International Journal of Engineering Education Vol. 39, No. 4, pp. 961–975, 2023
Printed in Great Britain

0949-149X/91 $3.00+0.00

Immersion Experiences for Biomedical Engineering Undergraduates: Comparing Strategies and Local Partnerships at Two Institutions*

JUSTIN HUBER
University of Kentucky, Physical Medicine and Rehabilitation, Lexington, KY 40506, USA. E-mail: justin.huber@uky.edu

STEVEN HIGBEE
Indiana University-Purdue University Indianapolis, Biomedical Engineering, Indianapolis, IN 46202, USA. E-mail: sjhigbee@iupui.edu

CHRISTINA ESPINOSA
University of Kentucky, Human Development Institute, Lexington, KY 40508, USA. E-mail: ctespinosa@uky.edu

BABAK BAZRGARI
University of Kentucky, Biomedical Engineering, Lexington, KY 40506, USA. E-mail: babak.bazrgari@uky.edu

SHARON MILLER
Indiana University-Purdue University Indianapolis, Biomedical Engineering, Indianapolis, IN 46202, USA. E-mail: sm11@iu.edu

Immersion experiences for undergraduate students in biomedical engineering are key contributors to their ability to identify medical needs. Despite this, as few as 25% of surveyed programs report providing such opportunities. Since 2010 when the National Institute of Health began its R25 grant mechanism to support curricular development toward team-based design, several institutions have established programs for immersion experiences, which provide precedent for their implementation. Published results from such immersion experiences highlight successes in structure and changes in student perspectives after these experiences. As more institutions expand their biomedical engineering curriculum with new immersion-focused programs, it is important to learn from these precedents while also considering opportunities to improve. For newly funded groups that are developing and implementing programs, they may find improved success by strategic use of unique partnerships. However, these partnerships may not be immediately evident to program organizers. Our objective is to discuss two institutions that recently established programs for immersion experience. In the comparison of our two immersion programs, we found five overlapping core features that include: immersion partner collaboration, team-based immersion experiences, needs-finding emphasis, team-based engineering design experiences, and immersion assessment and evaluation. Both programs developed collaborative partnerships with nearby medical schools. Additionally, one program partnered with a community resource (i.e., Human Development Institute). Despite nuanced program differences, we found that students at both programs self-reported increased knowledge or confidence in aspects of the design process (e.g., identifying and refining user needs, concept generation). Our results also highlight student gains unique to their programs – UK students self-reported gains on disability topics and IUPUI students self-reported gains on socioeconomic awareness. In summary, immersion partner collaboration, or partnership, surfaced as a core feature for both programs, and students in both immersion programs endorsed enhanced knowledge or confidence in engineering design.

Keywords: experiential learning; evidence-based practice; clinical immersion; user needs; engineering design

1. Introduction

1.1 Immersion Experiences in Biomedical Engineering

The biomedical engineering education community values experiential learning opportunities, particularly those that provide meaningful context for engineering design [1]. As such, undergraduate biomedical engineering (BME) programs continue to develop and integrate authentic undergraduate curricular experiences that combine experiential learning and design [1, 2]. Immersion experiences are a specific curricular example of experiential learning where BME students can practice refining their abilities to identify problems, or needs-find [3, 4], often in a clinical setting while being provided formalized instruction toward device design and the design process itself [2, 5, 6].

While needs-finding is a common aspect of BME immersion experiences, both the immersion length and program emphasis can vary. Many BME programs funded through the National Institutes of Health (NIH) R25 team-based design in biomedical engineering education mechanism have implemented 4–6 week summer shadowing experiences [3, 4, 6], where others offer academic year experiences typically in the junior and senior years [7–9]. Immersion program emphasis can vary as well and has included interdisciplinary collaboration between BME and occupational therapy [10], nursing [11, 12], global health [13], simulation labs [8], or information literacy [14]. Still, clinical immersion experiences that foster interactions between BME students and medical professionals also exist, and these cases have invited medical learners including medical students and residents [15, 16]. Beyond undergraduate programs, clinical immersion programs that emphasize innovation in medical technology and hypothesis-driven translational research continue to evolve for BME students

* Accepted 13 April 2023.

pursuing graduate education [2, 17]. Regardless of length or emphasis, immersion programs offer experiential learning opportunities where students encounter clinical or community environments and identify user needs after shadowing medical professionals, observing patient procedures, and seeing medical devices being used first-hand. Students then strive to make sense of their experiences using prior biomedical engineering knowledge to develop viable clinical needs [18].

Immersion experiences also help students develop practical engineering design skills beyond needs finding by considering users, community, and impacts beyond the design cycle. Intentional development of biomedical engineering design curricula includes all parts of the biomedical engineering design process: needs finding, identifying goals and constraints, generating multiple solutions and assessments, prototyping, verifying, iterating, and regulatory consideration [19]. For accreditation, programs are also required to demonstrate student ability "to apply engineering design to produce solutions to meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors" [20]. Thus, immersion experience structure and instruction have included stakeholder perspectives and economic viability. Specifically, Food and Drug Administration (FDA) guidance documents guide students on how user feedback can be helpful in developing user needs and user-device interactions [21]. Furthermore, structured immersion experiences in global and community settings [4, 13, 17], have provided technology transfer, marketing, and licensing aspects.

The literature is replete with structural aspects of clinical immersion program development (e.g., duration, compensation, curricular emphasis, collaborators) and can also offer guidance on program evaluation. While less is available to guide evaluation and assessment of student learning, examples of numeric reporting are common to share metrics such as the numbers of patents generated [17], student videos produced [22], or user needs identified [4]. Self-reported student surveys also aim to capture student perception on interdisciplinary collaboration [10], ability to achieve ABET student outcomes [5], teaming [23], preparedness for capstone design projects [6], professional aspirations [3], ability to needs-find [8], in addition to overall program evaluation and efficacy [2, 4, 6, 24]. Reported program and student learning outcome data continue to provide foundational assessment methods within and beyond the BME educator community to guide evaluation of immersion programs.

1.2 Leveraging Partnerships when Designing Immersion Experiences

At a recent educational summit, biomedical engineering leaders and educators discussed the importance of clinical context in student design projects and approaches to overcome identified barriers to immersion program success. Finding partnerships within the community (e.g., rehabilitation centers, assisted living) and extending clinical partnerships (e.g., immersed students lead non-immersed students, observational training to maximize stakeholder interaction) were two notable calls to action [1]. Leveraging partnerships when designing immersion experiences is not trivial which is evidenced by only 25% of biomedical engineering programs reporting that their students have access to clinical immersion opportunities [1]. Thus, newly funded programs continue to develop and implement immersion models and are doing so by leveraging their own unique strengths [21].

Our objective is to demonstrate implementation of an immersive learning experience for undergraduate biomedical engineering students through two institution-specific examples. Here, we offer perspectives from two programs that recently established immersion models that leveraged partnerships with strategic allies in their institution. Additionally, we demonstrate intentional program evaluation and student learning assessment planning that may help new programs contribute to the field of biomedical engineering education.

Both the University of Kentucky (UK) and Indiana University-Purdue University Indianapolis (IUPUI) are urban, public, academic institutions with biomedical engineering programs that have recently developed undergraduate immersion programs. At UK, this program has been developed by UK BME to leverage two partners – the UK Physical Medicine & Rehabilitation (PM&R) Department in College of Medicine and the Human Development Institute (HDI), a community resource in Lexington, KY. Through these partnerships, the program emphasizes an educational design experience that integrates clinical and community immersion activities to develop better assistive technology devices for people with disabilities. IUPUI BME has partnered with the largest allopathic medical school in the United States – Indiana University School of Medicine (IUSM) [25] – to provide students a broader perspective through a rotation-based, summer clinical immersion program. This immersion experience aims to highlight the role that biomedical engineers can play in addressing socioeconomic, racial, and ethnic disparities in health care, particularly within the specific context of urban health care.

2. Methods

In the 2020–2021 academic year, both UK and IUPUI universities enrolled engineering students in their own inaugural biomedical immersion learning programs. Each of these institutions developed and implemented their respective programs independently, and in doing so, leveraged unique strengths in their local communities. The following sections describe: (i) Institutional Context of and Overview of the Immersion Programs; (ii) Descriptions of the Immersive Experiences; and (iii) Program Evaluation Methods.

2.1 UK Institutional Context

The University of Kentucky (UK) campus features a broad selection of academic colleges located within close geographic proximity. Within the College of Engineering, an accredited undergraduate program in Biosystems Engineering debuted in 2009 – an evolution of previous accredited programs in Agricultural Engineering (debut 1967) and Biosystems and Agricultural Engineering (debut 2001). Although the UK BME Department has featured a well-established graduate curriculum since 1959, this department more recently initiated an accreditation-seeking undergraduate degree program in 2020. This degree program has subsequently seen substantial growth with approximately 60 students currently enrolled, which represents a two-fold increase since program inception. To support the UK BME department's missions, a total of 10 faculty holds primary appointments, all of whom have established research lines and contribute to the department's educational commitments.

The geographically centered academic campus is additionally neighbored by an extensive Healthcare network. As a result, academic relationships have established between the university and several large Healthcare campuses – UK Healthcare, VA Hospital, Shriners Hospital, and Cardinal Hill Rehabilitation Hospital. The latter is a freestanding acute inpatient rehabilitation hospital with over 130 patient beds, and this site serves as the home for the UK Department of PM&R. This rehabilitation setting offers two distinct advantages. First, rehabilitation hospitals represent one common post-acute care setting, which often admits a wide variety of patient populations and thus offers learners a wide variety of experiences. Secondly, the on-site presence of physiatrists offers a unique opportunity to observe a medical discipline that is traditionally highly adept at multi-disciplinary and team-oriented approaches to healthcare – a combination that maps well to values in BME curriculum.

The Human Development Institute (HDI) is a University Center on Disability – part of a national network of agencies created by the Developmental Disabilities Act of 2000. Affiliated with UK, HDI is an Institute within the Office of the Vice President for Research and has been housed at UK since 1969. HDI's mission is to advance efforts that build inclusive communities, address inequities, and improve the lives of all people who experience disability across the lifespan. Receiving core funding through the Administration on Community Living, HDI operates with a staff of over 340 personnel. Currently, HDI administers over 70 state and federal projects on topics of disability across the lifespan. One of these projects is HDI's Center for Assistive Technology Services (CATS), the regional Assistive Technology Resource Center (ATRC) for Central Kentucky. HDI CATS is a member of the Kentucky Assistive Technology Services (KATS) Network, which serves as the Assistive Technology Act Program for the State of Kentucky and whose mission is to make AT information, devices, and services easily obtainable for people of any age and/or disability. Through this mission, HDI CATS has direct access to Kentuckians with disabilities who benefit from and are users of assistive devices and durable medical equipment. HDI CATS maintains an inventory of thousands of devices and pieces of equipment that increase independence for people who experience disability.

2.2 Clinical and Community Immersion Program

The UK immersion program (Fig. 1) seeks to achieve three specific aims that are: (1) to provide a multidisciplinary team-based design experience, (2) to provide a unique holistic biomedical training associated with adoption and use of assistive technology devices (ATDs), and (3) to provide training in ATD needs identifications through clinical and community immersion experiences. Each cycle of the program starts with a spring semester course on social, technical, ethical, and economic challenges associated with design and use of ATDs. This first course occurs in spring and is offered in collaboration with the HDI – a resource that provides access to a wide network of practitioners specialized in community-based and rural disability care and management. With HDI as a partner, UK program offers several community immersive sessions, focused on use of ATDs, to participating students wherein they will closely observe the interactions between practitioners, persons with disability, and their family members. Leveraging the clinical facilities and resources available at UK, the second component of the program is a 5-week summer clinical immersion during which participants shadow and work with healthcare professionals involved in the rehabilitation of patients with physical disabilities. The summer clinical immersion component is offered in collaboration with the UK PM&R at the Cardinal Hill Rehabilitation Hospital in Lexington, KY. Students completing community and clinical immersions will each be guided to identify and report an unaddressed ATD need by the end of each immersion experience. The final component of this educational program is a fall semester team-based design course wherein students design and develop prototypes for select ATD needs identified earlier in the program. Involvement of persons with disability, their care giver and healthcare provider in design of ATD project(s) particularly is emphasized.

2.3 IUPUI Institutional Context

Indiana University Purdue University Indianapolis (IUPUI) is Indiana University's urban health and life sciences campus, situated adjacent to both downtown Indianapolis and the Indiana University School of Medicine (IUSM), the largest allopathic medical school in the United States [25]. The BME undergraduate program at IUPUI was founded in 2004, with a vision of bringing together two of the state's preeminent higher education institutions: Purdue University Engineering and Indiana University Medicine. There are currently 13 faculty members with full-time appointments in the IUPUI Department of Biomedical Engineering; eight of these faculty members run active research labs (including five with active NIH funding), three are fully dedicated to undergraduate teaching, and the remaining two hold significant administrative positions while teaching in the program. BME students at IUPUI have the good fortune to be just a 10-minute walk from a medical campus that serves hundreds of thousands of patients each year, functions as the state's hub of medical education, and is home to more than 130 biomedical research laboratories [26]. Five hospitals in total are located within a 1.5-mile walk of the IUPUI campus: IU Health University Hospital, IU Health Methodist Hospital, Riley Hospital for Children at IU Health, Eskenazi Health, and the Roudebush VA Medical Center. IU School of Medicine and its partner hospitals collaborate to run 76 residency and fellowship programs in Indianapolis, currently reaching over 1,000 trainees and employing more than 800 teaching faculty [27].

When designing a clinical immersion program for undergraduate BME students at IUPUI, program planners sought to leverage both the urban location of the campus and its proximity to hospitals and medical education. Furthermore, community engagement – both among faculty and students – is valued highly at IUPUI, as it an institution that strives to serve the broader Indianapolis community. When considering all these institutional strengths, the idea was born to create a clinical immersion program that highlights the role that biomedical engineers can play in addressing socioeconomic, racial, and ethnic disparities in health care, particularly within the specific context of

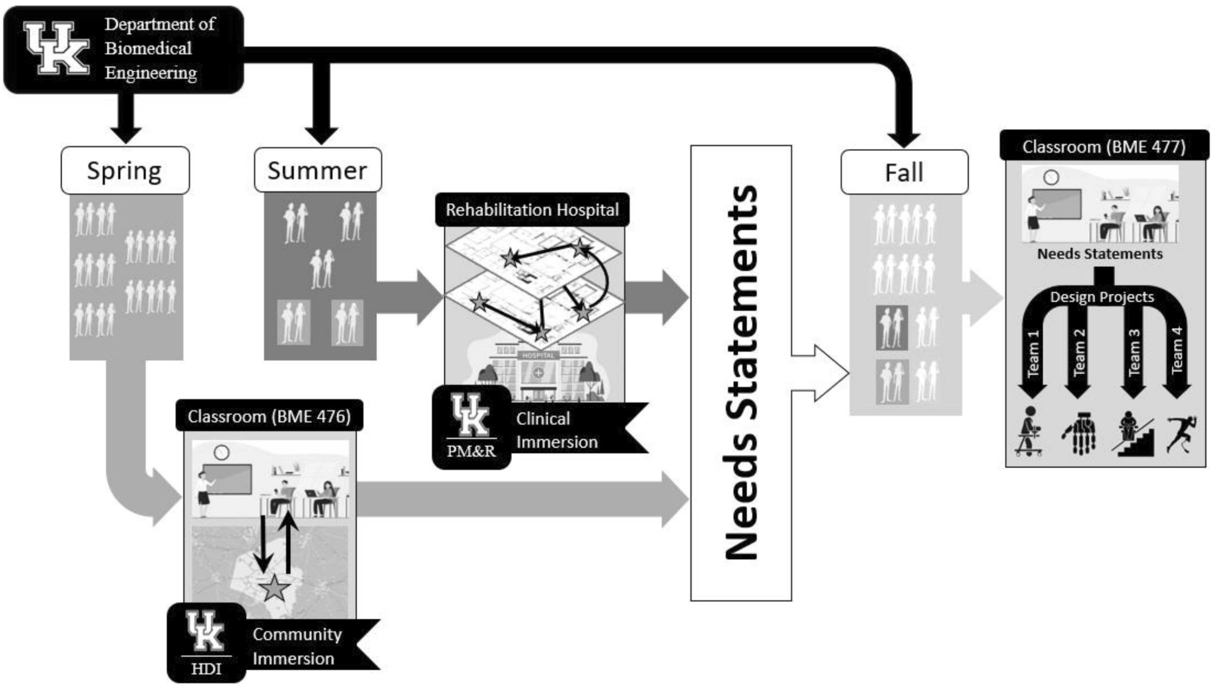

Fig. 1. Infographic depicting course maps for students in the immersive learning program developed at the University of Kentucky. The University of Kentucky program has aspects of both community immersion and clinical immersion.

urban health care. Program planners have since worked to develop collaborations that ensure student participants are able to observe care in diverse clinical settings – both in terms of the populations served and in the types of care delivered. Further, several of the program's clinical collaborators serve patients at both the IU Health hospitals and at Eskenazi Health, which is a public hospital that places special emphasis on treating the most vulnerable populations of Indianapolis. This often allows our participants to observe care across highly diverse populations within a single weeklong clinical immersion rotation.

In addition to our efforts to leverage IUPUI's location and collaborations to create a clinical immersion program that highlights health care disparities, it was important to develop a rigorous plan for program evaluation and student assessment given the lofty goals of the program. Again, program planners were able to leverage strengths of the IUPUI campus toward this end. IUPUI is home to the STEM Education and Innovation Research Institute (SEIRI), a campus group that funds and provides guidance to faculty engaged in curriculum development and educational research in STEM fields. The program planners received a seed grant from SEIRI in advance of applying for the NIH R25 grant that ultimately funded the INdiana Summer Clinical Residency in Innovation for Biomedical Engineers, or (IN)SCRIBE Program. This seed grant supported work to establish collaborators within IUSM, to create new curriculum in needs identification for third-year BME undergraduates, and to begin crafting assessment tools for clinically connected programming. SEIRI faculty and staff have provided guidance through development of curriculum and assessment tools. Beyond IUPUI, program planners have leveraged their proximity and connections to faculty within the Purdue School of Engineering Education.

2.4 IUPUI Clinical Immersion Program

The (IN)SCRIBE Program at IUPUI (Fig. 2) seeks to achieve three specific aims: (1) to immerse undergraduate biomedical engineering students in diverse clinical settings, (2) to develop student skills and self-efficacy in needs identification and clinically relevant design, and (3) to create student awareness of socioeconomic disparities in health care. The program runs for seven consecutive weeks in May and June, and participants include rising sophomores, juniors, and seniors in the IUPUI biomedical engineering program. During the program, student participants first spend one week in the classroom to build skills and knowledge related to BME design, to learn about health care delivery and sociology, and to prepare for productive clinical immersion experiences. Then, in collaboration with physicians across the IU School of Medicine and its partner hospitals, participants engage in five separate one-week clinical immersion rotations. In the final week of the program, student participants return to the classroom to discuss needs identified in the clinic, to select and refine a single need, and to engage in team-based design toward a preliminary solution. Throughout the entire seven-week pro-

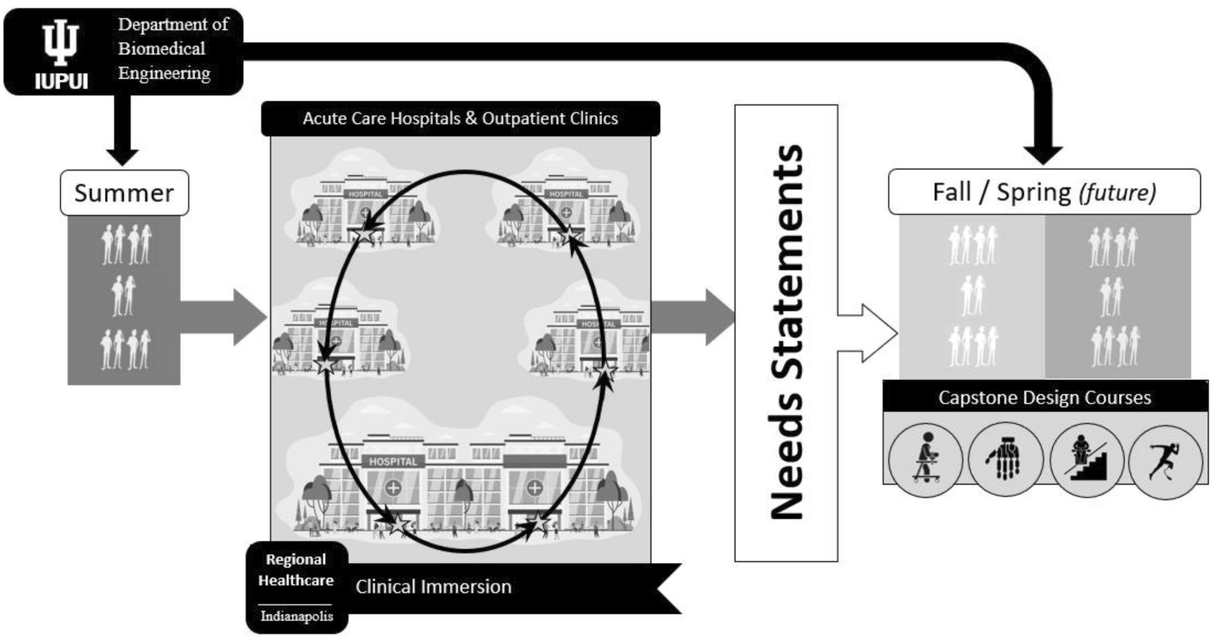

Fig. 2. Infographic depicting course map for students in the immersive learning program developed at Indiana University-Purdue University Indianapolis. The IUPUI program provides a summer clinical immersion for participants in urban clinics and hospitals.

gram, each student participant is asked to continually engage in written reflection in response to prompts that were developed to guide students to connect the ideas of socioeconomic disparities in health care and BME design.

Unlike the program at UK, the IUPUI immersion program does not explicitly extend beyond the summer term into the academic year. The (IN)SCRIBE Program does, however, connect with the broader BME curriculum in several important ways. First, all (IN)SCRIBE participants return to their BME courses as (IN)SCRIBE Ambassadors, a role in which students take on leadership in design tasks and disseminate skills and knowledge from the (IN)SCRIBE Program to fellow students. Second, clinical needs identified by students during the (IN)SCRIBE Program become candidates for senior capstone projects. Finally, participants in the (IN)SCRIBE Program bring fresh perspectives to other (non-design) priority areas of the BME curriculum, including engineering ethics and technical communication.

2.5 Description of UK Community and Clinical Immersive Experiences

The UK program offers two opportunities for immersive experience: a community and a clinical immersive experience. UK community immersion experience takes place in the Spring semester during which student teams visit weekly a local center specializing in assistive technology for persons with disability. During these visits, students observe the interaction of staff members of these offices and centers with persons with disabilities and their family members. Each student team is also required to complete five projects including two projects focused on maintenance of ATDs, two projects on personalization of ATDs based on patient profiles, and one project on design and development of a smart home ATD. A written report is expected for each project that captures descriptive and pictorial summary of tasks completed along with the team reflection about the project experience. At conclusion of the spring semester, each student identifies a disability, performs a literature review of this disability, and then generates a written report sharing their findings and a formal needs statement.

The UK clinical immersive experience takes place in summer and involves two phases: onboarding and observation. Onboarding is completed to fulfill the clinical shadowing requirements (e.g., background check, vaccination) of the partnering Rehabilitation Hospital. During the onboarding stage, students are also guided to complete relevant training on Health Insurance Portability and Accountability Act (HIPAA) as well as responsible conduct of research (RCR). The Rehabilitation Hospital includes several dedicated units which focus on rehabilitation of specific populations, e.g., stroke survivors and individuals with spinal cord injury. During onboarding, students indicate preferences for these units and are assigned in pairs to a specific unit. Subsequently, the students are given reading materials related to the assigned unit to enhance their clinical communication ability for actual observation. The observation phase lasts five weeks in June and July during which participants spend 20 hours per week in their assigned unit, and each week, students focus their time with a specific discipline, e.g., physical therapists, occupational therapists, and case managers, among others. Participants and program directors meet weekly during the clinical immersion. These weekly meetings serve two purposes: (i) during the onboarding stage, students are provided guidance during meeting regarding completion of all the required training and onboarding steps and (ii) during the observation stage, the intent of meetings is to guide the students for identification of unmet ATD needs.

2.6 Description of IUPUI Clinical Immersive Experience

The IUPUI clinical immersion program is an application-based, optional educational experience for BME undergraduate students. Student participants experience the (IN)SCRIBE Program in four phases, across the seven weeks that make up the Summer I session at IUPUI. First, in Phase 01, participants complete pre-program training (e.g., HIPAA, RCR) and paperwork to prepare for experiences in the clinic. Second, in Phase 02, students participate in a one-week Innovation Boot Camp, which incorporates didactic instruction, guest speakers, and team-based activities to prepare students for the immersion experiences, needs identification, and clinically relevant design. The Innovation Boot Camp also highlights topics including innovation, commercialization, and intellectual property, which are minimally covered in the traditional undergraduate BME curriculum at IUPUI. Another major focus of this phase of the (IN)SCRIBE Program is learning about the US healthcare system and some of the specific challenges that face Indianapolis and Indiana. Student participants learn about the demographics of the city and state, challenges facing urban and rural health care delivery in Indiana, socioeconomic and racial disparities in health care outcomes, and the basics of health insurance and personal finance for health care. Third, in Phase 03, students complete five one-week clinical immersion rotations in a variety of settings on or near the urban IUPUI campus. IUPUI shares a campus with the Indiana University School of Medicine (IUSM) where clinical immersion rotations have been hosted by a number of medical departments, including Cardiology, General Surgery, Neurosurgery, Obstetrics & Gynecology, Ophthalmology, Orthopedic Surgery, Pediatrics, Physical Medicine & Rehabilitation, and Urology, among others. Finally, in Phase 04, student teams spend the final week of the Program on needs refinement and design. Each team of 2-3 participants selects one identified need, works to develop and refine a needs statement, and works toward a preliminary design solution. The final student deliverables include design pitch presentations and final design reports, which highlight the identified need, give context related to marketability and intellectual property, and describe the early design work.

2.7 Program Evaluation Methods at UK

During the inaugural program release at UK, a total of 47 students participated with 10 and 16 students included in summer and fall of 2021, respectively, and 21 students included in spring of 2022. Anonymous surveys were administered to students after their involvement in the clinical immersive experiences of the summer and spring. Based on available survey data to-date, self-reported demographics from nine students during the summer program included one-third juniors, one-third seniors, and one-third undisclosed. In addition to the surveys, students in the summer, fall, and spring were required to produce deliverables including project reports, journal club presentations, oral presentations at stakeholder's meetings, final written reports, and final oral presentations.

These deliverables contributed to an overall program database intended for ongoing evaluation of the program. Regarding the anonymous survey, summer students responded to 4-point Likert scale questions pertaining to knowledge of various elements of needs finding, elements of design, and topics pertaining to disability. Similarly, students responded to Likert scale questions about their confidence in needs-finding and design. Additional survey questions included qualitative and Likert scale inquiries on the course structure and efficacy as perceived by the students. All student data collection was performed according to methods approved by the UK Institutional Review Board, under Protocol # 66819.

2.8 Program Evaluation Methods at IUPUI

A total of 20 undergraduate BME students participated in the (IN)SCRIBE Program across its first two iterations; eight students participated in summer 2021 and twelve in summer 2022. The participants included ten men and ten women and varied in class standing (three rising sophomores, six rising juniors, and eleven rising seniors). Each participant completed surveys (healthcare awareness and self-efficacy) before and after the seven-week program and maintained a Design & Reflection Notebook throughout their experiences. Additionally, all participants were invited to complete a program survey at the end of the immersion experience. Student teams also produced deliverables including a final report and an oral design presentation.

Data included in this manuscript was collected from several sources. First, (IN)SCRIBE participants responded to 6-point Likert style questions on a Program Survey delivered at the completion of the program. This survey also included qualitative questions that allowed students to give feedback, including suggestions for program improvements. Second, (IN)SCRIBE participants performed continual written reflection in their Design & Reflection Notebook, providing qualitative data describing student experiences, observations, and attitudes. Finally, identified user needs and design solutions were obtained from both the design deliverables from the (IN)SCRIBE Program and from the BME capstone design course. All student data collection was performed according to methods approved by the IU Institutional Review Board, under Protocol # 2012065291.

3. Results and Discussion

3.1 Summary of Program Objectives

To implement experiential learning for BME students, two institutions leveraged the unique strengths in their local community to create two distinct model programs that were sponsored by the NIH R25 team-based design mechanism. At the University of Kentucky, a year-long program focused on multi-disciplinary team-based design of assistive technology, which featured community immersion, clinical immersions and classroom projects based on user-needs identified from immersions. At IUPUI, an intensive 7-week summer program focused on the socioeconomic considerations of design, which were highlighted through clinical immersion at urban healthcare centers in Indianapolis and subsequently developed into student projects guided by established commercialization expertise.

To illustrate the impact of these programs, we examine each program for evidence of student needs-finding and student engineering design. Next, we share student self-reported surveys assessing program effectiveness, student reported knowledge gains toward needs-finding, and student reported gains on topics of socioeconomic disparities (IUPUI) or disability (UK). Finally, we compare the programs with respect to five topics inspired by evidence-based practices in BME education. We further comment on how program similarities and differences may be connected to the institutional allies identified by each program.

3.2 Needs-Finding and Engineering Design

A common aspect of BME immersion programs, needs-finding instruction challenges students to learn how to observe and state a clinical problem with a target population and a desired outcome into one user need statement [28]. User need statements then guide design teams toward the process of iterative design to produce a solution that can be verified and validated.

When students enter a clinical or community environment, observation and interviewing become primary means to identify legitimate user needs. Table 1 summarizes a subset of the clinical needs identified by students in both IUPUI and UK immersion programs. Of note, many needs statements by UK students were consistent with the program focus on ATD, and several needs statements by IUPUI students identified social or economic considerations, which was consistent with the program focus on urban healthcare disparities.

During the year-long program at UK, students formulated a total of 39 user needs statements. All user needs statements were generated during the spring and summer sessions of the UK program – each session resulting in roughly half the total user needs statements (18 during spring and 21 during summer). The majority of these clearly identified a unique problem, a population, and an outcome – components of a needs statement that have been recommended in recent literature [28, 29].

After two summer offerings of the IUPUI program, students identified over two hundred user needs. The quantity of these user needs is not surprising, as each participant rotated through five different medical specialties. Student observations that translated to user needs included social, ethnic, and economic perspectives such as language translation for better medical professional-to-patient communication due to language barriers, medication reminder systems for children that experience organ transplants, and speedier ophthalmologic tests to allow patients to return to work faster. At the end of the IUPUI program, students assign difficulty levels to their list of user needs in addition to identifying needs with clear aspects of a social or economic disparity. IUPUI immersion program participants do not have enough time during the program to translate every observation into a robust user need statement (e.g., problem, population, and outcome). Instead, user needs are provided to students in senior capstone where further need statement refinement occurs.

While identifying viable clinical user-needs is an important skill for BME students to gain, another important skill of the BME discipline is engineering design – to generate solutions to identified user needs and to affect change in the way medical care is delivered. In both the IUPUI and UK programs, team-based project work is one mechanism that provides students with a complex, biomedical engineering problem to which they can apply the BME design process. For example, during the UK program, students participated in 29 team-based projects, which included 4 team-based design projects. Regarding the team-based activities, the spring session provided students with a majority of opportunities, which primarily featured three types of activities – projects that focus on disassembly/reassembly of assistive technology, projects that focus on personalization of existing technology for users, and one project focusing on design of a smart home assistive technology. While these spring activities were numerous in quantity, they tended to be brief in duration. In contrast, during the fall

Table 1. Clinical and Community Needs Identified by UK and IUPUI Students During Immersions

UK Student Identified User Needs Statements
"A way to prevent stroke survivors from injuring themselves on the side of their body that their perception neglects."
"Female wheelchair [users] catheterization without transferring."
"A way to communicate with persons with dementia while maintaining personalization of care."
"A device for bilateral transfemoral amputees to independently don their prosthetic legs without over exertion of upper extremities."
IUPUI Student Identified Needs Statements
"A way to more easily remove shoes and leg braces. Many patients who have musculoskeletal issues do not have care providers who can help them remove their shoes and leg braces, so a device that assists with this process can be of great benefit."
"An at-home way to read prograf and sirolimus levels. Patients have to get their labs drawn within an hour of taking their early morning medication, meaning they must be at the hospital between 6:00 am–7:30 am the day of their appointment no matter when the appointment time is. This is a real struggle for families who have to travel far distances, don't have reliable transportation, don't have the ability to take an entire day off of work, or have other commitments in the morning such as needing to get other kids to school."
"Child lock catheter can save expensive trips to hospital and costs for antibiotics for inevitable infection/new catheter equipment."
"A way to get drops in kids eye is the number one complaint at the ophthalmology clinic, because there are times when parents take their kids all the way to [the Indianapolis children's hospital] and don't end up getting a test done. The kids just simply can't handle getting drops in their eyes."

session, student teams tackled 4 unique semester-long design challenges, each inspired by a unique needs statement that was generated in spring/summer and vetted through an inter-disciplinary stakeholder meeting prior to the fall session. At IUPUI, while the summer immersion experience did not require design, the student summer observations funneled into design challenges for students in a subsequent fall capstone design project. These design projects offer an important opportunity for hand-on learning, which has been shown to increase retention in engineering [30]. Additionally, these design projects offer students first-hand experience with important factors in engineering design including resource constraints [12] as well as social and ethical considerations [31]. Fig. 3 illustrates several design projects undertaken by BME students at UK and IUPUI, via immersion program and capstone course respectively, and which lead to low-fidelity solutions through a team-based experience.

Both programs emphasize core BME skills of needs finding during immersion experiences and subsequent user need statement development. Needs statements from both programs illustrate that a focused program emphasis (e.g., disability awareness, urban health disparities) can provide students perspective that directly impacts their observations. Furthermore, immersion programs go beyond the identification of the program and provide complex biomedical engineering problems for student teams to consider. They are creating environments where students can experience first-hand needs identification, proposed solution contribution, and an opportunity to reflect on the societal, economic, environmental, cultural factors that can impact the efficacy of a proposed solution.

3.3 Immersion Program Surveys

Previously reported immersion program surveys have identified which program aspects students find most useful (e.g., needs finding lecture, interview skills, ethnographic observations) and that student participation is helpful in preparation for senior capstone experiences [4, 6]. Like precedent immersion programs, both UK and IUPUI acquired student feedback at the end of each program (or in the case of UK, at the end of a designated session of the broader program). Even though the UK and IUPUI programs did not disseminate the same program survey to students, many aspects of each survey overlapped, as can be seen in Fig. 4. The side-by-side comparison of student self-reported program survey data show students mostly feel the contents or program material and resources are valuable and that the program organizers or instructors help students find success in each program. Furthermore, students find the immersion experiences valuable in both programs; although, the IUPUI students did indicate that more preparation of medical terminology could have helped prepare them for their clinical immersion experiences. Immersion program sur-

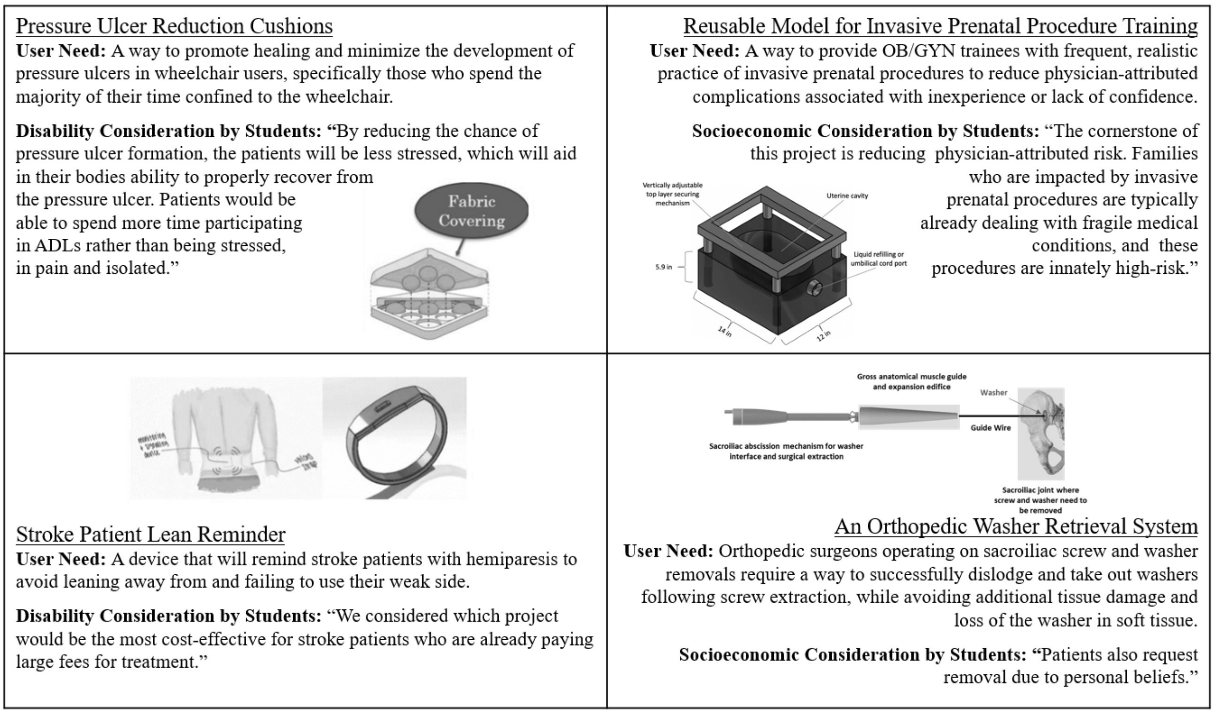

Fig. 3. Examples of low-fidelity solutions to identified user needs from both the UK (left) and IUPUI (right) programs. The UK projects share focus on disability, and the IUPUI projects share focus on socioeconomics.

veys are instrumental in learning what aspects can be quickly changed to provide improved experiences for the next group of students.

Both the UK and IUPUI programs have extended their student surveys to include student feedback on their self-reported knowledge or abilities related to disability and socioeconomic disparity topics, respectively. Fig. 5 shows that each program is succeeding in content delivery in the unique area identified at the onset of each respective program. We highlight this aspect of our programs, because we independently found it important to develop specific survey questions to inform efficacy of program emphasis (e.g., disability or socioeconomic factors).

As previously discussed, needs-finding and effective engineering design skills are important for BME students to develop. Both UK and IUPUI program surveys included aspects of needs-finding, problem-solving on a team, and confidence in concept generation (Fig. 6). Both programs seem to be successfully providing students resources and experiences to see self-reported knowledge and confidence in these areas of engineering design.

3.4 Student Connection with Community

Using journals or logbooks during clinician interviewing and general clinical observation has been shown to be a highly useful tool as reported by students [4]. During the UK program, a compar-

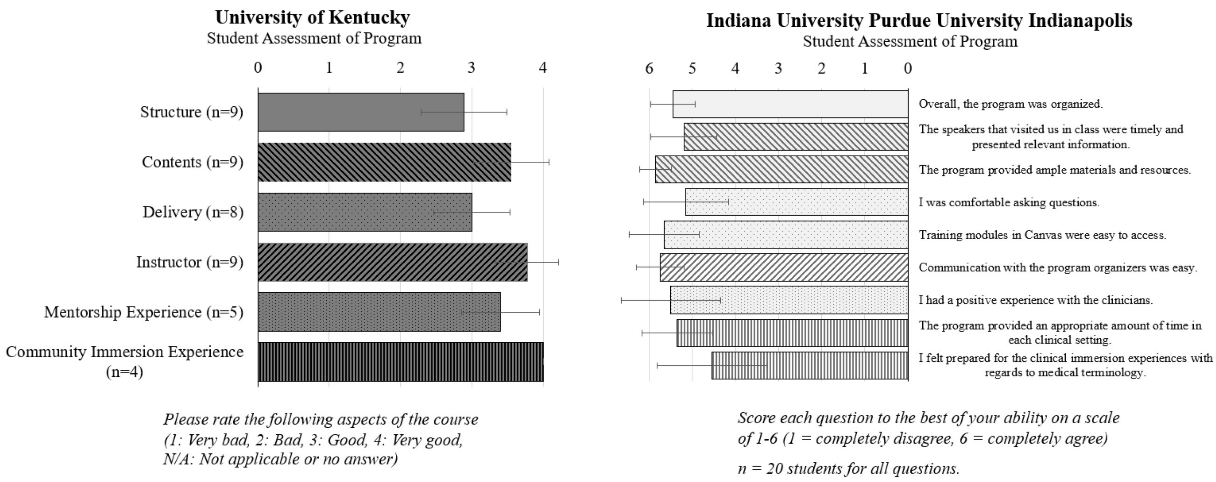

Fig. 4. Survey results for student assessment of immersion program for UK (left) and IUPUI (right). Mean ± standard deviation values are reported for each program respective to the scale used (UK implemented a 4-point Likert scale, where IUPUI used a 6-point Likert scale). General topics from each program that mapped are illustrated in figure with the same bar infill pattern. For example, the UK item *Structure* was mapped to the IUPUI question *Overall, the program was organized*, so both of these items are represented by solid-filled bars.

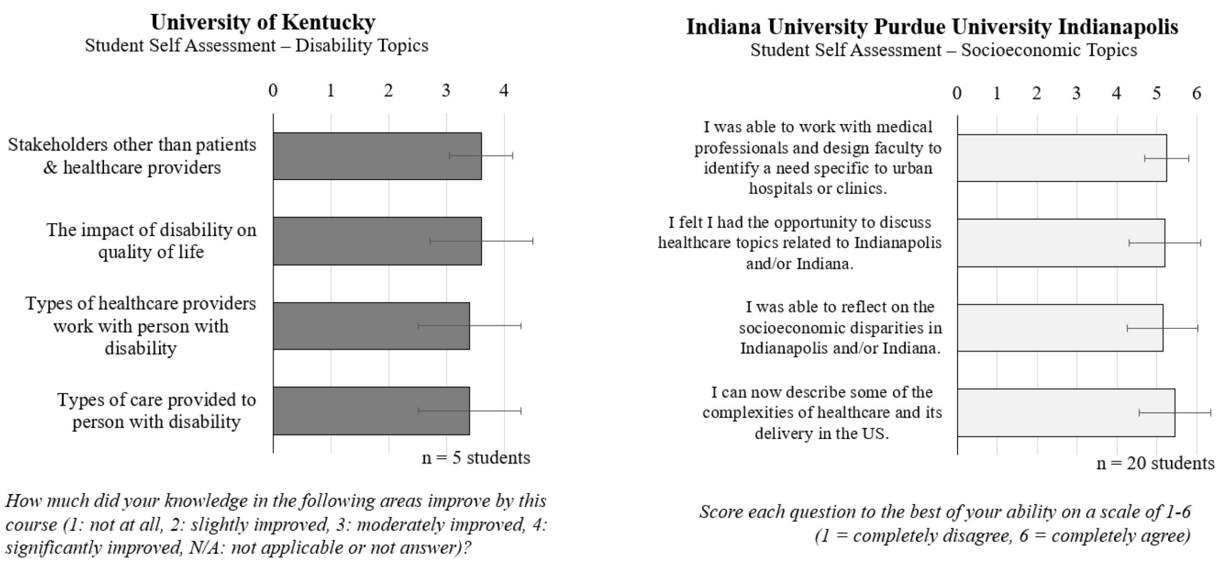

Fig. 5. Survey results for student self-assessment after immersion program and specific to disability topics (UK) and socioeconomic topics (IUPUI). UK implemented a 4-point Likert scale, where IUPUI used a 6-point Likert scale.

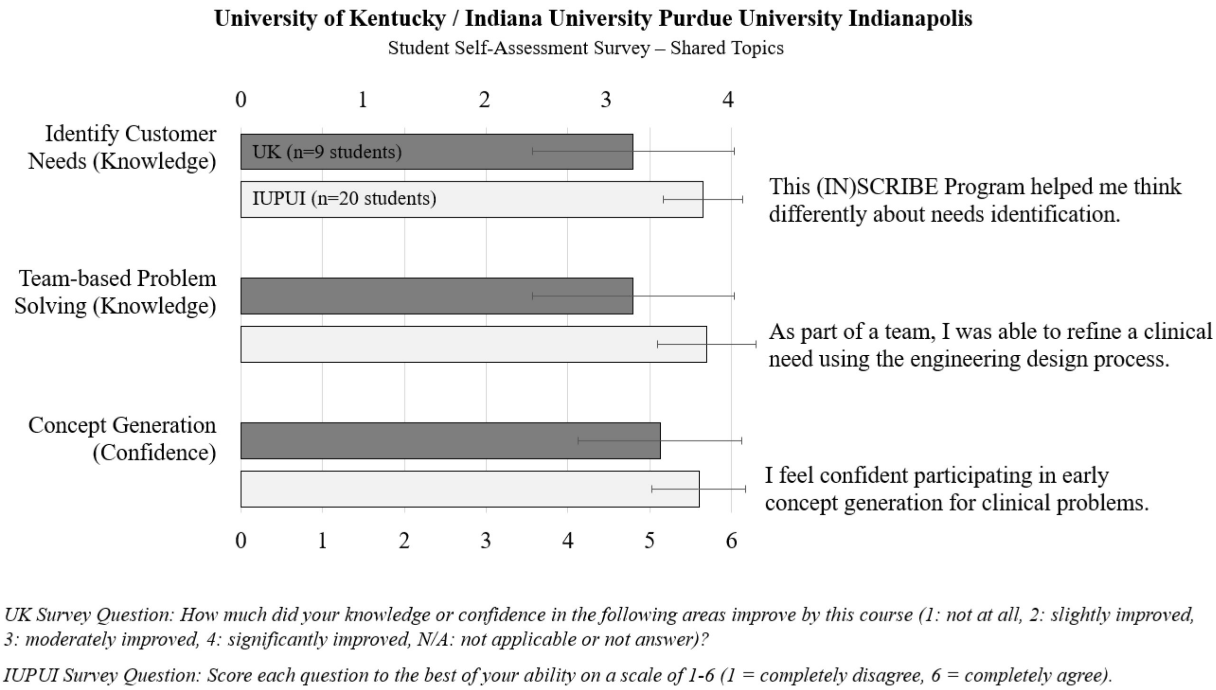

Fig. 6. Self-reported student survey results showing responses after immersion program completion on topics of needs-finding, teaming, and concept generation. UK implemented a 4-point Likert scale, where IUPUI used a 6-point Likert scale.

able approach was implemented for students meeting persons with disability during their spring community immersion. During team-based projects, students were asked to document their experiences using a narrative format. To illustrate, consider the case study below – an excerpt from one team's narrative regarding a power wheelchair modification that required (i) appraisal of user needs and (ii) prompted self-reflections on the project:

(i) "Some special considerations that had to be taken into account during this process are the fact that the user is right hand dominant and functionally one handed. This meant that all of her modifications needed to be added to the right side of the chair in order to be accessible. We also had to consider her height as a factor when mounting the new joystick to ensure it was within her reach . . . we disassembled the mounting bracket and reassembled it so that it was at the proper height and distance to be used as well as able to fold out away from the chair so that she is able to pull up to a table or other surface without being in the way . . . She also wanted the joystick to have the capability to be pushed to the side when approaching a table or counter so as to not be a further impedance . . ."

(ii) "This was a beneficial process for our group because it allowed us to see just how many different ways that an assistive technology could be used. This project allowed us to see how specific the customizations to an AT device can be. It also gives us a general idea of different problems people could have in our future as Biomedical engineers. This was also the first project where we could get hands-on experience in customizing a device for the specific needs of the user."

Following completion of their spring rotation, each UK student prepared a written report focusing on a self-selected disability topic. During this assignment, students were encouraged to interview a community member with first-hand knowledge of the disability. The quotes below demonstrate the students' entries from these interviews:

> "One issue that [he] has had with [spelling/grammar correction software] is since every dyslexic person is different and has different proficiencies, the software sometimes just corrects your words to the wrong one, and when the words are close, he can't always catch when the program makes an error."

> "Although his form of [cerebral palsy] is considered to be on the moderate to minimal severity, he still felt like he was held back by his parents and caregivers . . . One of the main things he spoke about was feeling isolated from his classmates. He was only able to sit in certain parts of the cafeteria . . ."

> "[She] does not view her husband as someone with limitations or a disability. She often forgets that he is even missing a limb since so many people, including herself, rely on him."

During the IUPUI immersion program, students were required to keep a Design & Reflection Notebook throughout the experience. This also allowed the program organizers to include reflection prompts probing students to react to social and economic disparities observed during each weekly rotation. In addition to clinical rotations, IUPUI students all visited a medical-student run outreach clinic as an experience to push students to consider societal factors beyond basic clinical observations. The quotes below demonstrate gained student awareness after completing the clinical immersion program:

> "We have a greater role than I originally thought."
>
> "Seeing the tools actually be used on real people opened my eyes to the severity that even a minor flaw could cause."
>
> "I believe that now I realize that not only do we impact the patient care but we also impact the hospitals and the staff that are participating in the treatment."
>
> "However, after this experience, I realized that if it isn't a BME's fundamental responsibility to incorporate all of those things into a product or be mindful of them during research, quality control, or system analysis, then they simply get left out. In other words, I now feel that it isn't only a BME's responsibility to follow the rules, but to interject empathy into them as betterment for our patients, planet, and future society."
>
> "It [is] also important to be aware of the health care disparities as there were many complaints from both the doctors and the patient on what health care could be provided based on insurance."
>
> "Healthcare is not always accessible and medical devices can be expensive or inaccessible to all types of people."
>
> "A biomedical engineer has the responsibility to design products that can be used regardless of race"

3.5 Program Comparison

The collaboration between UK and IUPUI was impetus to compare the immersion programs at UK and IUPUI, and to do so in light of the many published examples of such programs. To do so, five core features were identified across which a BME clinical immersion program is likely to exhibit both similarities and differences with programs at other universities. These include (1) partners or collaborators who provide the immersion experiences, (2) team-based immersion experiences, (3) an emphasis on needs-finding, (4) team-based engineering design experiences, and (5) program evaluation and assessment. The major similarities and differences between the immersion programs at UK and IUPUI are highlighted in Table 2, which also includes references to pertinent immersion programs in literature.

Of note, a strength at both institutions was programmatic alignment with evidence-based practice guidelines such as authentic problem identification in clinical settings, experiential learning, team-based learning, and project-based learning [1]. The efficacy of guidelines implementation is still yet to be determined. Both programs continue to navigate an infancy stage, and future iterations will yield self-

Table 2. Between Institutions Comparison of Immersion Programs Based on Core Program Features

Core Feature	University of Kentucky	Indiana University Purdue University Indianapolis
Immersion Partner Collaboration	Both programs created student opportunity for hospital-based immersion with student-patient interaction. As others have established, these experiences emphasize the importance of clinical immersion as part of BME student training [3-5, 9, 21, 23]	
	Partnered with the Human Development Institute and College of Medicine to offer experiences for both community immersion and a clinical immersion [34].	Partnered with IUPUI School of Liberal Arts (Sociology) and IU School of Medicine to offers experiences across multiple urban healthcare settings.
Team-based Immersion Experiences	Both programs provided immersion experiences using a team (2 or more students) approach supported in literature, which provides accountability and reassurance to students in clinical environment [4, 6].	
	Longer duration of student immersion experiences to facilitate student familiarity with medical professionals and patients [11].	Quick rotations for student pairs over shorter time frames. To prepare students, pre-immersion training integrated during the first program week [13].
Needs-finding Emphasis	Both programs aim to provide biomedical engineering training associated with needs-finding to augment the development of clinically relevant devices for a chosen patient population [28].	
	Separate student cohorts focused on instruction and needs finding in community (Spring) and clinical setting (Summer).	Students at various points within the BS BME plan of study involved in a single program cohort, and all students received needs-finding instruction during first week before proceeding to immersion experience.
Team-based Engineering Design Experiences	Both programs provided student teams engineering design instruction and the ability to practice iterative design. Student teams are also able to choose the projects on which they work.	
	Adopting prior needs statements, students develop solutions via assistive technology design projects (Fall). Emphasis on multi-disciplinary, team-based approach to design [10, 11].	A required design experience at end of program based on prior needs-finding related to urban, healthcare-related technologies. Timing of program prior to capstone courses offers a helpful sequence to students approaching senior year projects [4, 9].
Immersion Program Assessment and Evaluation	Both programs include student surveys for program feedback and student self-assessments.	
	Student surveys focus on three main areas: 1) knowledge of topics related to the Biodesign process [28], 2) confidence to participate in program activities, and 3) overall program efficacy.	Student surveys focused on program (structure, content) and student self-perceptions (self-efficacy and healthcare awareness) [35]. For hypothesis-driven research, BME undergraduates not enrolled in program also surveyed for comparison.

assessment data and opportunities for program refinement. Moreover, this refinement can be magnified through shared findings and institutional collaboration.

Institutional collaboration was essential to our program comparison. For institutions embarking towards new curriculum with immersive experiences, finding a peer institution may provide substantial benefits including more confident implementation of immersion experiences. In the present case, this collaboration helped reduce the sense of isolation for planning teams at UK and IUPUI. Additionally, collaborative discussions between UK and IUPUI cultivated the following ideas: (i) student exchange between institutional programs to diversity student immersion opportunities; (ii) shared perspectives on course design for senior capstone; and (iii) cross-institution virtual meetings of student cohorts. In fact, the latter idea came to fruition. A virtual meeting was coordinated between UK and IUPUI students at the conclusion of the summer programs. While this particular meeting was intended for students to gain perspective, program planners also gained perspective. Students from each institution often voiced a shared observation, and these shared observations can be more profound feedback to planners than observations from their students alone.

3.6 Limitations

There are several limitations to consider with regards to the described immersion programs at UK and IUPUI. For instance, while collaboration between institutions offers several benefits, the collaborative interaction between UK and IUPUI occurred late after immersive programming was already implemented and inaugural student cohorts enrolled. However, despite this delay, collaborative discussions can still lead to constructive ideas on future programming as previously mentioned.

Another key limitation for both programs was assessment based on small sample sizes. Twenty students across two summer cohorts from IUPUI completed program surveys, while data were available for just nine students from a single summer cohort at UK. In the future, as data collection accrues from future program iterations, sample size will improve, confidence in findings will improve, and comparison between the two institutions, may become easier. Lastly a key limitation to our program comparison was the lack of a standardized evaluation tool across institutions. While independent programs may coincidentally find overlaps in their assessments, as was demonstrated by student surveys at UK and IUPUI (see Fig. 6), the likelihood of overlap is unpredictable without a concerted effort. This complicates data pooling and creates barriers to future meta-analyses.

4. Conclusion

The implementation of an immersive learning experience for undergraduate biomedical engineering is demonstrated through two institution-specific examples, each relying on partnerships with strong allies at their institution. While evidence-based practices in BME education were employed by both programs, differences in implementation are apparent and are partly a reflection of the institutional allies chosen by program planners. For future program developers, these institution-specific examples might inspire discovery of their own allies and illustrate how programs can be implemented to leverage those allies.

Past literature has supported the need for cross-institution studies and scalable clinical immersion opportunity [1, 32], both of which have potential to benefit from standardized evaluation tools that help document and assess program development and student growth. From the perspective of program planners, a common assessment format would support data collation, improve study power, and enhance relevance of study findings to the broader BME community. For students, similar benefits may be achieved with standardized self-assessments. Although students within an institution might have the opportunity to compare their self-reflections, experiences, and perceptions with their classmates, these comparisons are inherently confined to the context of their unique institutional environment.

For student self-assessment, standardization might enhance student's ability to evaluate themselves, to consider their environments, and to arrive at meaningful insights. For example, consider a cohort of students spanning multiple institutions versus a single institution. A student within this expanded cohort is more apt to find and relate to peers with a similar social/economic/educational background. By comparison to such peers, a student might then better identify environmental factors that can contribute positively to their learning experiences and self-reflection, and vice versa.

As the number of undergraduate biomedical engineering programs with clinical immersion experiences continues to grow, we see two possible areas for collaboration across institutions. First, there is an opportunity to create shared resources for program evaluation. Highly impactful clinical immersion programs exist in many BME programs across the US; however, there is little consistency in the way that the programs are evaluated and the sample sizes are generally quite low. The development and broad adoption of a shared program evaluation instrument for BME clinical immersion programs would allow for both comparison across programs and the possibility of studying larger and more diverse samples of students.

Second, there may be opportunities to share unique or particularly impactful experiences with BME students from other institutions. Our programs and other examples from the literature demonstrate how specific (often local or institution-specific) resources can contribute to the impact of BME clinical immersion programs [4, 5, 23, 33]. Either through student exchange programs or venues for students to interact across institutions, the benefits of individual clinical immersion programs might be shared more broadly across BME programs.

Acknowledgments – Activities reported in this publication were supported by the National Institute of Biomedical Imaging and Bioengineering and the National Institute of Child Health and Human Development of the National Institutes of Health under Award Numbers 1R25HD106831 and R25EB031389, respectively. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

References

1. K. Billiar, et al., Learning Environments and Evidence-Based Practices in Bioengineering and Biomedical Engineering, *Biomedical Engineering Education*, **2**, pp. 1–16, 2022.
2. M. I. Miga and R. F. Labadie, A Novel Clinically Immersive Pre-doctoral Training Program for Engineering in Surgery and Intervention: Initial Realization and Preliminary Results, *Biomedical Engineering Education*, **1**(2), pp. 259–276, 2021.
3. W. H. Guilford, M. Keeley, B. P. Helmke and T. E. Allen, Work in Progress: A Clinical Immersion Program for Broad Curricular Impact. Annual Conference & Exposition: final program and proceedings. *American Society for Engineering Education*, p. 26640, 2019
4. B. Przestrzelski and J. D. DesJardins, The DeFINE Program: A Clinical Immersion for Biomedical Needs Identification, in *2015 ASEE Annual Conference & Exposition*. 2015.
5. J. Kadlowec et al. *Clinical Immersion and Team-Based Design: Into a Third Year*. in *2017 ASEE Annual Conference & Exposition*. 2017.
6. M. Kotche, Clinical Immersion Internship Introduces Students to Needs Assessment, in *2016 ASEE Annual Conference & Exposition*. 2016.
7. C. Arena, et al. WIP: Transdisciplinary Design Education in Biomedical Engineering and Industrial Design Towards Identifying Unmet Needs of U.S. Veterans and their Healthcare Teams, in *2020 ASEE Virtual Annual Conference Content Access*, 2020.
8. A. Singh, D. Ferry and S. Balasubramanian, Efficacy of Clinical Simulation-Based Training in Biomedical Engineering Education *Journal of Biomechanical Engineering*, **141**(12), 2019.
9. J. S. Stephens, S. I. Rooney and J. Higginson, Bridging Courses: Unmet Clinical Needs to Capstone Design (Work in Progress), in *2016 ASEE Annual Conference & Exposition*, 2016.
10. P. A. Meyers and J. L. Cezeaux. Board 11: Work in Progress: Fostering Cross-Disciplinary Collaborations between Biomedical Engineering and Occupational Therapy Students – A Model for Clinical Exposure for BME, in *2018 ASEE Annual Conference & Exposition*, 2018.
11. M. J. Geist, et al., Clinical Immersion: An Approach for Fostering Cross-disciplinary Communication and Innovation in Nursing and Engineering Students, *Nurse Educator*, **44**(2), pp. 69–73, 2019.
12. B. J. Ranger and A. Mantzavinou, Design thinking in development engineering education: A case study on creating prosthetic and assistive technologies for the developing world, *Development Engineering*, **3**, pp. 166–174, 2018.
13. K. Sienko, et al., Global health design: Clinical immersion, opportunity identification and definition, and design experiences, *International Journal of Engineering Education*, **34**, pp. 780–800, 2018.
14. A. J. Carroll, A. J. DiMeo Sr., H. O. Ozturk and J. McCall, Board #2: Integrating Medical Economic Perspectives through Information Literacy in a Biomedical Clinical Immersion Design Course (Work in Progress), in *2017 ASEE Annual Conference & Exposition*, 2017.
15. P. Cantillon-Murphy, et al., Addressing Biomedical Problems Through Interdisciplinary Learning: A Feasibility Study, *International Journal of Engineering Education*, **31**, pp. 282–291, 2015.
16. R. Schmedlen et al, The Medical Device Sandbox: A Creative Learning Experience for BME Students and Medical Learners, in *2016 ASEE Annual Conference & Exposition*, 2016.
17. Y. Yazdi and S. Acharya, A New Model for Graduate Education and Innovation in Medical Technology, *Annals of Biomedical Engineering*, **41**(9), pp. 1822–1833, 2013.
18. W. L. Saunders, The Constructivist Perspective: Implications and Teaching Strategies for Science, *School Science and Mathematics*, **92**(3), p. 136, 1992.
19. M. J. Grimm, Design as a Feature of Biomedical Engineering Education – Satisfying ABET and Preparing Students to Address Clinical Needs, *Journal of Biomechanical Engineering*, **142**(11), 2020.
20. "Criteria for Accrediting Engineering Programs, 2022–2023 | ABET", [10 July 2022]; Available from: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023.
21. M. Kotche, et al., Perspectives on Bioengineering Clinical Immersion: History, Innovation, and Impact, *Annals of Biomedical Engineering*, **48**(9), pp. 2301–2309, 2020.
22. V. Mittal, et al., Clinical needs finding: developing the virtual experience-a case study, *Ann. Biomed. Eng.*, **41**(9), pp. 1899–912, 2013.
23. S. Stirling and M. Kotche, Clinical Immersion Program for Bioengineering and Medical Students, in *2017 ASEE Annual Conference & Exposition*. 2017.
24. A. E. Felder, et al., Interdisciplinary Clinical Immersion: from Needs Identification to Concept Generation, in *2018 ASEE Annual Conference & Exposition*. 2018.

25. Indiana University School of Medicine, [10 July 2022]; Available from: https://medicine.iu.edu/.
26. Faculty Labs | Research | IU School of Medicine, 10 July 2022]; Available from: https://medicine.iu.edu/faculty-labs?pageSize=10&currentPage=13.
27. Clinical Partners | Indianapolis | IU School of Medicine, 10 July 2022]; Available from: https://medicine.iu.edu/indianapolis/clinical-partners.
28. P. Yock, et al., *Biodesign: The Process of Innovating Medical Technologies*, 2nd ed. 2015: Cambridge University Press.
29. N. Mokarram et al., Need Statements in Healthcare Innovation, *Annals of Biomedical Engineering*, **49**(7), pp. 1587–1592, 2021.
30. L. Carlson and J. F. Sullivan, Hands-on Engineering: Learning by Doing in the Integrated Teaching and Learning Program, *International Journal of Engineering Education*, **15**, pp. 20–31, 1999.
31. I. Oosterlaken, Design for Development: A Capability Approach, *Design issues*, **25**(4), pp. 91–102, 2009.
32. B. Bakka, et al. Towards scalable clinical immersion experiences for engineering students, in *ASEE 2021 Gulf-Southwest Annual Conference*. 2021.
33. A. Singh, D. Ferry and S. Mills, Improving Biomedical Engineering Education Through Continuity in Adaptive, Experiential, and Interdisciplinary Learning Environments, *Journal of Biomechanical Engineering*, **140**(8), 2018.
34. J. Goldberg, Opportunities to Identify Unmet Needs Outside of the Operating Room [Senior Design]. *IEEE Pulse*, **6**(5), pp. 48–50, 2015.
35. N. Mamaril et al., Measuring Undergraduate Students' Engineering Self-Efficacy: A Validation Study, *Journal of Engineering Education*, **105**(2), 2016.

Justin Huber, MD, MSc is an Assistant Professor in Physical Medicine and Rehabilitation at the University of Kentucky College of Medicine with joint appointment in College of Engineering. With prior engineering training and industry experience in biomedical devices, he is passionate about cross-disciplinary collaborations between Engineering and Medicine to improve health outcomes. In addition to an interest in engineering education, his research focuses on improving quality of life for individuals after stroke by leveraging user-centered design of assessment, assistive, and rehabilitation technologies.

Steven Higbee, PhD is a Clinical Associate Professor of Biomedical Engineering at Indiana University-Purdue University Indianapolis. He received a PhD in Bioengineering from Rice University (Houston, TX) in 2013, after earning BS and MS degrees in Biomedical Engineering from Purdue University (West Lafayette, IN). With a background in biomaterials and tissue engineering research, he now focuses on teaching and discipline-based education research in biomedical engineering. His areas of interest include biomedical engineering design, experiential learning, first-year engineering, and biomedical ethics.

Christina Espinosa, MA is the Division Director of Community Education at the University of Kentucky Human Development Institute – a federally funded University Center on Disability with mission to build inclusive communities, address inequities, and improve the lives of all people who experience disability across the lifespan. She has prior training in Rehabilitation Counseling, and she is passionate about accessibility and universal design.

Babak Bazrgari, PhD has more than 15 years of research experience related to the biomechanics of the human spine and the lower back as related to low back pain. His research has been supported by federal and local funding agencies and has resulted in > 60 peer-reviewed research publications. Dr. Bazrgari's training has been in mechanical and biomedical engineering.

Sharon Miller, PhD is a Clinical Associate Professor of Biomedical Engineering (BME) at Indiana University Purdue University Indianapolis (IUPUI). She received a Bachelor of Science degree in Materials Science and Engineering from Purdue University (West Lafayette, IN) and a Master of Science and PhD in Biomedical Engineering from the University of Michigan (Ann Arbor, MI). Her educational efforts focus on the development, implementation, and assessment of undergraduate biomedical engineering curriculum. Furthermore, her biomedical engineering discipline-based educational research includes design self-efficacy, project-based learning, critical reflection, and high-impact practices such as clinical immersion and senior capstone.