2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #37014

Work In Progress: Professional Development Through High-Impact Experiences

Dr. Charles Patrick Jr., Texas A&M University

Dr. Charles Patrick Jr. currently serves as a Professor of Practice in the Department of Biomedical Engineering at Texas A&M University. He serves as Director of the Undergraduate Program and administers the Ideas to Innovation Engineering Education Excellence Laboratory. He is involved in Texas A&M's Center for Teaching Excellence, the Institute for Engineering Education and Innovation, and the College of Engineering's Faculty Engineering Education Group. His research focuses on enhancing undergraduate and graduate student learning, engagement, and workforce development by transforming biomedical engineering education through scholarship and research of innovative teaching and learning practices and technologies. He has worked in higher education for more than 35 years at state and private universities and an NCI comprehensive cancer hospital.

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Introduction

The Department of Biomedical Engineering at Texas A&M University (TAMU) comprehensively redesigned its undergraduate curriculum in response to a host of factors, and the new curriculum launches fall of 2023 [1-3]. All core and elective courses were assessed for gaps, redundancies, and bottlenecks, and the curriculum was redesigned – except one non-lecture-based or lab-based course, namely the high-impact engineering course required by TAMU's College of Engineering. The learning outcomes are stated as: "Upon successful completion of this course, students will be able to (a) reflect on professional outcomes from the engineering body of knowledge and (b) assess learning experiences." The intent of high-impact courses is to ensure that students have the opportunity outside the formal classroom setting to develop essential and professional skills such as communication, problem-solving, organization, leadership, teamwork, adaptability, creativity, interpersonal skills, and global competency. This work evaluates a high-impact course over four semesters to determine if the course meets its learning and curriculum outcomes.

Literature Review

The inclusion of high-impact experiences is intended to enhance engineering education by broadening students' academic preparation so as to prepare them to be professional engineers. The high-impact experiences are generally focused on providing students an opportunity to practice what they have learned and to acquire additional technical and professional skills. It has been evidenced that participation in high-impact experiences can be life-changing for students [4]. Assessment of high-impact experiences is routinely accomplished using summative critical reflection [5-11].

Reflection in engineering education increases the value of the learning process and enhances students' ability to handle and process concepts and is well-established as a valued component of education and lifelong learning [5, 9, 12-14]. There are numerous frameworks for reflection, including Gibbs' framework for reflection [8], Kolb's model of reflection [15], and John's structured model of reflection [16]. This work employs the DIEP model [17, 18] that is based on the seminal work of Boud et al. [19] and Schön [20]. The DIEP model (Appendix Table 1) aims to have students think about and understand their high-impact learning experience.

Methods

The biomedical engineering curriculum at TAMU requires a zero-credit-hour course entitled BMEN 399: Engineering Professional Development as a requirement of graduation. Students must participate in an approved high-impact engineering-centric experience or activity that is commensurate with a junior or senior undergraduate level. Appendix Table 2 illustrates representative high-impact experiences available to undergraduate students. To receive credit for the high-impact experience, students must demonstrate proof of participation (documentation required varies based on the experience) and submit a two-page reflection assignment. The reflection assignments from the cohort of students were analyzed for five types of engineering-centric activity experienced: career enrichment experience, clinical immersion experience, design challenge, industry immersion experience, or research experience.

In addition, students' reflection assignments were scored for the technical and professional competencies realized in the high-impact experience. The department has defined 23 curriculum outcomes or competencies that define a professional biomedical engineer matriculating through its program [1]. The thirteen competencies investigated in this study are defined in Appendix Table 3. These competencies were defined a priori in spring 2021 as being desirable for a high-impact experience to demonstrate, with the caveat that the variety of high-impact experiences would not necessarily support all 13 competencies being addressed.

Four semesters (fall 2021, spring 2022, summer 2022, and fall 2022) involving 168 students were analyzed. There are a wide variety of methods available to assess student reflections [6, 10]. Reflection assignments were assessed and scored by the author in a blinded fashion with no student identifiers. Students were asked to provide a critical reflection about their experience by answering four questions (Appendix Table 1). There was no face-to-face interaction with the author – the reflection assignment was deployed to students via the learning management software Canvas. Students were not informed they were following the DIEP model, were not informed of the five engineering-centric categories, and were not informed of the 13 competencies being investigated. That is, students were blind to analysis.

The scoring of competencies realized by the high-impact experience was based solely on the text provided by students in reflection assignments and not any potential knowledge of the experience. That is, in some cases, the author knew a certain research lab or industry internship traditionally covered a competency but this was not included in the analysis if the student did not mention it in their reflection assignment. A "satisfactory" grade was assigned to students who completed the reflection assignment, but the reflection was not scored for the purpose of assigning a grade. Reflections were scored only for the purpose of this study.

Results

The 168 junior and seniors represented 34% of the biomedical engineering students (495 head count, sophomore-seniors). All students provided the four components of the DIEP model in their reflection assignment (data not shown). Appendix Figure 1 shows the four-semester total and per semester experience categories encountered by students. The majority of students (61%) participated in a research experience (32%) and career enrichment experience (29%). Research experiences included undergraduate research in laboratories within the department, within TAMU, and in the Texas Medical Center. Career enrichment experiences included, but are not limited to, leadership positions in student professional engineering societies and humanitarian organizations, as well as study abroad programs. The industry immersion experiences accounted for 21% (internship companies listed in Appendix Table 4). The number of students participating in each specific category varied with each semester (Appendix Figure 1A). In summer of 2022, the overwhelming majority of students participated in a career enrichment experience and noticeable low participation in industry and research experiences. It remains unknown if this was an artifact of a summer semester or a COVID-related lag. Anecdotally, it is known that many companies and research labs did not recruit in 2021 for 2022 summer positions due to COVID-related budget constraints.

Four of the 13 curriculum outcomes were well reflected (>80%) in the high-impact experience assignments – "attitudes," "communication," "teamwork," and "project management" (Appendix Figure 2). These professional competencies are of critical value and meet the intent of the College of Engineering's purpose for the BMEN 399 course. "Systems engineering" and "problem solving and recognition" were reflected in >50% but <80% of the experience assignments. This is an expected level given that career enrichment and clinical immersion experiences frequently are not engineering problem-based.

Discussion and Future Work

The intended goal of this work is to determine if the required BMEN 399 course is meeting the department's learning and curriculum outcomes. It is clear that students meet the first learning outcome (i.e., "reflect on professional outcomes from the engineering body of knowledge") but it is perhaps weak on meeting the second outcome (i.e., "assess learning experiences"). Is a reflection assignment enough to meet the spirit of "assess learning experiences" or is something more rigorous needed? This question will be addressed in future work, potentially investigating the use of a survey or similar instrument that other investigators have employed [6, 11, 21-23].

This qualitative study demonstrated that some key curriculum outcomes are met with the high-impact experience course. Most notably four professional skills almost universally were realized and adhere to the College of Engineering's goal. There are some limitations realized in this work-in-progress study that warrant mentioning. First, neither the reflection assignment nor the analysis investigated the level of "experience maturity" of the students. That is, it is unknown how may high-impact experiences students participated in prior to or after taking the BMEN 399 course. Anecdotally, the author is aware that the majority of the students in the competitive biomedical engineering degree program participate in multiple extracurricular activities that enhance their technical and professional skills. Exposure to multiple high-impact experience could create variety in the depth of critical reflection.

Second, the duration of the high-impact experiences varied from 48-hour design competitions to semester long internships. The varied duration of the experience can potentially affect the amount or depth of competencies realized in the high-impact experiences. Further, although teamwork was mentioned in the majority of students' reflections, the degree of mentoring within the high-impact experience is unknown and is most assuredly variable. It is unclear how the variable mentoring affected the 13 competencies investigated.

Additional data from future semesters is needed to investigate potential trends. Especially needed is additional summer semester data to ascertain if the lower participation in summer research and industry internships is normative. Moreover, it would be highly valuable to connect with 1-year and 5-year alumni to ascertain the influence of the high-impact experiences on long-term career goals. Finally, it would be fruitful pedagogically to investigate how students transfer learning to academic and career ecosystems via the high-impact experience vehicle.

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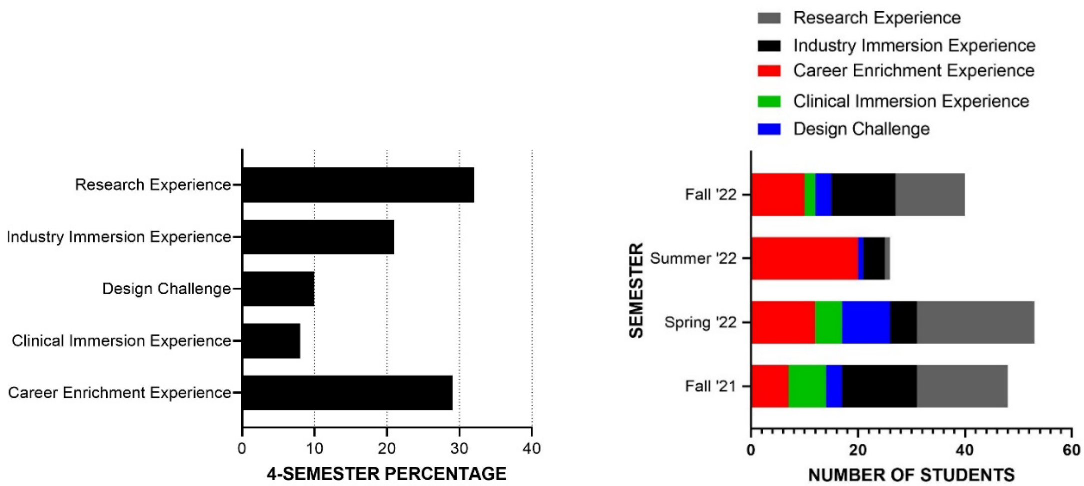
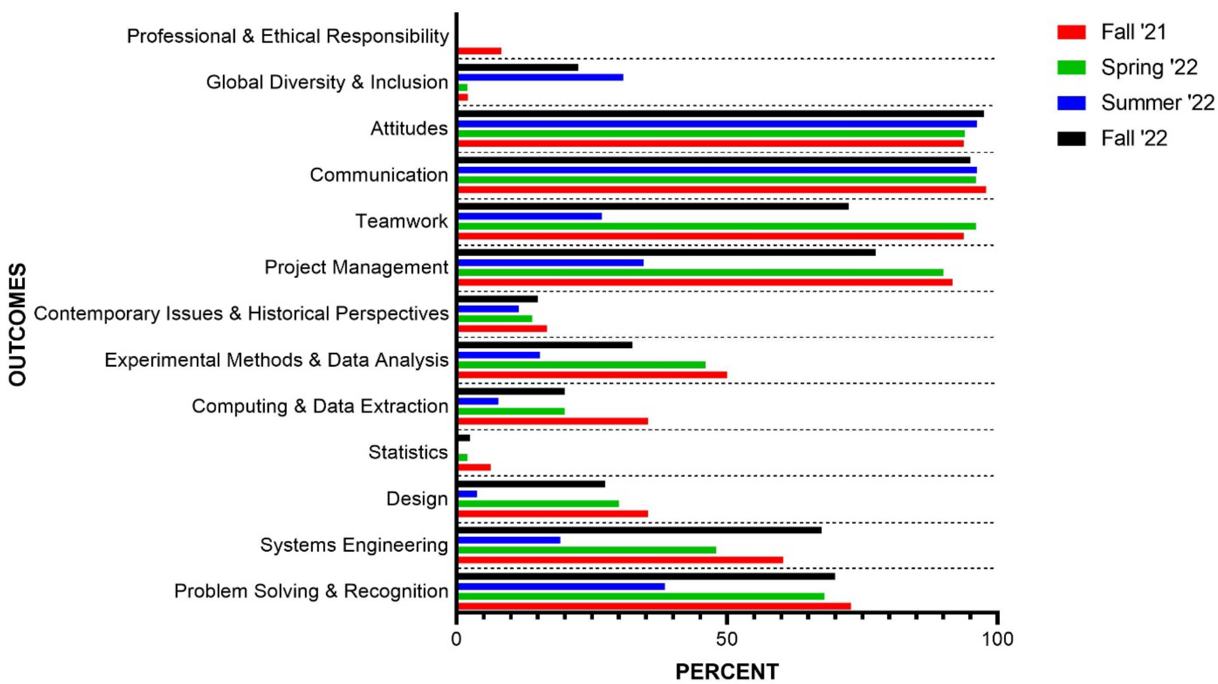
Appendix



A. B.

Appendix Figure 1. High-impact experience categories encountered by students. (A) Cumulative four-semester totals expressed as a percentage of 168 students. (B) Student head count per category for each semester.



Appendix Figure 2. Percent of experiences that demonstrated one of the 13 curriculum outcomes each semester.

Appendix Table 1. The DIEP model for reflective thinking within the context of TAMU.

DIEP Reflection Model	Questions Students Are Asked to Answer
Describe objectively what happened	What did you do? Provide a ½-page summary description of the high-impact experience.
Interpret the events	What did you learn beyond your technical education from this high-impact experience?
Evaluate the effectiveness and usefulness of the experience	How valuable was the high-impact experience to you? What recommendations can you provide future students on how to maximize the value of the high-impact experience?
Plan how this information will be useful to you	How will you apply this high-impact experience to your career and professional life?

Appendix Table 2: Representative examples of approved high-impact experiences.

Experience	Description	Activity Category
AggiE-Challenge	This is designed to engage engineering undergraduate students with multidisciplinary team research projects related to engineering challenges facing our society. The grand challenges include the fourteen Grand Challenges for Engineering (National Academy of Engineering), the fourteen Grand Challenges for Global Health (Bill and Melinda Gates Foundation), and Engineering World Health: Projects That Matter.	Research Experience
XXXX Invent	This is a 48-hour intensive design experience in which undergraduate students in multidisciplinary teams push their innovation, creativity, and communication skills. Each event has a specific theme and is designed in collaboration with industry and faculty.	Design Challenge
BME Summer Enrichment Experience	The program provides undergraduate students with insight into practical applications of biomedical engineering in the industry to enrich learning and explore career paths.	Career Enrichment Experience
Clinic/Hospital Shadowing or Volunteering	Undergraduate students observe or assist in a clinic or hospital setting to gain experience with medical staff-patient interactions, patient medical care, and regulatory matters.	Clinical Immersion Experience
Corps of Cadets Membership	Undergraduate students enroll in one of the Corps of Cadets units, TAMU Band, ROTC-Air Force, ROTC-Army or ROTC Navy/Marine. Participation prepares students for global leadership.	Career Enrichment Experience
Design Competitions	Undergraduate students participate in local, state, and national engineering design competitions.	Design Challenge
Grand Challenge Scholars Program (GCSP)	A 3-year program beginning in sophomore year. Undergraduate students meet with a Grand Challenge Faculty Mentor to build a custom curriculum that meets the five GCSP components: Research, Interdisciplinary, Entrepreneurship, Global Perspective, and Service Learning. Students engage in research and complete a thesis, as well as serve as GCSP Ambassadors. Students present their research at an Annual Spring Symposium.	Research Experience

Internship or Co-op Experience	A paid or unpaid internship or co-op with a company doing work that is related to an engineering career over a period of six weeks or more.	Industry Immersion Experience (for companies) Clinical Immersion Experience (for hospitals)
Leadership in Student Organizations	Undergraduate students serve in a TAMU-approved student organization in a recognized officer position. Participation in student organizations that are in engineering (e.g. BMES, AIMBE, etc.) and at the crossroads of engineering and humanitarian aid (e.g., Engineers Without Borders, BUILD, etc.) are preferred.	Career Enrichment Experience
Startup XXXXland	This is a student-designed business incubator and accelerator. Mentors and coaches help qualified student-owned startups leverage TAMU resources and private support without relinquishing equity ownership in their companies.	Career Enrichment Experience
Student Research Worker	Undergraduate students are hired to work for a faculty or staff member on the university campus. The work must be research, development, teaching, or training in nature. Administrative and/or office work does not satisfy the requirement.	Career Enrichment Experience
Study Abroad Courses and Experiences	An international travel and study abroad course. The experience must be two weeks or more in duration and administered by the Halliburton Engineering Global Program.	Career Enrichment Experience
Undergraduate Research	Students engage in research that pertains to their major with a chosen professor.	Research Experience

Appendix Table 3. Technical and professional curriculum outcomes investigated. Adapted from [1].

Competency	**Description**
Problem Recognition and Solving	Develop and solve problem statements related to fundamental biomedical engineering problems by applying appropriate techniques and tools.
Systems Engineering	Apply systems thinking to integrate disparate concepts, information, and components that synergistically result in solutions for biomedical problems.
Design	Design and evaluate a system, component, or process to meet desired needs and standards within realistic constraints such as those based on economic, environmental, sustainability, constructability, ethical, health and safety, social, legal, regulatory, and political issues.
Statistics	Apply knowledge of descriptive statistics, measurement concepts, hypothesis testing, and probability distributions.
Computing and Data Extraction	Apply knowledge of computer programming, numerical methods, and data science for biomedical applications.
Experimental Methods and Data Analysis	Conduct experiments in the laboratory, virtual experimentation, or numerical simulation; interpret data; and convert raw data into information and visual representations useful for engineering decision-making.
Contemporary Issues and Historical Perspectives	Explain historical and contemporary issues in biomedical engineering and consider their impacts while solving engineering problems.

Project Management	Apply the principles of project management to biomedical engineering problems.
Teamwork	Function effectively as a member of a team.
Communication	Communicate clearly and effectively through verbal, written, mathematical, and visual means to promote understanding by both technical and non-technical audiences.
Attitudes	Demonstrate attitudes (curiosity, persistence, flexibility, diligence, etc.) conducive to effective practice of biomedical engineering.
Global Diversity and Inclusion	Understand, organize, formulate, and solve biomedical engineering problems within the context of diverse and inclusive populations.
Professional and Ethical Responsibility	Explain the professional and ethical responsibilities of a biomedical engineer, and use codes of ethics to determine an appropriate course of action in a situation.

Appendix Table 4. Host for industry and clinical immersion experiences during fall 2021-fall 2022.

Industry Immersion Experience Hosts		Clinical Immersion Experience Hosts
• Abbot • AIG Global Command Center • Argon Medical Devices • Boston Scientific • CardioQuip • Colgate-Palmolive • Confluent Medical • DJO Global • Eli Lilly • Enovis • ENTVantagedx • Epimed International • Fujifilm Diosynth Biotechnologies • G-Con Manufacturing	• Home Group Inc • Johnson & Johnson • Jordan Foster Construction • Lynntech • Medtronic • Noctrix Health • Pfizer • Quest Medical • Reynolds and Reynolds • SimDynamX • Sri Gayatri LLC, intern • Starling Medical • Texas Instruments • Uptime Health • Velentium	• Houston Methodist Hospital • Memorial Hermann Hospital • North Texas Orthopedics • Paramedic program • Private Dental Clinic • Private ObGyn Clinic • The University of Texas at San Antonio Institute of Regenerative • The University of Texas M.D. Anderson Cancer Center • TAMU Physical Therapy Clinic