomore	Junior	Senior
1994	32	10	7	7	8
1995	40	12	9	10	9
1996	32	10	8	9	5
1997	40	10	15	9	6
1998	40	8	12	13	7
1999	38	6	10	15	7
2000	41	5	14	12	10
2001	40	8	16	8	8
2002	36	3	16	14	3
2003	29	2	11	11	5

Table 1: High School Student Profile

PARTICIPANTS

The Pre-Engineering target groups are students from the 9th through 12th grade participating in Academic Achievement Programs. A profile of the high school students over the past ten years is provided in Table 1. Approximately, forty students are selected for the program at the beginning of each summer. Their race and gender are summarized in Table 2. To be accepted into the Pre-Engineering Program, prospective students are: (a) required to have a 2.5 grade point average, (b) must attend a briefing with their parents, and (c) interview with the program director. The following are the criteria for the selection of participants: (i) students must live in Ohio or the neighboring states of Pennsylvania, Indiana, or Michigan, (ii) students must have demonstrated some interest in or show the potential in college prep math/science curriculum, (iii) students must possess a level of maturity and independence sufficient to enable them to live away from home for a period of six weeks (determination is made subsequent to personal and family interviews), and (iv) the family must meet federal poverty income guidelines, which are 150 % of the family income level established by the United States Census Bureau for determining poverty status and/or first-generation college requirement (neither parent has a four year baccalaureate degree).

There is no cost to qualified students for the six-week summer program. The Department of Education pays student expenses for: (a) transportation both to and from the program, (b) dormitory housing, (c) meals, (d) field trips and cultural events, (e) classes, and (f) course material. Qualified students receive a weekly stipend during the summer months to cover any miscellaneous expenses and a monthly stipend during the academic year. In addition, the program includes an academic year and summer bridge post-secondary program. Graduates from the program are eligible to receive a $1,000-$1,500 tuition scholarship to attend The University of Akron. The College of Engineering and the IDEAs program fund these scholarships.

Year	Total # of Students	Male	Female	African American	Asian	Hispanics	White
1994	32	24	8	27	0	0	5
1995	40	31	9	33	1	0	6
1996	32	20	15	30	0	0	5
1997	40	15	25	33	3	0	4
1998	40	17	23	32	2	1	5
1999	38	25	13	25	3	2	8
2000	41	30	11	32	3	0	6
2001	40	26	14	26	4	1	9
2002	36	22	14	24	4	0	8
2003	29	22	7	23	1	0	5

Table 2: Participants' Race and Gender

PROGRAM CURRICULUM

3.1 Summer Component

The Pre-Engineering Program at The University of Akron consists of a six week summer resident component plus it also provides for a series of career workshops and tutorial programs throughout the academic year. For six weeks during the summer months, pre-engineering students take a full schedule of academic classes, which includes English composition, mathematics, physics, biology, and a foreign language. Computer environment, word processing, spreadsheets, computer graphics, math software packages and an exposure to and use of the internet are available to students through computer workshop sessions. However, keeping the students motivated, interested and enthusiastic about sciences and mathematics has become more and more difficult to accomplish in a typical classroom setting. To promote inspiration, interest and motivation among the students, the teaching approach was restructured from a lecture based approach to a pedagogy that was demonstrative and included inquiry-based activities based on practical experiences. A typical physics syllabus and schedule is shown in Table 3.

The physics curriculum consists of three units. Part 1 covers the fundamental concepts in electrostatics and electricity. Part 2 focuses on the fundamental concepts of thermal combustion. This unit also included a hands-on design focusing on building an internal combustion V-8 model engine. Part 3 discusses the fundamental concepts of kinematics, dynamics, and aerodynamics. The hands-on component of this unit consists of a design project involving building and launching rockets. The fundamental knowledge gained helps build self-confidence among the students, while keeping them enthusiastic about science and technology, and concurrently enhancing their skills in problem solving.

In addition to the summer academic curriculum, the students spend a full hour and thirty minutes daily with the engineering faculty and staff who involve the students in building projects and laboratory demonstrations. During this time period, faculty members are available to provide structure to the learning experience as well as to provide direct instruction, career planning and mentoring. Applying scientific and mathematical principles, students work together on projects such as designing bridges, building engines, building model roller coasters, designing rockets, testing building materials and designing electronic circuits. The primary areas of emphasis are mechanical and electrical engineering. The approach is based on the primary premise that students can be challenged regarding the fundamental concepts of mathematical and physical sciences. By using a hands-on approach to learning, the students are reinforced regarding the concepts in fundamental science that are essential for the preparation of future scientists and engineers. The projects offer the students an opportunity to learn about engineering and to concurrently function in the role of an engineer in order to solve problems during a normal classroom session.

A notable difficulty of the program is the creation of a new project every year since many of the students are returning students from the preceding year. In addition, the engineering curriculum varies from year to year. Topics covered in past years include vector algebra, materials science, statics, as well as mechanical, electrical and civil engineering tools and software. A typical engineering curriculum and listing of design projects appears in Table 4.

Over a five-year period, 1999 to 2003, a survey (Table 5) was taken of participants at the end of the summer pre-engineering education. Of the 94 % of students that returned the questionnaires, 75 % of the students rated the pre-engineering program as "Excellent' or "Good," 19 % of the students rated the program "Fair," and 5 % rated the program "Poor." The responses indicate that students accepted this teaching method with a very positive attitude. The reasons for the positive response were:

Week 1	Rules, regulations, and syllabus discussed. Upward Bound Pre-Test, and Physics Pre-Test. Introduced course objectives, provided the goals of the class. Lectured on physics and how it is related to current technology. Showed a video on general subject of physics and its applications to current technology.
Week 2	Introduction on electrical conductors and insulators. Perform an investigation on electricity, conductors, insulators, and the electrical path due to the effects of conductivity. Discussion on electrical ef fects on magnetism. Perform an investigation electricity & magne tism using a magnetic compass. Discussion on electrostatics and moving charge. Electrical diagrams and symbolic representation of electrical components will be studied. Introduction to "charge-hold ing" materials. Perform an investigation on Capacitors. Video on electrostatics, capacitors, resistors, and inductors.
Week 3	Discussion on generators and their mechanisms. Do an investigation on using a gencon as the source of electricity. Discussion on ways to charge a capacitor. Perform an investigation charging an air capacitor. TOUR OF THE ENGINEERING AND PHYSICS LABS. TEST ON CHAPTER 1 and 2
Week 4	Discuss internal combustion engines.
Week 5	Introduce the principles of rocketry, terminology. Identification of rocket components and their functions.
Week 6	Post Test, and Evaluation

Table 3: Physics course outline and schedule

1. It provided an insight into physical science problems and practical situations.
2. Engaging and meaningful activities were used.
3. Cooperative learning was emphasized.
4. Projects fostered curiosity and creativity.
5. The hands-on experiences provided stu dents a chance to explore without the stigma of having right and wrong answers.
6. Students defined their own goal and collect data that provide opportunities to explore concepts of their design.
7. Peer mentoring and tutoring were provided.

The end results stemming from a careful use of these teaching strategies were that the students were highly motivated and excited about exploring natural and physical sciences, and also engineering concepts. Furthermore, the students were able to see the applications and effects of these fundamental concepts in their daily life. Also, and perhaps most importantly, the students did not necessarily view science as being difficult and intimidating.

3.2 Academic Year Component

During the academic year, students attend a series of career workshops at local manufacturing companies and research facilities. These activities are designed to inform students about the STEM profession. They also include one-on-one discussions between the engineers and the students. For out-of-state participants, Internet and the World Wide Web are used for interaction. Special projects are another component of the academic year program. Pre-Engineering students have participated in statewide competitions such as the Ohio Space Institute symposium on visionary technologies by designing, building, and navigating a roving robot for lunar exploration. During the engineering week the students participated in the bridge design competition.

In partnership with the College of Engineering, the academic year component also consists of weekly tutorial sessions. Engineering students from the **IDEAs** program and student members of The National Society of Black Engineers (NSBE) volunteered six hours per week and served as mentors and tutors for the Pre-Engineering students. These tutorial services occur at the permanent study center for minority engineering students; we have found such center to be essential for an effective retention program (Lam, 1994). The student study center not only provides a location for the delivery of tutorial services, it also is a facility for students to form their study groups. Utilizing a collaborative learning model, students are encouraged and challenged to work together on hands-on problems and in organized study sessions specifically designed to meet the needs of participants. The focus of the tutorial session is on promoting academic excellence, while also promoting positive competition and peer interaction. Equally important, the program provides students with extensive academic support and facilitates the creation of a sense of academic community among students which creates a buffer against the feelings of academic isolation often encountered by academic minorities.

Based on the data collected from The University of Akron **IDEAs** and other minority engineering programs (Lam, 1997, Landis, 1991) the under-represented students historically have lower scores on American College Test (ACT) or the Scholastic Aptitude Test (SAT). As a result, this prevented most of the minority students, interested in the STEM programs, from applying for many academic scholarships and the university honors program. Future plans of the achievement program essentially includes SAT or ACT tutorial service for the sophomore and junior participants during the academic year.

Week 1	Basic Mathematic Pre-Test. Introduction of types of engineering, course objectives, teamwork concept, and provide goals of the class.
Week 2	Microsoft word, excel, power point and Netscape.
Week 3	AutoCAD LT
Week 4	Basic concepts of material science, force and motion, and stress-strain terminologies. Each concept followed by a commercial example
Week 5	Group design projects: 1) 1994- Water pressure rocket design 2) 1995- Balsa wood glider 3) 1996- Model rocket design 4) 1997- Design rehabilitation device to help a disabled client. Each group will be assigned a disabled client in the class period, and based on their experience, design a device to assist in everyday life. 5) 1998-The Whale Net research project, develop an adhesive device to be used to attach a satellite tag to a whale. 6) 1999- Lego decta robot design 7) 2000- Design of radio frequency modulated receiver. 8) 2001- Model Rocket design. 9) 2002- Model Roller Coaster design. 10) 2003- Tensile, Charpy impact tests of various alloys.
Week 6	Oral presentation and preparing a poster for displaying the summer design engineering project.

Table 4: Engineering course outline and listing of design projects

Year	Total # of Students	Excellent	Good	Fair	Poor
1999	38	9	20	6	0
2000	41	9	17	6	7
2001	40	11	26	0	0
2002	36	2	15	18	0
2003	29	11	11	3	3
Total	**184**	**42**	**89**	**33**	**10**
%	94.5	24.1	51.2	18.9	5.7

Table 5: Student Survey of the Pre-Engineering Program 1999-2003

3.3 Freshmen Transition Program

Following high school graduation, a special one week freshmen transition program is offered in order to improve students' fundamental concepts of college algebra, pre-calculus mathematics, and calculus. Students declaring themselves as STEM majors are admitted to this program, which combines a traditional classroom lecture and academic workshops. This preparation aids in improving the mathematical skills of students in preparation for taking The University of Akron's placement test from the Testing Office. In addition, the program pays for room and board, tuition, and books. For students whose high school preparation falls below the standard freshman level, the summer program is capable of providing a necessary effective intervention plan with the purpose of developing and improving their future academic performance. The new incoming engineering students have an opportunity to associate with both the faculty and upperclassmen in the College of Engineering. Students are also made aware of the availability of the tutorial service during the academic year. The final phase of the program involves academic advising, placement testing, financial aid budgeting, scholarships, and peer counseling. Also, for the new students and their parents an informal welcome social or picnic is held at The University of Akron. This experience enables the incoming students to get acclimatized while concurrently introducing them to other engineering students at the university.

RESULTS

The University of Akron summer integrated and year-round academic programs have increased access and retention of identifiable under-represented students pursuing STEM careers. As described above students reactions to the STEM learning experience have been extremely positive. In addition to reactions, the pre-engineering curricula actually results in several significant student outcomes such as, (i) increase grade point average, (ii) less anxiety toward math and sciences, (iii) fostering the can-do attitude, and (iv) increasing personal self-esteem. For the senior high school students, the program prepares them in mathematics through academic workshops to ensure that they place themselves into upper level mathematics and science courses. The project has an immediate impact on new incoming STEM students as they enter the freshman academic year. The freshmen transition activities or summer bridge program help to re-engineer the academic environment to create learning situations that both empowers students while also enhancing the opportunities for success in their pursuit of a career in STEM. The program provides academic advising to new incoming STEM students to ensure that they are placed in the required courses that correspond to the STEM curriculum of their selected major. In addition, the project creates a partnership between the College of Engineering and the community in an effort to increase retention at The University of Akron. The summer bridge program not only enriches well prepared students that can succeed in the STEM disciplines, it also addresses the issue of better college preparation that will be needed during both the junior and senior years in the engineering curriculum.

It is also possible to do additional quantitative analyses of the program. Based on the data obtained for the past ten years, 100 % of the participants from our program graduated from high school, and 94 % of the participants entered colleges. A summary of participation retention rate and their high school grade point average both before and after participating in the achievement program is provided in Table 6.

As shown in Table 6, of the sixty-eight seniors that graduated from the academic program, thirty-eight students (53 %) attended The University of Akron. Twenty-four of the thirty-eight students attended The University of Akron majoring in STEM. One other significant result is that 66 % of the participants (45 out of 68) majored in a STEM career area.

As indicated in Table 7, the participation retention rate from year to year was between 59 % to 75 %. Those students who dropped out of the achievement program were predominately senior high school students who had to work during the summer in order to earn their tuition prior to entering college. In addition, Table 7 shows that the mean high school grade point average upon entering the program was 2.67. The mean high school grade point average after participating in the program was 2.89. Thus, participation in the program was accompanied by an increase in the grade point average of 0.22. The estimated student population standard deviation for grade point average is 0.14. Us-

Year	Senior	College Enrollment	Majoring SMET	Attending U. Akron
1994	8	7	5	3
1995	9	9	6	4
1996	5	5	3	3
1997	6	5	3	3
1998	7	7	7	4
1999	7	7	4	5
2000	10	9	6	4
2001	8	7	5	5
2002	3	3	2	2
2003	5	5	4	3
Total	**68**	**64**	**45**	**36**

Table 6: Students Profile of Attending College

ing a z test, this change would correspond to a z value of 5.0014, which would be significant at beyond .0001, with 95 % confidence that the true effect of participation in the program will improve the grade point average of between .14 and .30 points.

A second approach to assessing the significance of the program is to calculate a binomial or sign test in order to determine whether a null hypothesis of no effect of entering the program would be rejected based upon the yearly results. In 10 out of 10 years, there was a positive effect on grade point average for the program. If there were no effect for participation in the program on grade point average, this result would occur only 1 time out of 1000 (using a one-tailed test). Thus, using conventional significance levels, we can conclude that entering the program does have a positive effect on the grade point average.

Year	Total # of Students	Retention Rate (%)	Average HS GPA Upon Entering Program	Average HS GPA After Participating Program
1994	32	72	2.70	2.93
1995	40	70	2.65	2.94
1996	32	63	2.80	3.09
1997	40	65	2.60	2.88
1998	40	75	2.75	3.15
1999	38	64	2.64	2.75
2000	41	59	2.59	2.81
2001	40	69	2.81	2.88
2002	36	60	2.60	2.75
2003	29	64	2.51	2.70

Table 7: Ten Year Study of Pre-Engineering Participants

CONCLUSIONS AND IMPLICATIONS

(a) The program can be analyzed based upon both qualitative and quantitative data. The analysis of the quantitative results of this study should be interpreted with caution due to the small sample size and unique nature of the sample. However, the positive results are consistent with reactions, qualitative reports and our observations.

(b) Longitudinal evaluation of participants as they graduate from college is also being investigated statistically. On the other hand, the data presented does provide a start toward understanding characteristics related to a success in pre-engineering intervention program.

(c) Overall, the effectiveness of the program is measured by: (i) the significant increase of the mean high school grade point average for students pre and post participation of the program, (ii) 66 % of the participants major in the STEM career, and (iii) 94 % of the participants entered colleges. This was true even though the students in the sample came from a diverse group of high schools, college prep to inner city high schools.

(d) The students will be prepared to meet the "new" engineering challenges in the College of Engineering adopted by the Accreditation Board of Engineering and Technology (ABET). These challenges involve an integration of meaningful design and computational skills, which builds upon the concepts of mathematics, science, communication skills, engineering, and humanities.

(e) As a result, the pre-engineering academic achievement program provides students with quality academic advising, hands-on activities and tutorial service that help to: (i) establish a strong foundation in computer usage for the students, (ii) develop their study skills, and (iii) motivate group dynamics and cooperative learning. The program also identifies the students' abilities in mathematics, science, design and conduct experiments, communicate effectively, cooperate on group design team, analyze and interpret data and understand professional and ethical responsibilities, which are required by ABET.

It is the hope of the authors that the implementation of such pre-college programs will improve the learning opportunities for high school students and serve to interest them in STEM careers and majors. We also hope that it will generate excitement in these talented students with regard to the possibility of taking more advanced math and science classes. Future improvements include a) offering the ACT/SAT prep program to all students, b) academic and social support: diversity initiatives, role models, and cooperative learning, c) cooperative sponsorships: industrial field trips and internships, d) developing an early intervention and diagnostic program that reaches out for potential prep engineering students before they enter high school, and e) maintaining the peer network throughout the students' academic career pathway. The ultimate goal is to increase the numbers and proportion of under-represented students in STEM majors and careers.

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Dr. Paul C. Lam is Professor and Associate Dean of Undergraduate Studies, Diversity Programs and Co-op Education Director in engineering at The University of Akron. Research interests include structural dynamics, fatigue and fracture evaluation of material behavior, pre-engineering and minority engineering retention issues. He received his BS degree in 1969 at Purdue University, MS degree in 1970 at University of Illinois, and PhD at The University of Akron in 1978. In 1996 Dr. Lam was elected as an ASME Fellow and also the recipient of numerous outstanding teacher awards.

Dr. T. S. Srivatsan is Professor of Mechanical Engineering at The University of Akron. He received his MS (1981) and PhD (1984 degrees in Mechanical Engineering from Georgia Institute of Technology, specializing in fields synergizing aspects related to processing, characterization and mechanical behavior of engineering and engineered materials. He has authored/co-edited 28 books, delivers over 135 technical presentations and has authored and/or co-authored over 410 archival publications in International Journals, Proceedings of national and international conferences. Dr.Srivatsan also serves as the co-editor of the International Journal on Materials and Manufacturing Processes. In 1996 he was chosen as Outstanding Young Alumnus of Georgia Institute of Technology. In 1997 he was chosen as Outstanding Research Faculty of the College of Engineering, at The University of Akron. In 1998 he was elected Fellow of the American Society of Mechanical Engineers. In 2002 he was elected Fellow of the American Society for Materials International.

Dr. Dennis Doverspike, Ph.D., ABPP, is a Full Professor of Psychology at the University of Akron, a Fellow of the Institute for Life-Span Development and Gerontology, and Director of the Center for Organizational Research. He serves on the Board of IPMAAC and is Chair of the Professional and Scientific Affairs Committee. Dr. Doverspike holds a Diplomate in Industrial/Organizational Psychology from the American Board of Professional Psychology and is a licensed psychologist in the State of Ohio. He has over twenty years of experience working with consulting firms and with public and private organizations. Dr. Doverspike is the author of 2 books and over 100 refereed journal publications. He also provides consulting services in the areas of Industrial Psychology and Human Resource Management. He is on the Editorial Board of *Organizational Analysis*.

John Vesalo is the Coordinator of the Upward Bound Math Science and Pre-Engineering Programs at The University of Akron, Akron, Ohio. He has 12 years experience preparing low-income, high school students for post-secondary education including teaching, grant management, program planning and federal record keeping/ reporting. He has a B.S. Degree in Biology, B.A Degree in Sociology/ Social Work and a M.A. Degree in Sociology.

Dr. P. Ruby Mawasha received his BS degree in Mechanical Engineering from The City College of the City University of New York. He holds MS and PhD degrees in Mechanical Engineering from The University of Akron. Currently, Dr. Mawasha is the Assistant Dean of Engineering and Computer Science at Wright State University. Dr. Mawasha is also an Adjunct Faculty in the Department of Mechanical Engineering at WSU. He is involved in several professional societies including the American Society for Engineering Education. Dr. Mawasha has received numerous honors including Omicron Delta Kappa, Pi Tau Sigma, Pi Mu Epsilon, and Tau Beta Pi. His research interests include thermo-fluids sciences, bioengineering, applied mathematics, and engineering education.