Developing Problem Solving Competency for Future Engineers in Medicine

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This paper summarizes five critical aspects of problem-solving competency for engineers in medicine, including the balance of depth and breadth, research capability, ideation skills, teamwork, and communication skills. Furthermore, the paper outlines the imperatives for enhancing undergraduate engineering education to cultivate problem-solving competency. An interdisciplinary approach to education in medical engineering can cultivate students to develop a holistic view of the field and equip them with a broad range of skills for problem-solving.

Keywords: undergraduate education for engineers in medicine, problem-solving competency, balance of depth and breadth, research capability, ideation skills, teamwork, communication skills

INTRODUCTION

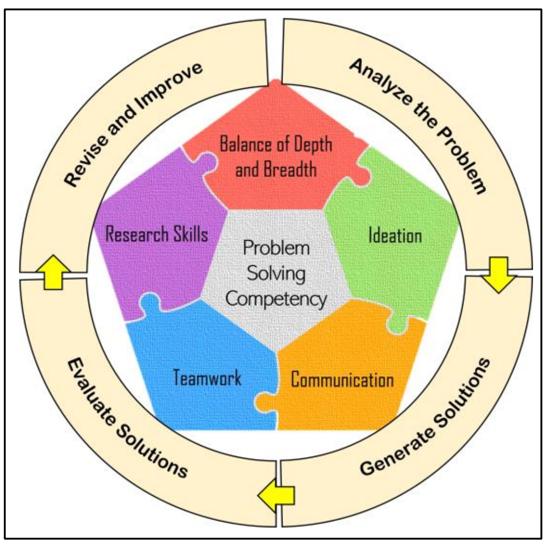
Engineers for biomedical and healthcare industries have experienced the largest growth in the engineering labor market, with an estimated 72% growth rate over the last decade (Magjarevic & Diaz, 2014). It is crucial to prioritize strengthening collegiate education and pursuing excellence in the upcoming generation of STEM and healthcare leaders in the US. Improving the quality of students' learning and motivation in engineering for medicine has always been a priority and a continuous improvement process. For decades, engineers in medicine were from various established majors, such as chemical, electrical, and mechanical engineering. The first independent biomedical engineering (BME) programs in the United States (US) were established in the late 1950s at several universities, including Drexel University, Johns Hopkins University, and the University of Pennsylvania (Abu-Faraj, 2008). In 1972, the Accreditation Board for Engineering and Technology (ABET) first recognized BME as a separate engineering discipline. It began to accredit undergraduate and graduate programs in this major (Linsenmeier & Saterbak, 2020).

Throughout the 1970s to 1990s, the pharmaceutical and medical device industries grew rapidly, and more universities began to offer undergraduate and graduate programs in these fields.

Nowadays, 117 universities in the US offer undergraduate programs in BME or bioengineering (BIOE) (Linsenmeier & Saterbak, 2020). These programs typically merge traditional engineering disciplines, such as electrical, chemical, and mechanical engineering, and life sciences and medicine, coupled with hands-on experience through internships or research projects that provide more in-depth knowledge and training in specialized areas of the field, such as medical device development, tissue engineering, or bioinformatics. Unlike capstones or senior designs in other engineering majors, BME projects often require interdisciplinary work, as they typically involve integrating knowledge and expertise from multiple fields, perspectives, and approaches.

To distinguish engineers working in biomedical industries from engineers who graduated from the BME programs, we use the term "Engineers in Medicine" to cover all engineers who contribute to the technology innovations for improving human health. Due to its interdisciplinary nature, the education for engineers in medicine is not limited to a single academic department or discipline. Many other engineering departments where BME originated, such as electrical engineering and mechanical engineering, still offer biomedicine or healthcare-related electives to train students to address medical challenges through domain knowledge and hands-on training. In addition, many national engineering societies have subdivisions in biomedical engineering, including the Institute of Electrical and Electronics Engineers (IEEE), the American Society of Mechanical Engineers (ASME), The American Institute of Chemical Engineers (AIChE), and the Institute of Industrial and Systems Engineers (IISE) among others. The education for biomedical engineers was born as an interdisciplinary effort and will continue to grow through an interdisciplinary effort.

FIGURE 1
FIVE CRITICAL ASPECTS OF PROBLEM-SOLVING COMPETENCY FOR ENGINEERS IN MEDICINE



For decades, educators have developed and examined learning models (Harris et al., 2002; Hart, 2015; LaPlaca et al., 2001; Martin et al., 2007; Newstetter, 2006; White et al., 2020) for engineers in medicine to balance the broad base of fundamentals with in-depth analytical skills. The overwhelming consensus is that problem-based learning (PBL) (Jamison et al., 2022) with open-ended questions that address authentic clinical needs is one of the most effective approaches to preparing undergraduates for careers in the biomedical industry. In 2020, White et al. led a group discussion on the core competencies for future engineers in medicine (White et al., 2020). According to the MedTech and BioTech industries survey, problem-solving is the most important skill that "positively influences bachelors-level hiring decisions" (White et al., 2020). Therefore, even though there is no single model curriculum fits all engineering programs, the core educational objective for future engineers in medicine remains the same, which is to equip students with the ability to formulate and solve medical problems, including the design of devices, systems, and processes to improve human health.

In this paper, we reviewed five critical aspects of problem-solving competency for engineers in medicine (Figure 1), including the balance of depth and breadth, research capability, ideation skills, teamwork, and communication skills. We also discussed the needed improvement for undergraduate engineering education to foster the development of problem-solving competency. The continuous improvement in undergraduate education for engineers in medicine will ensure that individuals have the knowledge and skills needed to address the complex health challenges of our time and propel biomedical innovation and a thriving global economy.

SCOPE OF ENGINEERS IN MEDICINE

Engineering entered modern biological and medical research through instrumentation. Since the 20th century, electronic instrumentation, later combined with digital technologies, had played an increasingly important role in biomedicine and clinical practice. In 1952, the Institute of Radio Engineers (IRE) established the first professional biomedical engineering group to address "problems in biology and medicine which might be aided in solution by use of electronic engineering principles and devices (Magjarevic & Diaz, 2014)." In 1963, the IEEE formed the Engineering in Medicine and Biology Society (EMBS). Later, the Biomedical Engineering Society (BMES) was incorporated in 1968. Enderle and Bronzino defined Biomedical Engineering or Bioengineering as "applying engineering principles to understand, modify, or control biological systems" (Enderle & Bronzino, 2012).

In 1989, Goodman and David laid out a comprehensive set of critical roles engineers play in the healthcare system (David & Goodman, 1989). Ever since then, many institutions and literature started using the term healthcare engineering with a wider perspective encompassing all domains of engineering and the crucial role that they play in the healthcare systems (Abu-Faraj, 2008; Bronzino, 1992; Ghahramani, 2000; Goldberg, 2000; Verricchia, 1998). Chyu et al. defines healthcare engineering as "engineering involved in all aspects of healthcare", including prevention, treatment, diagnosis, and management of illness (Chyu et al., 2015). In other words, healthcare engineers refer to biomedical engineers working in the clinical setting to improve the services rendered by healthcare professionals. A similar term commonly appearing in the literature involving engineering in healthcare systems is "Clinical Engineering." The American College of Clinical Engineering (ACCE) defines the role of engineers in healthcare and clinical systems as "a professional who supports and advances patient care by applying engineering and managerial skills to healthcare technology" (Hyman, 2001). The responsibility of clinical engineers is to maintain and support those new technologies and assure patients' physical and psychological safety through system design and risk analysis (Zambuto, 2004). Grimes portrays healthcare/clinical engineers as the "stewards of healthcare technologies" (Grimes, 2004).

The interdisciplinary nature of biomedical problems and the increasing complexity of healthcare systems have blurred the boundaries between the terms mentioned above. In many cases, these terms can be used interchangeably, but they may also have nuanced differences relevant in specific contexts. Typically, biomedical engineering is a comprehensive umbrella term for the entire field. Bioengineers tend to focus on materials and biological sciences, whereas medical engineers tend to concentrate on the development and application of medical devices and instruments. Healthcare engineers may emphasize addressing process and system-level problems. In contrast, clinical engineers tend to prioritize the implementation and maintenance of technologies and equipment used in the clinical setting. The education for future biomedical engineers encompasses all engineering disciplines. In this paper, we use the term "Engineers in Medicine" to underscore the comprehensive nature of this field, which extends beyond any specific engineering major.

BALANCE OF DEPTH AND BREADTH

Problem-based learning prioritizes acquiring knowledge relevant to addressing a particular challenge. It emphasizes the ability to effectively apply that knowledge when needed to achieve the best outcome. The human body is a complex mix of systems that requires understanding chemistry, mechanical functions, electrochemical responses, and how humans interact with their environment. The interdisciplinary nature of engineers in medicine means that students must have a strong foundation in multiple fields, including biology, chemistry, physics, engineering, and medicine. However, it can be challenging to strike the right balance between providing students with a broad knowledge base and allowing them to specialize in areas of interest.

Broad and deep expertise are useful in their own ways, and both are required for problem-solving (Boh et al., 2014). In general, students with in-depth domain knowledge tend to be good at analyzing the cause-effect of technical problems and developing solutions in their area of expertise. They can optimize the outcome based on various factors and anticipate potential pitfalls, making them well-suited for making breakthroughs in a specific field. Meanwhile, students with diverse knowledge can connect different technologies to new areas, as they have a broader view of how various technical issues can be addressed. Additionally, they may be better at applying and integrating existing solutions in new ways. Sometimes, a lack of deep knowledge can be an advantage as they are not bound by preconceived notions or aware of everything that could go wrong. Therefore, it can be argued that broad and deep expertise are essential for driving biomedical innovation and making breakthroughs in bottlenecks for healthcare systems.

The bachelor's degrees have limited credits to complete. It may not be feasible for undergraduate students to develop broad and deep expertise within the constraints of their academic program. Therefore, the design of the programs for engineers in medicine should be flexible and adaptable to allow students to prioritize their learning objectives and focus on developing either broad or deep expertise depending on their career goals and interests (Enderle & Bronzino, 2012). A practical approach is to have a degree plan that equips students with a fundamental understanding of different fields and a holistic view of biomedical engineering. Meanwhile, it allows students to choose specific directions with personalized depths (Abu-Faraj, 2008). Ambitious students can further expand the breadth and depth of expertise by comprehending how their core domains interconnect with other fields.

It should be noted that no single curriculum design fits all institutes. A degree without focus may cause students to feel a lack of specialty (Becerik-Gerber et al., 2011). To avoid this issue, the department or college should provide academic advising and mentorship early on, such as through conferences or workshops, to assist students in identifying their interests and subsequently provide research projects or internships to focus on a specific area of interest within biomedical engineering. In addition, collaborative teaching and mentorship across engineering departments will support students as they navigate their education and career paths. Overall, by taking a proactive approach to their education and seeking out opportunities to learn and grow, students will better identify what they need to succeed in their chosen field and follow a personalized study plan that customizes the breadth and depth of domain knowledge.

RESEARCH CAPABILITY

Research skills are critical in both analyzing problems and evaluating solutions. Before providing solutions, engineers must clearly understand the problem, including background, significance, cause-effect relations, and existing solutions. After generating solutions, engineers must properly design and conduct robust experiments, analyze and interpret data, and validate the solutions. To be an effective researcher, "there is a set of special traits that help the student to solve, successfully, a research problem. These traits are being organized, good judgment, effective communication, creativity, and persistence" (Jamieson & Saunders, 2020, p. 2). These traits are those that help a student attain a basic level of competency in terms of conducting research. One of the most obvious problems with assessing research competence is that competencies related to research skills "are not easily observed or measured in the classroom setting and they need to be identified and measured in more realistic environments" (Jamieson & Saunders, 2020, p.

3). This means that traditional direct instruction approaches such as a professor lecturing and only assessing students on the quality of the problem set solutions that they turn in are not adequate to provide the more realistic environment needed for these skills to be applied and assessed. An authentic performance task, or test, can provide the best possible insight into student mastery of a subject. “An authentic test enables us to watch a learner pose, tackle, and solve slightly ambiguous problems” (Wiggins, 1989, p. 705). An authentic test or authentic assessment will allow a student to demonstrate mastery instead of rote recitation.

When students must defend their ideas or position, they become emotionally invested in the unique, authentic solution they developed. The motivation moves from extrinsic (grading) to intrinsic because the student has a sense of ownership in their solution. An inquiry-based classroom gives opportunities, by using authentic performance tasks and informal assessments, to get feedback from students regarding their interests and level of engagement. It also provides the opportunity to assess their research competence in a way impossible in the traditional engineering classroom experience. By the incorporation of tasks that mirror the experiences a student would potentially face when they move beyond the classroom and become a practitioner of their discipline, the students are now “invited to partake in the whole research process with their peers, in a safe and supportive classroom setting, yet solving a realistic priority” (Davidson & Palermo, 2015, p. 2).

Another essential research skill is to review the literature of relevant works while doing research to identify the problem, future scope, relevant methods to get the solution, new perspectives etc. (Boote & Beile, 2005). Nurturing the skill of conducting literature review systematically and effectively in the undergraduate level helps students to grow the habit of going through all the relevant works in medicine (Coughlan & Cronin, 2016; McLellan & Jones, 1996) or any other particular aspect and searching for something new to benevolent any research domain (Bandara et al., 2011; Torraco, 2005). For engineering students, learning to review literature systematically with various software tools and coding to perform multiphase extraction of data from relevant literature guides them to do comprehensive and efficient literature reviews (Bandara et al., 2011). Furthermore, the literature review will inform them about emerging technologies, tools, and techniques for developing innovative solutions.

While going through the research methodology process, students can develop the good ability to analyze real life problems and synthesize the research data systematically and gradually and conclude them in a meaningful and understandable way (Keppel & Zedeck, 1989; Susiani et al., 2018). Also, undergraduate students get the chance to construct identity development while going through the active process of research which later on can develop their ability to express their ideas in an organized way (Davis & Jones, 2017). An undergraduate in engineering discipline with up-to-date technical knowledge can develop his skills to properly and promptly analyze data and communicate research findings effectively in writing and presentation (Sułkowski et al., 2022). Burgoyne et al. showed in one of their studies that undergraduate students who perceive more research skill competencies tend to be more motivated to conduct research in any domain they are interested in (Burgoyne et al., 2010). Ultimately the research experiences will prepare students for future pursuit as an independent researcher in academia, government, and industry.

IDEATION SKILLS

Ideation is defined as “the generation of ideas to address a given brief or problem” (Hay et al., 2019, p. 1), while innovation is best described as “the complete process of development and eventual commercialization of new products and services, new methods of production or provision, new methods of transportation or service delivery, new business models, new markets, or new forms of organization” (Box & Woodall, 2012). Although these two terms are often used interchangeably, from these two definitions, one can see that to solve new problems in the realm of engineering, particularly at the intersection of medicine and engineering, both concepts are critical to addressing new challenges. Ideation helps us to develop new ideas or approaches. It is applicable when one must borrow concepts from other disciplines and leverage the domain knowledge gained to synthesize new solutions from disparate specialties within engineering and medicine. Innovation is taking the idea and refining, developing, implementing, and ideally, commercializing it for the end user's benefit. Whereas ideation requires creative applications of thinking and domain knowledge, innovation is where the practical realities influence the idea, turning it into a product with tangible benefit to a person or community.

One challenge with teaching ideation to undergraduate engineering students is that since it focuses on creativity and potentially combining concepts from various knowledge domains, it can be difficult to develop proposed solutions when a student or group is homogenous in their background knowledge, culture, or preparation for a course. It has been widely accepted that diversity of thought and problem-solving approach is beneficial to ideation (Close & Harris, 2020; Jones et al., 2020), and some authors have stated that they have "consistently observed that the more diverse their project teams were, the more likely they were to come up with breakthrough concepts" (Govendo, 2005, p. 214). In short, "diverse idea generation provides multiple potential solution paths, and so maybe the foundation for a successful outcome" (Daly et al., 2019). While teamwork will be discussed in a later section of this article, it is valuable to notice the key role that a successful team plays in the ideation and innovation process. In the undergraduate engineering classroom, there are effective tools that can be used to help improve the quality of ideation and keep students from getting bogged down on their initial ideas and failing to consider other possible solutions. These tools can help facilitate the flow of ideas, derive new ideas from existing ones, and help students transform their ideas into additional or improved solutions (Daly et al., 2019). These tools include IDEO Method Cards, brainstorming and idea mapping (Masi, 1989), TRIZ (Ilevbare et al., 2013), and lateral thinking (Klymchuk, 2017).

TEAMWORK

To successfully work within a team, students must learn key teamwork skills. Teamwork skills can include communication, conflict management, leadership, trust-building, decision-making, and leadership skills (Smith, 1995). Teaching these skills is just as important, if not more important, when compared to teaching academic skills as the need for competency in one's ability to work as part of a team is critically important both inside and outside of the classroom. By its very nature, academic instruction is centered on the specific learning objectives for a given course of study. Suppose a student is enrolled in a Calculus class. In that case, the expectation is that the instruction will be focused primarily on developing the necessary mathematical fluency to be able to solve Calculus problems. Success will be measured on the students' ability to earn a good grade on an assessment and the positive evaluation provided to the professor at the end of the course will be based on their ability to provide the necessary discipline-specific knowledge to the students as well as the students' overall opinion on whether the course met the learning outcomes defined in the syllabus and course catalog. However, by explicitly including teamwork in the course design, this makes it evident to the students and the broader educational community that the development of competencies in cooperative learning is a serious endeavor and should be approached with as much rigor and focus as the course's academic content. By encouraging the development of teamwork skills, students are being prepared to become not only smarter but also by showing them how to learn better as a team; it stands to reason that they become better individual scholars as well (Sein-Echaluce et al., 2016). Cooperative learning benefits students by converting tacit knowledge into explicit knowledge by encouraging students to have a more enriching engagement with the knowledge being transferred in the course through the ability to "solve complex problems in a team, to exchange ideas and to benefit from synergistic effects" (Schuster, 2013, p. 1).

When students are provided with opportunities to explore a variety of potential research topics to choose from along with options to present the methodology and results of their work, such as conference presentations, peer-reviewed publications, and poster presentations, they tend to improve their confidence with and competence in conducting research. Students in the environment mentioned above at Philander Smith College exhibited improved teamwork and collaboration skills, developed stronger interests in understanding the research process, and exhibited a greater confidence in presenting their research work to others (Kardash, 2000).

Waltz and Barrett's curriculum also aims to develop undergraduate engineer students' listening skills, quintessential in a collaborative work environment. When asked to add commentary and peer review, the students in the audience group inherently start adapting "listening skills", which are essential to understanding and providing feedback when working in a multi-disciplinary environment (Kline, 1996). This is also applicable in an interdisciplinary environment that involves engineers from different domains and medical and life science experts working together to improve or solve a particular problem in healthcare. As ineffective verbal speech can distort effective teamwork, mishearing or inattentively missing out on crucial information can impede effective communication. The "Goal to learn Mindset" (Black & Allen) is a psychological aptitude that can be adopted in undergraduate engineering training. It would make them keener to learn new concepts from experts in other domains in a collaborative environment. This would nourish their mindset to pick up key information from a speaker. Furthermore, "Picturing the scenario" (De Koning & van der Schoot, 2013) in a speech rather than just listening to the words creates a more attentive and empathetic listener for multi-disciplinary collaboration.

COMMUNICATION SKILLS

Engineers require skills beyond their expertise in their academic paradigm to be successful in a real-world scenario. Effective communication is a crucial aspect of problem-solving in an interdisciplinary scenario. Students who are able to communicate effectively about the problem and problem-solving strategies are more likely to be successful in their studies (Baum, 2000; Savrda, 2007). Lack of proper communication skills undermines an engineer's overall professionalism despite their technical experience (Yurtseven, 2002). Especially when it comes to practicing engineering in a highly cross-disciplinary environment like healthcare, the need for strong communication and other soft skills are strongly interlinked with their basic technical skills. Although specialists from the same domain might find this specific and highly technical wording and phrasing suitable in their common workspace, it impedes the transmission of opinion between speakers of different technical languages, such as a medical surgeon and an engineering expert.

The ultimate challenge in improving the overall communication skills of undergraduate engineering students aiming for healthcare is deciphering techniques on how future engineers can effectively communicate ideas with specialists from other domains. This requires expertise in different areas of communication, such as oral, written, non-verbal, and visual communications. Watz and Barrett have identified that combining experimental project labs and communication practicum trains undergraduate students to effectively pick up oral communication skills alongside technical learning (Waitz & Barrett, 1997). In their curriculum design, students are required to pick research topics at the undergraduate level and eventually engage in different activities to exercise their communication skills (Waitz & Barrett, 1997). These exercises include in-class presentations of their research topics, peer reviews where students from different groups comment and evaluate others, writing recommendations, etc (Waitz & Barrett, 1997). Through in-class presentations, the presenting students can look beyond the technical rationale of their topics and shed light on the bigger picture, such as economic, social, organizational, and environmental factors when drawing the bigger picture for the general audience. This enables the students share a common vision with others who might not be technical experts in that domain. In a multi-disciplinary workplace like healthcare, learning how to simplification of technical terms and presenting them in a rather "general tone" is essential for cross-disciplinary knowledge exchange (Pomales-García & Liu, 2007).

Furthermore, certain other innate characteristics of oral communication like eye contact, body language, vocal pitch and pace, reflective silence, etc. (Andrew & Tan, 2010; Brindley & Reynolds, 2011) are just as important as the message being communicated. Effective oral communication requires a great deal of connection with the audience (Nikitina, 2011). The speaker must account for how much of the conveyed information is absorbed and the audience's impression in connection to the topic and the speaker. A famous expression by Theodre Roosevelt "people do not care how much you know unless they know how much you care" can be used to describe the importance of expressing a speaker's enthusiasm and strong connection to the logic of the topic they are presenting on (Brindley et al., 2014). In developing a curriculum for undergraduate engineers aspiring to serve in healthcare, such innate oral communication skills must be addressed and incorporated into their communication strategy buildup.

Written skills are essential for engineers in their specific area of work and multi-disciplinary workplaces. Ineffective written communication in engineering workplaces results in misinterpretation, mistrust, and aggression, and affects the problem resolution timeline (Keane & Gibson, 1999). Written miscommunications may be expected to have even more serious consequences in a multi-disciplinary environment such as healthcare. Studies have shown that writing improves critical thinking and problem-solving skills, and confronts personal misconceptions (Sheth, 2015; Waitz & Barrett, 1997).A written technical document must have a purpose and clear objective, and convey information/fact/data, methodology, results, and conclusions (Budinski, 2001). Although these are more related to the technicalities of the written document, an engineer working in a cross-disciplinary environment must have additional attributes that make it more accessible to readers from a different domain. Using an "impersonal voice" such as 3rd person pronouns makes it less self-authoritative and establishes a more congenial tone for the readers (Budinski, 2001). Statements must be more concise, directed toward the readers, and written in a non-archival format for a better text-to-reader connection (Budinski, 2001). When it comes to honing writing skills, there is no alternative to prescribing exercises. Waltz and Barrett's curriculum for training undergraduate students involves writing weekly "trip reports" as a summary or a memorandum of a student's interaction with their advisor on experimental projects (Waitz & Barrett, 1997). This enables them to recollect, reflect and revise prior information. Extensive writing like reflective journals, essays, peer reviews, and conference papers can be incorporated into the undergraduate curriculum with adequate feedback and benchmarking from mentors (Riemer, 2007).

The skill of oral presentation of the research findings can be nurtured while doing research work at the undergraduate level. Visual forms of information like diagrams, pictures, schematics, graphical contents, etc. can play a powerful role in rapid idea and knowledge sharing amongst personnel from different backgrounds in the form of non-verbal communication (Riemer, 2007). Engineering education heavily relies on visual data representations (Larkin-Hein, 2000), and skills such as drawing and design should be embedded in the undergraduate curriculum as an essential part of future collaborative workplaces. Technology plays a big role in conducting research, from finding journals, conference papers, articles, and metadata creation to presenting it to audience (Clarke et al., 2013; Masinde et al., 2021). The knowledge of using presentation tools such as PowerPoint, Prezi etc. works predominately in the field of engineering and medical science while engaging with the audience in a conference (Chávez Herting et al., 2019). The undergraduate engineering programs can adopt these attributes through group projects, collaborative learning, and teamwork in their curriculum.

DISCUSSION

Engineering acts as a bridge between human knowledge and human needs (Yazdi, 2013). Engineers, in their undergraduate days are taught fundamental knowledge and how to apply them to solve wide arrays of problems. From that perspective, engineering can be seen as a very versatile domain that deals with problems on community, society, national, and civilization scales. Inspiring undergraduate engineering students to solve problems specific to healthcare requires giving them insights and ideas about the overall healthcare system and directing them to grow an interest in solving problems related to the healthcare industry.

Engineers in a particular domain are taught to deal with problems specific to their areas during their undergraduate studies. The problems given in assignments and tests are designed to test their competency in solving those specific problems. Real-world problems are much different from textbook problems and require real exposure to such problems. Practical exposure to problem-solving in the healthcare industry plays a strong role in kindling interest in early engineering education days. The Healthcare Hackathon is a unique program designed by physicians at Stanford University where students from medical science and different engineering domains are put into groups to find solutions to practical healthcare problems (Wang et al., 2018). The unique collaborative atmosphere the students are exposed to while working towards solving real-world healthcare issues is conducive to fostering interest in healthcare problem-solving. Although the Healthcare Hackathon program initiated by Stanford University was a six-month-long event (Wang et al., 2018), the idea can be incorporated into the undergraduate engineering curriculum on shorter scales, like summer camp programs or industrial attachments, to expose students the real-world healthcare issues.

Seminars on healthcare advancements can also play a dominant role in nurturing specific interests related to healthcare problem-solving in undergraduate engineering students. Studies show that seminars can influence students' cognitive response to seeking purpose, meaning, and a desire for life-long learning (Padgett et al., 2013). Through systemic and routine seminars, students can get exposure to a real-world situation, the scope for development in particular areas, and innovative ways experienced professionals work towards solving problems (French, 1974). This can be utilized to broaden the spectrum of undergraduate engineering students and eventually help them grow interested in that specific area. Seminars can be arranged with current engineers from industries, entrepreneurs in medical services and products, and faculty members working in academia on solving real problems in healthcare engineering. Real-world examples, thinking strategies, problem demonstration, unique solution methods, market trends, etc. will help bridge academic engineer learnings to real-world problems in healthcare.

Curriculum design to motivate and encourage undergraduate engineering students toward healthcare problem-solving can be another option for kindling interest in that area. Unique academic programs and initiatives to engage students in real-world problems can be a successful methodology for this attempt. Rice University has designed Beyond Traditional Borders (BTB) to engage undergraduate students to solve global health challenges (Oden et al., 2010). This initiative persuades the students to look at problems beyond the national borders by considering the global perspective of healthcare, especially in underdeveloped parts of the world (Oden et al., 2010). Designing course programs of such sort to better aid humanity on a global scale can serve as a strong motivation for undergraduate engineering students to direct their careers towards healthcare improvement. Another popular trend in reforming curriculum is to encourage entrepreneurship. Engineers in medicine should have opportunities to learn the basics of business planning, market research, and product development. Universities can also create incubators and accelerators specifically for biomedical students, to provide them with lab spaces, equipment, mentoring and networking opportunities, and training to help them turn their ideas into businesses.

Last but not least, creating a supportive and inclusive classroom environment is important. Future biomedical engineers with ethics should be incubated in a culture where everyone feels valued and respected (Austin et al., 2022). Meanwhile, a diverse team is more likely to develop creative solutions to problems (Martins & Sohn, 2022). Promoting diversity can start with building a sense of community in the classroom by including diverse perspectives and examples in course materials and encouraging students to share their experiences. At the college or university level, faculty should provide mentorship, training, and development opportunities to help students from underrepresented groups to manage conflicts, accommodate special needs, and advance their careers. Faculty contributions to promoting diversity and inclusion need to be recognized and celebrated. In addition, unconscious bias training (Atewologun et al., 2018) for all students can help raise awareness of how bias can affect decision-making. Overall, diversity must be encouraged at all levels, especially in leadership positions, to ensure that all future engineers can be represented in role models.

CONCLUSION

The education for engineers in medicine is an interdisciplinary effort and will continue to grow through cross-departmental effort in academia. An effective approach to prepare undergraduates for careers in the biomedical industry is problem-based learning (PBL). We reviewed five crucial aspects of problem-solving competency for engineers in medicine: balancing depth and breadth, research capability, creativity, teamwork, and communication. We also discussed areas for improvement in each of the five aspects to cultivate problem-solving competency for undergraduate students. The design of the programs for engineers in medicine should be flexible and adaptable to allow students to prioritize their learning objectives and focus on developing either broad or deep expertise depending on their career goals and interests. Students can better develop their research skills by participating in projects in authentic clinical settings, attending workshops and seminars, and joining established research groups. In addition, ideation tools should be included in the current curriculum to help students develop their skills in a structured and focused way and provide new insights that they might not have considered otherwise.

Last but not least, solving biomedical problems always needs interdisciplinary teams that require individuals to communicate effectively, understand diverse perspectives, and work towards a common goal. Therefore, team management tools and technical communication skills should be taught and practiced repeatedly throughout undergraduate studies. In summary, cultivating students with the necessary knowledge and skills to tackle our time's intricate health challenges requires continuous improvement and periodic review.The continual advancement of undergraduate education for engineers in medicine will promote future biomedical innovation and drive a flourishing global economy.

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