Raising Interest in STEM Education (RISE): A Community College-University Partnership for Engaging Minorities in STEM

Daniel Christe[1,2], Brian Wisner[1], Jay Bhatt[3], and Antonios Kontsos[1,2*]

[1]Department of Mechanical Engineering & Mechanics
[2]Drexel Center for Functional Fabrics
[3]Library Academic Partnerships, Drexel University Libraries
*****Corresponding Author: e: akontsos@coe.drexel.edu | t: 215-895-2297

Abstract

Despite recent efforts, the fraction of underrepresented minorities employed in STEM fields continues to mismatch the current demographics of the United States (U.S). In this context and over the past three years, an educational program between the Community College of Philadelphia and Drexel University with the overall objective to increase the interest of underrepresented minority students (URMs) in STEM has been implemented. The working hypothesis for the University component of this effort has been that learning about science and engineering is most effective if it is paired with the challenge of independent research in a collaborative "micro-environment", such as the one in academic research laboratories. In this approach, six undergraduate URMs (three male, three female) were selected in the inaugural year, expanding to eight students (four male, four female) in the program's second year and seven in the current year (five males, two females). Each student selected a faculty advisor and research group aligned to their individual interests within the first week of the ten week program. From the outset, students were introduced to library professionals and digital search tools which they employed to review literature relevant to their research foci, forming a basis for research proposals to present before panel of faculty and student judges. To complete the program, each student produced three final deliverables - an oral presentation, a technical poster and a final paper designed to familiar students with technical communication. In addition, students were exposed to an industrial R&D setting through a visit to a multinational corporation known for its innovation and provided with information on STEM research opportunities at the national level (e.g. DoE, DoD, NSF-REU). Students demonstrated familiarity with basic research methods and universally reported increased interest in STEM education and careers.

Keywords

Research-based Learning, Community Colleges, Minority Participation

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Introduction

In the United States, only 4.9% of all college students graduate with a Bachelor's degree in any engineering discipline[1], with just under two-thirds of students STEM degree programs overall graduating with STEM degrees[1]. Compared to their white male peers, females and URMs face particular challenges in STEM education that need to be understood to drive an increase in this vital talent pool for the American STEM workforce. Despite efforts, underrepresented minority (URM) and female students representation in STEM does not reflect their true portion of United States demographics. With minority groups currently accounting for the fastest growing segment of the U.S. population [2-4], American global technical leadership will increasingly depend on minority demographics succeeding in science and technology fields[5].

However, minority and female students face particular challenges in university settings, often finding themselves one among few, if any, in STEM courses [6]. Freshman and sophomore "gateway" courses typical of STEM programs, with high attrition rates overall, disproportionately impact minority and female students[7]. In many cases, minority students are first in their families to attend college, tend to come from lower-income households[7, 8], and speak English as a second language[7]. Such factors may lead to academic under-preparation and create intimidating situations upon arriving in collegiate settings[7].

Community Colleges (CCs) serve nearly half all undergraduate students, making them a critical component of the American higher education and STEM education landscape. URMs and females are more likely to enter higher education through CCs. For instance, fifty-seven percent of all African-American and sixty percent of all Hispanic college students were enrolled in CCs during the 2011-2012 academic year[9]. While CCs are a key gateway equipping students with the skills needed to successfully transition to Bachelor's (B.S.) granting institutions[10-12], the pathway between CCs and universities is fraught with challenges that disproportionately affect minority students, which may produce a drop in self-confidence and academic performance during the first year of university studies[10, 13-18]. Therefore, the importance of the first transfer year cannot be understated - if students successfully navigate the initial "transfer shock"[19], they are just as likely to attain a bachelor's degree as their peers who attended four-year institutions from the outset [20]. In several cases, it has been actually shown that CC transfer students may even academically outperform their peer group [12, 15].

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Undergraduate research experiences have well-known positive impacts for all students, which are further amplified in the case of minority and female students [8, 21, 22]. In fact, the first of the 1998 Boren Commission's fifteen recommendations [23] for the modern American research university was to "make research-based learning the standard" from freshman year. Research-based learning nicely aligns with Piapert's formulation of constructionism[24], which focuses on learning through making artifacts (e.g. maker movement) or creating knowledge (e.g. research-based learning). We adopt the latter in this work, empowering students to become co-creators of technical knowledge in a supportive learning environment. In this context, faculty and graduate students become encouraging mentors and coaches, rather than authoritarian "sages-on-stages". When students realize the meaningful contributions they can make to science/engineering, they potentially obtain extra motivation to further pursue STEM education and careers.

Mentoring by faculty, staff, and graduate students and professional staff is a particularly strong positive element of undergraduate research experiences[2, 17, 22, 25], giving students the confidence and identification with STEM fields needed to drive education and career decisions. Undergraduate research experiences often spark interests that subsequently translate to scientific careers [22, 26-28].

Objectives, Approach, and Methods

The Raising Interest in STEM Education (RISE) program was structured to create an engaging, hands-on STEM learning ecosystem based on the premise that STEM learning is most effective if paired with the challenge of conducting independent research. Philadelphia has one of the most impoverished large urban school districts in the U.S., predominantly serving minorities. Only 1 in 10 graduates of Philadelphia high schools earn a four-year college degree within ten years of graduation [29]. Community College of Philadelphia, having a total enrollment of approximately 31,000[30] is the largest educational institution in Philadelphia. The partner institution Drexel University is a mid-size private research university with a total enrollment of 26,000[31] students and strong emphasis placed on experiential learning in the form of a large cooperative education program (co-op).

The program was structured to produce a collaborative microenvironment in which students became producers of new information, individually "coached" by their faculty advisors and graduate student mentors. A combination of academic and social activities were planned to

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faciliate students' integration to the university environment, aligned with Tinto's model of student retention[32]. The RISE program operated on the fast-paced, ten-week quarter timeline depicted in Figure 1. Each year, students were welcomed to Drexel through a kickoff in which undergraduate, graduate students, and faculty shared their perspectives on research experiences. Within the first week, students independently contacted a minimum of three prospective faculty supervisors of their choice. Following this pairing, students were additionally paired with graduate student mentors to guide daily technical progress.

With a topic and goals formulated, students had to immediately begin critically reviewing relevant literature to formulate research proposals, presented in Week 4 (Figure 1). The Liaison Librarian for Engineering became an integral teaching partner, embedded in RISE from the outself to guide students through digital library resources and research skills. This concept is known within the library community as "embedded librarianship"[33], in which a librarian inserts himself into the daily functions of a user group, enabling him or her to interact with users on a deeper level.

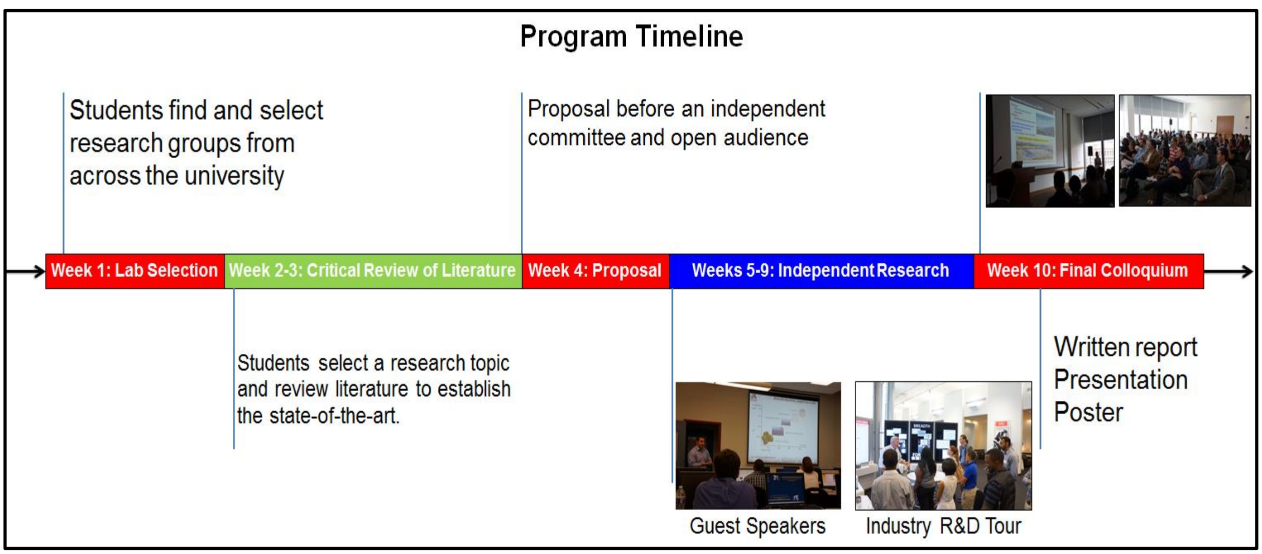

Figure 1: A schematic depicting the ten-week research program timeline.

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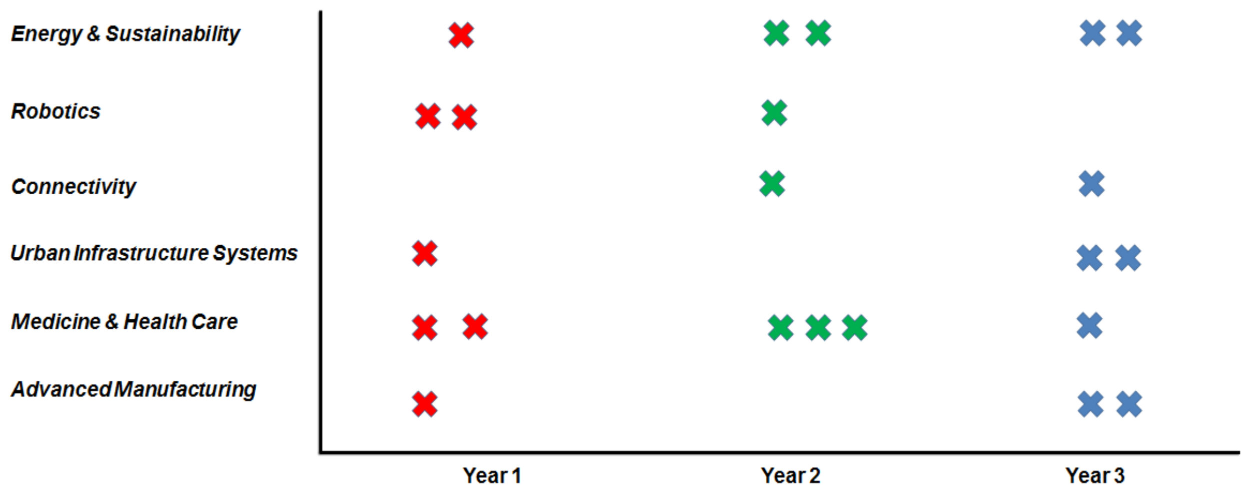
Results & Discussion

Table 1: A breakdown of the three RISE student cohorts by race and gender

	Number of Students	Breakdown of Race & Gender
Year 1 (2014)	6	3 Male (2 African-American, 1 Hispanic); 3 Female (White, 2 African American)
Year 2 (2015)	8	4 Male (2 Hispanic, 2 African-American); 4 Female (4 African-American)
Year 3 (2016)	7	5 Male (4 African-American, 1 Hispanic); 2 Female (1 Hispanic, 1 African-American)
Total	**21**	

RISE creates a compressed ten-week research experience, from affiliating with a lab, to identifying the state-of-the-art, formulating a proposal, executing proposed research and presenting results in written, poster, and oral forms. In addition, we included the students in departmental seminars, senior design presentations, Masters/PhD defenses and university classes to further acquaint them with the functioning of a research university.

In three years of RISE, students have selected a diverse array of topics based on their own interests, covering themes such as renewable energy, advanced manufacturing, urban infrastructure systems, robotics, and informatics as depicted in Figure 2.



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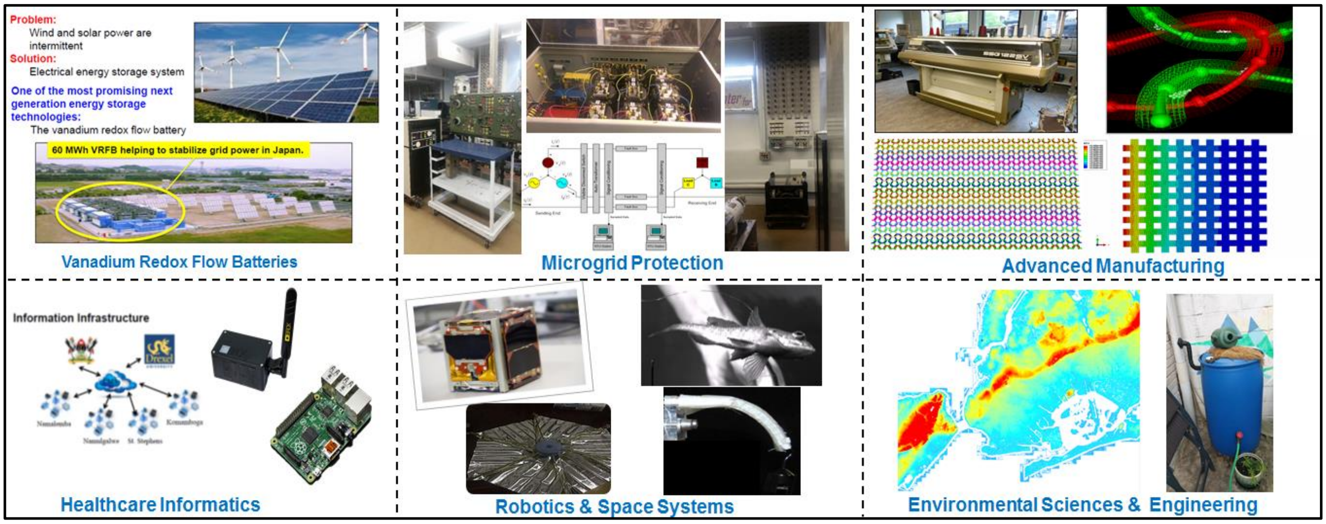

Figure 2: (top) Students' selection of research topics by theme **(bottom)** selected examples of RISE student projects

The abstract writing in Week 2, critical review in Week 3, followed by a proposal presentation in Week 4 forced the students to review relevant literature and define a scope of their work for the remaining six weeks. The RISE coordinator (a faculty in a STEM field) and teaching assistants provided additional reading materials to expose students to contemporary trends in STEM research, including reports published by the National Academy of Engineering (NAE), National Science Foundation (NSF), President's Council of Advisors on Science and Technology (PCAST) and other government agencies. Students were encouraged to relate their work to these broad themes in their proposals and final presentations.

We captured quantitative and qualitative feedback on the program from the students and their graduate student mentors. First, we asked students to provide an overall description of their RISE@Drexel experience, selected responses shown in Table 2. The students overall reported a sense of increasing confidence and identification with STEM in the face of an actual research challenge, as they learned the skills of a research scientist "hands-on". Furthermore, we asked the students to comment on multidisciplinary STEM exposure through RISE, as shown in Table 3. This was achieved through the RISE weekly group meetings, library integration, and individual coaching/mentoring. We also asked the students to comment on their future educational and career plans, selected comments shown in Table 4.

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Table 2: Students' self-reported experiences in RISE

Please detail your experience of the RISE@Drexel summer program
In the RISE summer program I was gifted with the experience to work with undergraduate, graduate students and professors in an academic research environment. I gained very important skills as far as talking to professionals, presentation skills and real experience in the research industry. This program exceeded all of my expectations and left me with a bounty of knowledge and experience.
The RISE@Drexel summer program consisted of 10 weeks of intensive exposure to the laboratory environment of our choice. In my case, the first few weeks were spent becoming accustomed to the research topic as well as learning the inner-workings of the lab. I had a PhD mentor who explained to me what needed to be completed in the lab. As time progressed, my reliance on the PhD mentor lessened and laboratory time seemed a bit more like independent study .
My RISE@Drexel experience was a challenging one but also a great one! I was exposed to aspects of electrochemistry and go to develop my own protocols for my research. The challenge for my research was creating a protocol that would run successfully. I near the end developed a protocol, but did not get the desired results for my research even though the protocol was one that worked. Not getting the results that I expected made me learn that that is in fact a reality of a career in research. A researcher may do lots of work and still get unexpected results.
I had a great time in learning all of the different components that involve research. The actual research was the best part since it showed myself that I can do an advanced level of research without all of the formal knowledge needed. The writing aspect of the research enhanced the technical experience that I was lacking. Presenting the research at both the proposal and final presentation helped improve my speaking skills.

Table 3: Students comment on multidisciplinary STEM exposure through the RISE program

During your summer, were multiple STEM disciplines presented to you? Explain.
In order to even begin researching my topic, knowledge from several STEM disciplines were explained to me by my professor and PhD mentor. As with many of the research topics studied within the RISE@Drexel program and engineering in general, components of many STEM disciplines are often used to come up with results.
My research topic involved concepts, vernacular, and definitions I hadn't previously been aware of which made things a bit intimidating initially. However, I was introduced to copious amounts of research articles by my lab professor and PhD mentor which made things a bit easier.
During my summer experience at Drexel University, I was able to learn about different resources that I could acquire with my fingertips. Before joining the program I did not have any clue where else I could find information besides Google's search engine. Different articles were presented to me to learn more about STEM and a large archive of information.
STEM disciplines that were incorporated were weekly meetings with the director of the program. Being surrounded with other intellectual people who are furthering their career in engineering has been very inspiring for me as a student. Also the program never once made me feel like I had to figure anything out online on my own. Very family based, I never had to sit on a burning question.

Table 4: Students describe their future career plans

Please Briefly Outline Your Future Career Plans
As I move forward in finishing my AS degree I look forward to transferring to a University in which I can explore my engineering ideas, in making people's lives better, and working through to my PhD.
I plan to continue to a four-year university to receive my Bachelor's in either Mechanical or Material Science and Engineering. I would like to continue on to grad school afterward and work in the field of research onward
First I plan to finish up my associate's degree. At the same time, I would like to have more opportunities at other research opportunities. My main goal is to gain a PhD. I have a long way to go, but I will get there and the RISE program has done so much for me. I will refer others to a program this well.
Computer programming research involving mathematics, data storage and server capacity on a global scale is my career plan, continuing to study math and expand it into open source computer science is what I'll be exploring.

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Table 5: Graduate student mentors give comments on the RISE experience

How was your experience with your summer student?
My experience with the RISE students has been awesome. I feel like I was able to share a lot of information with an aspiring student. Knowing that the student that I was paired with had very little technical background and fundamental understanding of research, it was an unforgettable experience to see him progress throughout the summer!
Overall it was a positive experience It was useful to get the opportunity to mentor a student and see him through a project. I was my first time on the other side of the advisor/student relationship. This gave me insight into what I'd like to do later in my career as well as shedding some light on my past experiences with other mentors of mine. - The compensation aspect is nice. - The work he did was a component of my own research, and therefore it was nice to have someone helping out with it.
My experience was enlightening. Since he had not even taken an electric circuits course yet, I had to figure out a way to take him from calculus all the way to micro grid power systems. While I do have experience as a TA, conveying a streamlined chain of explanation over about 5 courses worth of material is something I would never have to undertake as a TA.
My student was highly diligent and motivated individual. Without any core background in numerical analysis, mechanics, or thermodynamics, he became a prolific user of state-of-the-art Finite Element solvers including Abaqus and COMSOL. He started out hesitant, but with my coaching and encouragement rose to exceed expectations. He will be staying on with us throughout the year and working to produce a conference article.
My student gained a lot of confidence over the summer - initially she was very hesitant to touch anything in the lab without explicit instruction, and by the end of the summer she was able to debug an experimental setup and was comfortable varying experimental parameters in complete independence.

We also asked the graduate student mentors each year to describe their experiences mentoring RISE students, shown in Table 5. For many of the graduate students, RISE was their first mentoring experience, which allowed the graduate students to experience to role of an advisor.

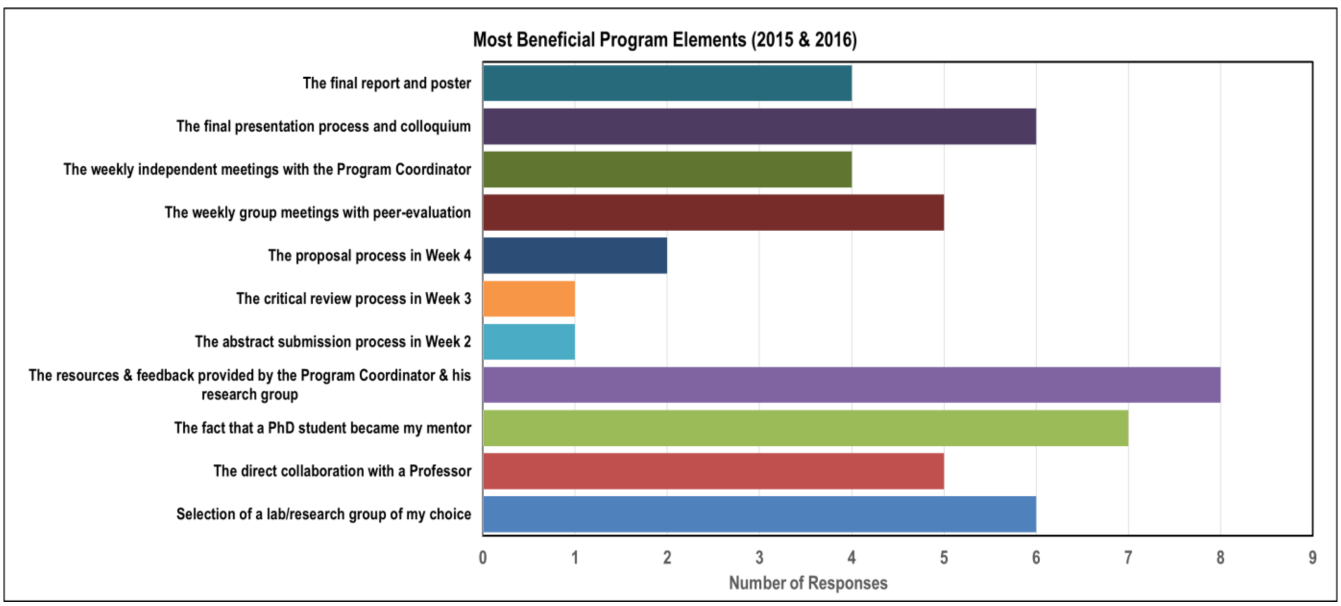

Figure 3: Students' selection of the most beneficial program elements

The 2015 and 2016 cohorts were asked to select the most beneficial program elements, presented in Figure 3. The students' deemed the most beneficial element to be the resources and feedback provided by the program coordinator's research group, which were provided in the form of weekly group meetings, coaching sessions by the RISE program coordinator and teaching assistant. This

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was followed by having a PhD student mentor, and the ability to select a research group of their choice.

Concluding Remarks

A research-based learning approach was adopted to introduce CC students to the university environment and foundational research methods (e.g. conducting literature reviews, design of experiments, writing and presenting scientific work), which they immediately applied to actual research projects in a compressed ten-week timeline. In the process, students learned valuable lifelong skills of searching and evaluating information, conducting research and presenting the results in multiple mediums. Furthermore, the students became acquainted with a research university and various scholarship and internship opportunities (e.g. Department of Energy, Department of Defense, NASA) to further enhance their future STEM learning.

The RISE program was structured to create a collaborative microenvironment, encouraging informal interaction between faculty, professional staff, graduate, and undergraduate students to facilitate vertical and horizontal integration within a university environment. Each year, several students voluntarily worked in their labs beyond the program's ten-week duration.

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Daniel Christe

Daniel Christe is a senior BS/MS student with research interests at the nexus of mechanical engineering, materials science, and manufacturing, centering on predictive design for functional fabrics that "see, communicate, sense, and adapt". Daniel currently a research associate in the Theoretical & Applied Mechanics Group in Drexel University's Center for Functional Fabrics and Theoretical and Applied Mechanics Group, in Mechanical Engineering & Mechanics Department. He also holds a research appointment at the Department of Energy's Los Alamos National Laboratory in New Mexico. He also has a strong interest in creating new student-centered approaches to STEM education. As an Innovation Advisor to Elsevier's Academic Engineering Solutions Library Advisory Board (AES-LAB), he is the lead content developer of the Elsevier Engineering Academic Challenge, guiding the design of the Engineering (formerly Knovel) Academic Challenge in 2015 and 2016.

Brian Wisner

Brian is a PhD Candidate in the Department of Mechanical Engineering and Mechanics at Drexel University. Brian received his bachelor's degrees in Mechanical Engineering and Physics in 2011 from Widener University and his Master's in 2013 from Drexel University. He then spent a year working at Piasecki Aircraft Corporation during which time he taught classes at Widener University as an Adjunct Instructor. In 2014 he returned to Drexel University and joined the Theoretical and Applied Mechanics Group under Dr.Antonios Kontsos. His research focuses on the identification of damage precursors in light metal alloys through the combination of nondestructive evaluation techniques including digital image correlation and acoustic emission monitoring coupled with in situ microstructure observation. Brian has been fortunate to be able to perform his work in collaboration with groups from Sandia National Labs and NASA Langley Research Center.

Jay Bhatt

Jay Bhatt received M.S. in Library and Information Science, M.S. in Instructional Design and M.S. in Electrical and Computer Engineering also from Drexel University, and M.S. in Education from the University of Pennsylvania. He joined the W. W. Hagerty Library at Drexel University as the Liaison Librarian for Engineering in December 1997. In 2013, he received the Outstanding Staff Mentor Award from the Graduate Student Association of Drexel University. He received IEEE's mentorship award and a Certificate of Appreciation in recognition of outstanding leadership as the Drexel University IEEE Graduate Students Forum Partnership Coordinator and Student Branch Liaison 2006-2007. In 2003, he received Drexel University's Harold Myers Distinguished Service Award.

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Antonios Kontsos

Antonios Kontsos joined the Mechanical Engineering & Mechanics Department at Drexel University in September 2009 and he is currently the Director of the Theoretical and Applied Mechanics Group (TAMG). He received his undergraduate 5-year Diploma (2002) from the Department of Mechanical Engineering and Aeronautics at University of Patras (Greece), and his MS (2005) and PhD (2007) degrees from the Department of Mechanical Engineering and Materials Science at Rice University (Houston, TX). He also held a 2-year Post-doc position at the Center for Mechanics of Solids, Structures and Materials in the Aerospace Engineering & Engineering Mechanics Department at the University of Texas at Austin (Austin, TX). Kontsos is a member of the ASME, ASNT and Sigma Xi societies and he is serving as the Faculty Advisor of the local ASME student chapter at Drexel University.

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