

STEM Outreach Efforts for Urban Students

Otilia Popescu
Old Dominion University, Norfolk, VA
opopescu@odu.edu

Vukica M. Jovanovic
Old Dominion University, Norfolk, VA
v2jovano@odu.edu

Jennifer G. Michaeli
Old Dominion University, Norfolk, VA
jgmichae@odu.edu

Stacie Ringleb
Old Dominion University, Norfolk, VA
sringleb@odu.edu

Alok Verma
Old Dominion University, Norfolk, VA
averma@odu.edu

Abstract

Four year universities and community colleges rely on outreach efforts to keep the awareness of STEM related careers to students which might be interested in joining their student body in the future. These events are of outmost importance for students who do not necessarily have all necessary role models to engage them in conversation about their future career. Some students might not perceive a STEM career as valuable and feasible in their future career path, even if their own school offers information and resources related to STEM career pathway. Hence, various outreach efforts on different levels of education have to be integrated to make sure that students learn about engineering careers early enough for them to consider this choice and to adjust their high school curriculum to align with their future career. This paper presents four different outreach efforts for four levels of K-12 education: pre-school, elementary school, middle school and high school. The activities used to implement these outreach events are also discussed in the paper. Activities related to robotics for example, have the advantage of engaging young students, and offer in the same time the opportunity to discuss different engineering branches such as electrical or mechanical engineering, electronics, wireless devices, or underwater robots. Location of the outreach event is also important since STEM information needs to reach both students and their families. As such, this paper discusses the placement of the STEM events in schools, in community places or in job related places such as a Navy base.

Introduction

The current generation of students growing up in the highly technological society of the twenty first century is facing advanced technologies in every aspect of their daily life, with computers, smartphones, tablets and other high tech gadgets being ubiquitous from very young ages [1, 2]. This level of technology in current society is due to the engineering advancements and there is a high demand for engineering educated people at all levels [3]. But in order to bring more people in engineering the first thing to do is to create awareness of the importance of engineering in current society, both for young students in grades K-12 and for their parents [4, 5]. Lately a plethora of STEM related programs are offered at all levels, starting with very young kids in elementary and even pre-school, ranging from summer camps, workshops, participation in conferences promoting specific careers or even professional development events focused on K-12 teachers, both in the U.S. and globally [6-9]. Other programs are sponsored by government agencies such as National Aeronautics and Space Administration (NASA) and National Science Foundation (NSF) and they provide summer programs related to engineering for K-12 students [10]. The programs may address the students as well as their teachers and they may include workshops and summer camps, in school or out of school programs, robotics clubs in schools or outside school grounds offered by different other organizations [11]. Some of these programs spread on few days – one week time frame but some shorter programs are one day only and may take the form of field trips or STEM fair events. All of these programs are important and they have specific goals. While a summer camp is more focused on a specific STEM area, which might be robotics or rapid prototyping for example or some other science or engineering topic, a STEM fair would have the goal to expose the participants to a broad selection of STEM related opportunities in the region and through displays and hands on activities to stimulate the curiosity of young students for science and engineering [12]. Before a student to start looking for a summer camp in engineering he/she should learn about such opportunity and have the understanding of the benefits of such camp, and here is where a STEM fair event can provide the necessary information. Even though these days there is a multitude of STEM programs, all of them have their limitations and there is a large group of students that still do not have access to them. A school might offer a robotics club, but there is always a limited number of students that can be part of it, and if a student does not have a clear idea about that club early enough at the beginning of a school year, the club capacity might be filled before he/she learns about it or decides to participate [13]. A summer camp that runs for a week is very often not an affordable option for a lot of students and again, the spots usually are filled by the time a family learns about the opportunity or has the chance to decide for it [14]. Thus, even with increasingly larger number of science and engineering related programs a lot of students still do not get the access to them, and they might be even intimidated by this and get the impression that STEM education is something that a lot of people get access to but not them. This is where community oriented STEM events can increase awareness and inform students and their families about engineering

careers and educational pathways to be pursued in the K-12 curriculum to enable successful STEM careers.

Old Dominion University College of Engineering Engagement in Outreach Events

Old Dominion University is fully engaged in reaching out in the community for science, technology and engineering careers, and the range of programs vary from funded and volunteer based programs, close collaboration with local school to develop programs in schools, in the university or community locations that facilitate the participation of everyone interested, either student or parent. In this paper we discuss some of the volunteer based outreach activities organized at different locations outside of the university.

Location of the event is crucial in reaching out for specific groups in the community, especially in areas of large groups of underrepresented students, rural areas or poor communities. Some of these activities are STEM fairs organized at different locations, such as a Navy base (Norfolk) or a high school in a community with a large group of underrepresented students (Portsmouth HS). For such events the participants come with displays and demos and very often with hands-on activities that introduce young students to basic concepts of science/technology and engineering, and to current issues in the community where STEM solutions are needed. Successful students in different STEM related programs have the chance to show their projects (very often robotics related projects) and get the chance to be role models for other students, to inspire them and give them information of how to get involved in such programs. Different organizations have the opportunity to distribute information about their offers in terms of STEM related programs or products (such as educational materials). Universities and colleges provide information about education pathways towards different careers in STEM related fields. The downside of such events is that most of the time they are overcrowded and a student can spend only very little time at each booth, especially when is part of a group and has to go along with the group. The amount of information it might be also overwhelming and young students might find themselves lost in front of all the exciting displays that they do not have much of an understanding. That is why the fair event is very important in distributing information, creating awareness and helping people of different organizations establish contacts, but they need to be followed by more specific events, which involve smaller groups of students and are placed in a different environment. Faculty and students from ODU College of Engineering and Technology participate frequently in STEM programs and activities on school grounds in the local community. These events are in collaboration with teachers and local school district and they may materialize as engineering days organized for groups of different grade level students or programs that go year around or for a period of time in conjunction with engineering classes or clubs that run in the schools. Faculty also get involved at individual level as they may volunteer time as tutors in the areas of math and science for K-12 kids, or they may get involved in senior projects that students enrolled in specific high school programs are required to develop to fulfill their graduation requirements.

The following sections outline the main components of four outreach activities in which faculty and students from Old Dominion University participated, each geared for a particular age group of students.

An Engineering Program for Pre-School Children

In 2012-2013 academic year, the 3-5 year old multi-aged classrooms at the Children's Learning and Research Center (CLRC) at Old Dominion University (ODU) implemented a teacher led engineering unit that spanned over approximately 3 weeks. Students were exposed to many areas of engineering, including, but not limited to mechanical, aerospace, civil, chemical and genetic engineering. This experience included fieldtrips in the campus where the students made magnetically levitated train cars and were exposed to balloon powered cars printed on a 3D printer. During the 2014-2015 academic year, the CLRC expanded the engineering unit and implemented a project based learning into their curriculum. The activities related to the 3D printed balloon powered cars were expanded. The students were brought in an engineering Design lab with a 3D printer and they were presented different 3D printed balloon powered cars. They discussed the process of engineering design, how cars are built out of various parts and how these parts were different in the models presented. Based on team analysis of the different models the students voted on which car they thought is the best, the measure being which car would go the farthest. Then, with the help of their teachers, they brainstormed ideas of how a car should be redesigned for better performance. Each of the four classes met with two engineering faculty members to turn their ideas into a new car designed in Computer Aided Design (Autodesk Inventor). Kids had the chance to design their cars to look like sharks for example, or to have parts of the cars remodeled in different shapes, such as a star, an octagon or a triangle. They discussed the influence of the car total weight, the size of the wheels and the overall car shape on the car speed performance. From all the cars that were designed according to the specifications, four cars voted by the kids were selected for printing. These final designs were tested by the children in a competition. The main design objective was to build the fastest car. After the competition test each model was discussed based on its performance. This way, young students were involved in the iterative process of engineering design and testing, and in discussions related to different geometrical shapes and properties of solid dynamics, speed and acceleration. The 3D printed cars from this project are currently used in STEM/STEAM outreach events, where students from elementary schools are asked to visually inspect the cars and estimate which one will go farther, to swap wheel sizes to determine how the wheels affect the distance the car will travel, and to investigate how the balloon affects the motion of the car. This way students are exposed to various facets of engineering such as aerodynamics, rigid body dynamics, reconfigurable design and testing.

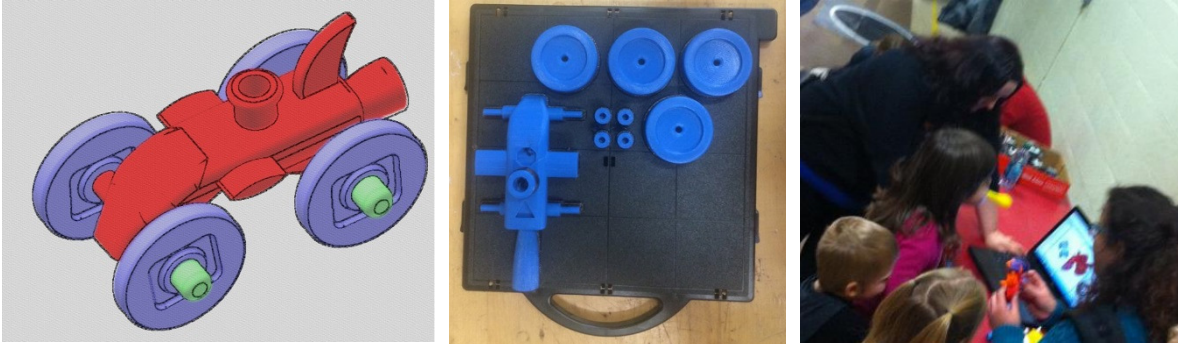


Fig. 1: Two different balloon cars designed by the preschoolers

In-School Engineering Day for Fifth Grade Students

This event was organized within an elementary school and addressed only a group of students, specifically the fifth graders which are at the point of making their choice for middle school. Virginia Beach has few choices for middle schoolers including gifted and IB programs, but even if a student chooses to pursue the neighborhood middle school, this is a time when a student starts thinking about future career and curriculum choices are important to create the grounds for success in those careers. For this event two faculty and several students from ODU participated. The event spanned over half of the school day. There were up to 100 students participating along with the fifth grade team of teachers. The engineering day consisted of two presentations made by faculty, demos and hands-on activities. One of the presentations introduced the students to the field of engineering, its importance along the time and its omnipresence in our everyday life today. The presentation made the distinction between engineering and science, and among the wide range of engineering areas. It was emphasized that engineers are curious and creative people and their work targets specific needs in the society and community. Students were encouraged to identify areas of engineering that they feel more attracted to, that they like and are particularly curious about. The idea transmitted was that one should not think of engineering as a very narrow and specialized field that only some people are fit for, but that it is a wide range of specializations and each student can find his/her own identity within the engineering and bring personal contribution to the development of the field. Students received very well the presentation. They were familiar with a lot of the information presented, and this eliminated the initial timidity of the students in front of college faculty and students and of a field perceived as very difficult. Since the familiar information was presented in a new context or was pointing to aspects they were not aware of, the presentation had the merit to inspire the students, to fire their curiosity and their desire to learn more about engineering in general and specific areas in particular. A second presentation was more specific and introduced the students to the aspects of mechatronics, its interconnections with various other fields of engineering, its history and presence these days in areas ranging from community jobs such as cleaning polluted areas or helping people with special physical conditions, to space exploration and advanced

manufacturing processes. The engineering day for fifth graders included along with the presentations demos with robots and small engineering projects featuring electrical and mechanical laws or properties. The setup of this event offered more time than a fair type event for every student to get a chance to try the demo projects and ask questions about them. After the engineering day the teachers continued in class the discussions with the students on the topics presented and students were asked to write about their learning through this event.

Since a large number of students approached the faculty to expressed their desire to become engineers after learning of the wide variety of engineering alternatives, and to talk how learning about the importance of engineering in society sparked their interest, it became apparent that targeting smaller and more homogeneous groups has the potential of being more successful in reaching to the students.

STEM Event for Middle School Students Organized in a Navy Base

Hampton Roads area is home of a large concentration of military populations, either living here permanently or being stationed for several years. A lot of the adult military population is often interested in furthering their education and getting a degree while staying in the area. In this context Old Dominion University has a lot of programs to accommodate military students, and a large portion of the student body is either active or retired military personnel, or coming from military families. Among the young population, enrolled in K-12 education system, there is a big number of students that are either coming from military families or that aspire to become part of the military forces later in life. For these students it is very important to introduce them to STEM and to the opportunities for engineering and science trained individuals in military related fields. In support of these ideas a science, technology, art and math fair was organized in spring 2016 at the Mid-Atlantic Regional Maintenance Center (MARMC) in Naval Norfolk Station. Interactive booths celebrating current and emerging technologies where presented by Old Dominion University in conjunction with U.S. Naval agencies and regional shipbuilding industry partners.



Fig. 2: “Roboat” Autonomous Surface Vessel

Over two hundred students from three middle schools in Hampton Roads engaged in STEAM activities through tabletop displays and hands-on activities, all organized by academic, private industry, and government participants to introduce students to the concepts and the outcomes of STEAM. Students had also the opportunity to talk directly with professionals in these fields. ODU engineering faculty and students were present at the event with some original projects built by college students, they introduced the middle school students to these projects, and explained to them how the ideas developed working on college projects are shaping the Navy and the related industry today. The demos presented with this occasion were related to areas such as naval and maritime, robotics and mechatronics, electronics and circuits. An autonomous boat to compete in the Roboat Competition sponsored by Office of Naval Research (ONR) was designed and built by a multi-disciplinary team of ODU undergraduate engineering students from Engineering Technology, Mechanical and Aerospace Engineering, and Electrical and Computer Engineering Departments. The “Roboat” Autonomous Surface Vessel was set-up as a static display with posters to explain the vessel design and competition details. Another stand had ODU students teaching ship design terminology and concepts of buoyancy and stability through hands-on activities. They also helped middle schoolers to build boats out of aluminum foil and let them use the different designs to compete in order to determine which ones would hold the most weight before sinking. Navy personnel and ODU faculty and students also explained middle-schoolers about unmanned underwater vessels used to respond to oil spill disasters. Middle-schoolers have the opportunity to remotely-operate small submersibles to respond to a “simulated” oil-spill in a small pool.



Fig. 3: Oil Spill Response using unmanned underwater vessels

Another group of displays were related to car building and intelligent machines. ODU Motor Sports Club’s Baja Car was set-up as a static display with ODU students on-hand to explain the design and competition details. This car was designed and built by a multi-disciplinary team of ODU undergraduate engineering students from Engineering Technology, Mechanical and

Aerospace Engineering, and Electrical and Computer Engineering Departments. Students from Computer Science department designed and built intelligent land vehicles to sense and respond to different obstacles as part of their academic requirements in ODU's Intelligent Machines Course. This project integrated robotic design and programming skills and visiting students were introduced to the importance of hardware/software integrated design need these days in a wide range of industries. A last group of displays from ODU introduced students to electronics and circuits through reconfigurable circuit boards that are commercially available. These boards may be found at affordable prices in toys department stores but they can be invaluable teaching tools for students at all levels, and can be used to introduce them to different circuit components and the laws that govern them through hands-on experiments, easy to put together, test and modify, without the need of soldering. Next to the circuits' stand students were also introduced to mechatronics and robotics, with the use of the SumoBots robots, in such a way that they could see how learning the basic principles through simple designs can lead them to more complex applications, such as robotics.

Since the event was hosted on Naval Station Norfolk inside the MARMC facilities, students saw first-hand what technical equipment and the type of engineering related work that sailors and civilians do on a daily basis. Students were able to see the US Navy's ships up-close and understand the engineering activities required to keep the ships afloat, full of advanced technology, and keep the sailors safe and prepared to do the country's mission. This whole event had the goal to get students excited about engineering and help them see the opportunity of achieving an engineering degree in their community, at ODU, and upon its completion, the fortuity of pursuing an engineering career with the Navy in the proximity of their home. For some students being able to get the required qualification and find job in their area of residence is crucial, especially when affordability of higher education becomes a priority for the young generation.

STEM Fair in High Schools or Local Colleges

STEM fairs, or science and engineering fairs as sometimes called, are nothing new these days, but it is important for them to reach the population that is in most need of the information that they provide. For students in local communities that struggle with poverty and social issues that are associated with it, it is crucial to bring to their attention not only the opportunities that are around them in terms of education or career, but the very fact that those opportunities are within their reach, that there is a chance for everyone to be successful, and that chance might be closer than they think. Sometimes a teenager might not be so open to discuss his potential and choices for future career with a family member or a guidance counselor in school. Even though the school's guidance offices have plenty of information about the local opportunities some students still do not take advantage of this information. The benefit of a STEM fair organized in the community, eventually in one's own school, is that it reaches better both students and their families, bringing the information directly to them. Hand-on demos and activities for all ages

make a fair joyful and brings people together, but along with these activities local colleges and universities come also with information and points of contact for the variety of programs that they offer, the career opportunities related to those programs, and the pathways to reach and succeed in these programs. An example of such event is the annual STEM fair day organized on public high school grounds in Portsmouth city of Hampton Roads area. It is a daylong event for neighborhood families and students of all grades. With this occasion local students from different grades have the chance to present the projects they built during past year science classes, strengthening the confidence in their own potential, raising their self-esteem, as well as inspiring other students, eventually their own classmates. Local industries and organizations come also with displays and science/engineering related demos and products that spark the imagination of young students and inspire them to pursue careers in engineering and science. Another similar example is the STEM fair organized annually by Christopher Newport University in Newport News City, also in Hampton Roads. To these fairs, ODU college of Engineering and Technology participates with demos (such as Sumobot robots) supported by students. Faculty are always present in these events, and they get the chance to rich to high school students that are preparing to choose their college pathway. Not only that different programs offered are discussed with the prospective students, but with students entering high school faculty also discuss the curriculum choices in high school that will lead to a successful college experience.



Fig. 4: STEM Fair Day at Wilson High School in 2015 and 2016 organized by Portsmouth Public Schools

Conclusion

With the need of highly trained engineers and scientists in the modern society comes the need of informing the students and their families about the wide variety of options available, and to make this information get especially to those students that have little exposure to higher education and pathways to reach it. Hampton Roads area, home of Old Dominion University, includes low income communities, large groups of minority population and a very large group of military personnel. ODU is dedicated to reach out to all members of this community and help them achieve their education and career goals. This paper discusses the need for variety among STEM outreach events, from fairs to in school programs, and their benefits, the importance of their

location and the population to which they reach out. The paper also presents four representative events in which ODU faculty and students participated, ranging from programs for preschoolers to in school programs for students entering middle school and fairs for middle and high school students.

References

- [1] R. McHaney, *The new digital shoreline: How Web 2.0 and millennials are revolutionizing higher education*: Stylus Publishing, LLC., 2011.
- [2] Y. Tehranian, "Social Media, Social Kids: Sociocultural Implications of 21st Century Media for Development in the Preteen Period," 2013.
- [3] A. K. Thiele, J. A. Mai, and S. Post, "The Student-Centered Classroom of the 21st Century: Integrating Web 2.0 Applications and Other Technology to Actively Engage Students," *Journal of Physical Therapy Education*, vol. 28, pp. 80-93 14p, Winter2014 2014.
- [4] J. Moore III, "A qualitative investigation of African American males' career trajectory in engineering: Implications for teachers, school counselors, and parents," *The Teachers College Record*, vol. 108, pp. 246-266, 2006.
- [5] M. Munro and D. Elsom, "Choosing Science at 16: The Influence of Science Teachers and Career Advisers on Students' Decisions about Science Subjects and Science and Technology Careers. NICEC Briefing," 2000.
- [6] L. S. Anderson and K. A. Gilbride, "Pre-university outreach: Encouraging students to consider engineering careers," *Global Journal of Engineering Education*, vol. 7, pp. 87-94, 2003.
- [7] L. S. Nadelson, J. Pfiester, J. Callahan, and P. Pyke, "Who Is Doing the Engineering, the Student or the Teacher? The Development and Use of a Rubric to Categorize Level of Design for the Elementary Classroom," *Journal of Technology Education*, vol. 26, pp. 22-45, Spring2015 2015.
- [8] H. Salmi, H. Thuneberg, and M. P. Vainikainen, "How do engineering attitudes vary by gender and motivation? Attractiveness of outreach science exhibitions in four countries," *European Journal of Engineering Education*, pp. 1-22, 12 / 16 / 2015.
- [9] L. Gumaelius, H. Mickos, P. O. Nilsson, A. Norén, M. Pinho-Lopes, M. Prenzel, *et al.*, "Outreach initiatives operated by universities for increasing interest in science and technology," *European Journal of Engineering Education*, pp. 1-34, 02 / 04 / 2016.
- [10] J. A. Momoh, "Outreach program in electrical engineering: Pre-college for Engineering Systems (PCES)," *IEEE Transactions on Power Systems*, vol. 29, pp. 1880-1887, 01 / 01 / 2014.
- [11] R. Hammack, T. Ivey, J. Utley, and K. High, "Effect of an Engineering Camp on Students' Perceptions of Engineering and Technology," *Journal of Pre-College Engineering Education Research*, vol. 5, pp. 10-21, 06// 2015.
- [12] J. C. Musto, W. E. Howard, and S. S. Rather, "Using solid modeling and rapid prototyping in a mechanical engineering outreach program of high school students," *International Journal of Mechanical Engineering Education*, vol. 32, pp. 283-291, 01 / 01 / 2015.

- [13] E. Levy, M. Tan, R. Gale, T. Karp, and A. Barhorst, "Affordable K-12 robotics programs," in *41st ASEE/IEEE Frontiers in Education Conference (FIE 2011)*, 2011, pp. S1D-1.
- [14] F. Tuluri, "Using robotics educational module as an interactive STEM learning platform," in *Integrated STEM Education Conference (ISEC), 2015 IEEE*, 2015, pp. 16-20.

Biographies

OTILIA POPESCU is currently Assistant Professor of Electrical Engineering Technology, Frank Batten College of Engineering and Technology, Old Dominion University, Norfolk, Virginia. She received the Engineering Diploma from the Polytechnic Institute of Bucharest, Romania, and the PhD degree from Rutgers University, all in Electrical and Computer Engineering. In the past she has worked for the University of Texas at Dallas, University of Texas at San Antonio, Rutgers University, and Politehnica University of Bucharest. Her research interests are in the general areas of communication systems, control theory, and signal processing. She is a Senior Member of the IEEE and serves as an Associate Editor for the IEEE Communications Letters. In addition, she is an active member of the technical program committee for several IEEE international conferences including GLOBECOM, ICC, and WCNC conferences.

VUKICA M. JOVANOVIC is currently serving as Assistant Professor of Mechanical Engineering Technology, Frank Batten College of Engineering and Technology, Old Dominion University, Norfolk, VA. She received the PhD degree from Purdue University. She is teaching classes in the area of mechatronics, computer aided modeling and computer integrated manufacturing. She served as Chair of Student Hardware Competition at IEEE SoutheastCon 2016. She was serving as an ASME Robots for Relief adviser and IEEE Car Team co-adviser. Prior to joining ODU's Engineering Technology Department Dr. Jovanovic was teaching at Trine University, Angola, Indiana in Design Engineering Technology Department and was a Lead Faculty of International Studies program at Master of Leadership degree in School of Professional Studies. Prior to joining Purdue as graduate student, Dr. Jovanovic worked as a faculty at University of Novi Sad, Serbia.

JENNIFER G. MICHAELI is currently an Assistant Professor of Mechanical Engineering Technology, Frank Batten College of Engineering and Technology, Old Dominion University, Norfolk, VA. Dr. Michaeli received her BS in Naval Architecture and Marine Engineering from Webb Institute of Naval Architecture in 1998, MS in Ocean Systems Management in 1999 from Massachusetts Institute of Technology and PhD in Mechanical Engineering in 2010 from Old Dominion University. Prior to joining ODU in 2013, Dr. Michaeli spent ten years in the Department of Defense and three years in private industry as a Naval Architect and Program Manager where she carried out design and engineering, construction oversight and testing of advanced marine vehicles and new technologies for the US and Foreign Naval Forces. At ODU,

Dr. Michaeli leads the Marine Engineering Systems Specialty in the Department of Engineering Technology and the Marine Engineering Minor for the Batten College of Engineering and Technology. Dr. Michaeli's research and teaching interests include topics concerning naval architecture; marine engineering; design, manufacturing and testing of composites and lightweight structures, and engineering decision tools. Dr. Michaeli is a Registered Professional Engineer in Virginia and actively consults to the marine industry.

STACIE RINGLEB is currently serving as Associate Professor of Mechanical and Aerospace Engineering, part of Frank Batten College of Engineering and Technology, Old Dominion University, Norfolk, VA. Dr. Ringleb received a B.S. in biomedical engineering from Case Western Reserve University, a M.S.E. in mechanical engineering from Temple University and her Ph.D. in mechanical engineering from Drexel University. She completed a post-doctoral fellowship at the Mayo Clinic before joining Old Dominion University as a research faculty member at the Virginia Modeling, Analysis and Simulation Center in 2006. In 2008, Dr. Ringleb joined the Department of Mechanical and Aerospace Engineering at Old Dominion University.

ALOK VERMA is Ray Ferrari Professor and director of the Lean Institute at Old Dominion University. He also serves as the director of the Automated Manufacturing Laboratory. Dr. Alok Verma received his BS in Aeronautical Engineering from the famed institution, IIT Kanpur, MS in Engineering Mechanics, and PhD in Mechanical Engineering from ODU. Prof. Verma is a licensed professional engineer in the state of Virginia, a certified manufacturing engineer and has certifications in lean manufacturing and Six Sigma. He has organized several international conferences as general chair, including ICAM-2006 and ICAM-1999 and also serves as associate editor for three international journals. He serves as the president of the International Society of Agile Manufacturing and as the chief editor of the *International Journal of Agile Manufacturing*.