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A Coding Scheme for Measuring Biomedical Engineering Students' Breadth of Exposure to the Discipline

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Abstract

Biomedical engineering (BME) is an increasingly broad field. Yet, the experience of instructors is that undergraduate students just entering a BME program typically voice a very narrow view of the field, focusing primarily on prosthetics and stem cells, and therefore have limited interests within the BME discipline. The purpose of this work was to both develop a coding scheme that could be used to classify and monitor students' biomedical engineering interests and demonstrate how it could be used in a particular context to gather base-line data to which future classroom interventions, focused on expanding students' interest and understanding, might be compared. To develop and test a coding scheme, students' proposed topics for an assigned term paper in a junior level introductory BME course were examined. The coding scheme was based on the 2019 Biomedical Engineering Society (BMES) conference tracks and subtracks and was applied to two years' worth of data. When applying the coding scheme to two separate offerings of the course, differences were found in students' proposed topics. A discussion of possible factors contributing to these differences is provided, along with implications for instructional practice and limitations of the BMES-based coding scheme.

Introduction

Biomedical engineering (BME) is a loosely defined subject area that has great diversity. Unfortunately, many people, including college students majoring in BME, think of prosthetics and stem cells as the most prevalent, and sometimes the only, branches of BME. In a recent unpublished pre-class survey of BME students (n=45) enrolled in the introductory BME course that is the setting of this study, 28 students list tissue engineering and/or prosthetics as a topic of interest. The preconceived notion of BME's focus on prosthetics and stem cells/tissue engineering is not surprising when looking at the information about BME that is available to students. When looking at various websites that are directed towards a students' level of understanding, including Wikipedia, Biomedical Engineering Society (BMES), and STEMJOBS, readers are informed that BME is "artificial limbs and organs, new-generation imaging machines, advanced prosthetics and more" [1] and "genetically engineered organs are an answer to the shortage of donor organs" [2]. Despite the importance of prosthetics and stem cells/tissue engineering to the field of BME, there is a need to expose students to a broad range of specializations so that they can better understand the opportunities a degree in BME affords. The pivotal role that broad exposure to the field plays in shaping career decisions and actions is exemplified in a recommended roadmap to a successful career in BME [3]. Step three out of 25 is "develop a comprehensive understanding of the field and its key divisions." (p. 1556).

Acknowledging the need for broad exposure to the field, the instructor of an introduction to BME course (the second author) decided to reconsider the purposes and design of a term paper assigned in the course. Since the assignment's inception, one purpose was to provide students' choice to delve into something they care about but for which there was not time in the course to discuss. The topics students selected were managed in so far as they could not duplicate a topic in any one offering of the course; this was thought to maximize students' exposure to the field when students presented their topic to the class. But the question was: how broad was the range of topics students are interested in? Were there key divisions of BME that students did not get exposed to through this assignment? If breadth was indeed minimal and specific gaps could be identified, this could both serve as an indicator of students' interest in and understanding of the field and could inform changes to the assignment. The purpose of this work was to classify students' proposed topics so that interest in and breadth of understanding of BME could be determined and used to inform assignment, course, and curricular design.

Background

Across engineering majors, there is evidence that students enroll in engineering with little understanding of engineering in general [4], much less the specific fields and subfields therein. Further, engineering students graduate having limited understanding of career options or commitment to engineering careers [5].

Within BME, work has been done to employ instructional strategies to improve introductory students' perceptions of the skills necessary for the engineering profession, specifically with regards to technical skills, professional skills, and project management skills [6]. Similarly, work has been done to improve introductory BME students' awareness of broad classifications of available BME job functions (e.g., research, technical sales) [7]. A gap in the BME retention and career-decision research is investigations into introductory students' interests and understanding of the subfields within BME that might promote sustained interest in BME as a post-graduate career.

Theoretical Framework

Interests are at the core of social cognitive career theory (SCCT), as career goals and choices stem from interests [8]. The early phases of the Hidi and Renninger interest development model [9] suggest that students' level of interest, in this case in biomedical engineering topics, may range from triggered situational interest (e.g., questioning based on brief exposure) to maintained situational interest (e.g., being inspired to learn more) to emerging individual interest (e.g., attaching personal value). These levels of interest are fragile and mediated by self-efficacy and outcome expectations derived from learning experiences. Limited exposure to biomedical engineering topics and engagement in exploration could lead to students not having a well-developed individual interest [9] or finding interests that endure into a career choice, resulting in attrition from the field. To put this more concretely, if students' exposure to biomedical engineering is only focused on prosthetics, that might be initially interesting to them; but if that interest is lost, then interest in biomedical engineering as a whole is compromised. Without exposure to the many areas associated with biomedical engineering, students cannot proceed from triggered situational interest to maintained situational interest; meaning they will not explore the wide range of research opportunities and internships that are available to them and find their personal niche within the field.

Research Purpose

The purpose of this research is to develop a scheme that can be used to classify and monitor students' biomedical engineering interests and demonstrate how it could be used in a particular context to gather base-line data to which future classroom interventions to expand students' interest and understanding might be compared. To demonstrate the use of this coding scheme, the research question guiding this work was: What is the breadth of interests in the BME field as expressed through topic proposals for a written and oral term paper submitted by students taking a junior level introductory BME course in an embedded BME program?

Methods

Setting and Participants. The course under investigation is Introduction to Biomedical Engineering (Intro to BME) offered at an R-1 Midwest U.S. institution. This is a junior level course typically taken by Biological Systems Engineering (BSE) junior and senior level students; it is required for BME students and an option for non-BME BSE (BSE-Other) students. The course is also open to other engineering students. The first two years of the BSE curriculum trains students as engineers with knowledge of biological systems. In their third year, students choose an emphasis area, in this case BME, on which to focus their remaining studies. Because of this sequencing, students in Intro to BME have a deep knowledge of biology and engineering principles/practices that they can bring to bear to perform in-depth, engineering-based analysis of BME topics/technology.

One drawback to students taking Intro to BME in their junior year is that they frequently still have a limited view of the BME field. As such, the goals of Intro to BME are to enable students to explain the most prevalent research areas and industrial applications in biomedical engineering, and evaluate the engineering aspects of medical technologies and advancements.

This study examines Intro to BME students' topic proposals for term papers submitted in two consecutive years (2016 and 2017). The student demographics can be seen in Table 1. In 2016 there was one electrical engineering student enrolled in the course. In 2017, there was one electrical engineering student and two mechanical engineering students.

Table 1. Participant demographics

Year	N	Gender	Major	
			BSE-BME	BSE-Other and Other Engineering
2016	36	Female = 16	14	2
		Male = 20	19	1
2017	27	Female = 11	6	5
		Male = 16	10	6

In 2016 the course was co-taught by a faculty member with research interest in biomedical imaging and a faculty member with research interest in nanotechnology and molecular/cellular engineering (second author). In 2017, the course was only taught by the instructor with the nanotechnology and molecular/cellular engineering interest.

Data Collection. The data for this study was gathered from the topic proposal stage of a final term paper assignment culminating in a written paper of 5-7 pages (2016) or 4-6 pages (2017) with proper citations and an oral presentation to the class. In both years, students were instructed to: "Select a topic in biomedical engineering to explore in more detail. Some examples could be:
• A research area we did not cover or covered lightly (e.g. gait analysis)
• A particular device/instrument of interest (e.g. self-contained insulin pump)"
The instructor verbally conveyed that students could pursue topics of interest to them or topics that could be found through popular media (e.g., news outlets). Students also had to ensure that they could locate scientific work on the topic.

For the written term paper in 2016, the instructions for the assignment read: "Concentrate on the aspects that are important to engineering. Some example questions might be: How does the device work? Why does this research area require an engineer? Why is it interesting to you? What skills are required to be successful in this area? What classes could you take to help you prepare for this area / build this device? What companies make this device / perform this research?". In 2017, the written term paper instructions were reduced to "Concentrate on the aspects that are important to engineering. Some example questions might be: How does the device work? Why does this research area require an engineer? Why is it interesting to you? What skills are required to be successful in this area?" In both years, for the oral report component, students were encouraged to "try to convince your classmates that this is a good research area / interesting device."

The oral presentation portion of the class allowed students to be exposed to topic areas that were not covered in depth, or at all, during the instructor led lectures. Because of this, the instructor decided that each student should have a unique topic. Every student proposed two ideas, each communicated in one or two paragraph abstracts (one page total). If a student preferred one topic over another, they could note their preference on the assignment.

The instructor reviewed each student's topic choices and assigned one of the two topics to the student for their final term paper; topic preference was accounted for as often as possible. There were situations that led to a student not being assigned to their preferred topic, including when the topic proposed was too narrow for the student to find sufficient citations, too broad to be fully covered in the page limit, not BME focused, or requested by another student. If two or more students requested the same topic, then the student with the abstract that was more thoroughly researched/cited was assigned the topic. The students were informed about how the instructor would make topic assignment decisions before submitting their abstracts.

Students that proposed topics that could not be used were instructed to write an additional abstract on a new topic, continuing this procedure until an acceptable topic was identified. While the instructor worked with the students to assist in topic choices, students were ultimately responsible for deciding on their term paper's focus.

In 2017, the instructor suggested to students that they look more broadly for possible topics. She explained that in 2016 many students chose prosthetics or stem cells for their topic and therefore were unable to be assigned to their first topic choice and, in some cases, had to write a third abstract to identify an appropriate topic.

Students submitted their topic choices at different times during the 2016 and 2017 semesters. In 2017, the instructor wanted to provide students with more time to complete their term papers. Table 2 indicates the course topics that were completed in 2016 and 2017 prior to the topic abstract submission.

Table 2. Lecture topics completed prior to term paper topic abstracts submission (topics taught after abstract submission are not listed)

Lecture Topics	2016	2017
History of Medical Technology and Biomedical Engineering	Yes	Yes
Engineering Design	Yes	Yes
Sensors	Yes	Yes
Bioelectricity	Yes	Yes
Nanotechnology	Yes	No
Medical Imaging	Yes	No
Biomaterials	Yes	No

Data Analysis. A qualitative analysis of students' abstracts (proposed topics for the term paper assignment) was completed using an a priori coding scheme. The Biomedical Engineering Society's (BMES's) 2019 Annual Meeting paper tracks [10], which is similar to Bronzino's list of key divisions in the field of BME [11], was used as the a priori coding scheme. Table 3 lists the 16 tracks relevant for use in this study with the number of subtracks possible for each track, including an Other/Non-Specified option. Tracks for Biomedical Engineering Education and Undergraduate Research & Design were not applicable to this study. The Translational Biomedical Engineering track was also not used as it repeated the subtracks of other tracks.

Many proposals could be broadly classified as being about a device (54% and 46% in 2016 and 2017, respectively). A device was defined in this study to be a designed physical object (often but not always with mechanical or electrical components), that is not cells, tissues, techniques, and processes, that was described in enough detail to allow the reader to have a mental image of the features and design considerations. As there were so many device proposals, a third code could be applied to better understand students' breadth of interest in devices. Therefore, each proposed topic was coded as either a Device or Non-Device. Then each topic was coded according to the most applicable BMES track(s). When the Device code was applied, a third code was applied using the 14 subtracks for the Device Technologies and Biomedical Robotics (DTBR).

Table 3. Biomedical Engineering Society's (BMES's) 2019 Annual Meeting paper tracks used in coding scheme

Track	No. of Subtracks
Bioinformatics, Computational and Systems Biology	13
Biomanufacturing	11
Biomaterials	12
Biomechanics	23
Biomedical Imaging and Instrumentation	22
Cancer Technologies	14
Cardiovascular Engineering	13
Cellular and Molecular Bioengineering	18
Device Technologies and Biomedical Robotics (DTBR)	14
Drug Delivery	12
Nano and Micro Technologies	15
Neural Engineering	19
Orthopaedic and Rehabilitation Engineering	12
Respiratory Bioengineering	8
Stem Cell Engineering	14
Tissue Engineering	18

Table 4 shows a selection of coded proposal topics. For comparison, consider a single BMES code that was used for a Non-Device and a Device. The proposed topic *fluorescence-guided surgery for cancer* was not concerned with a device but rather with an imaging process. This topic was coded as Non-Device/Biomedical Imaging and Instrumentation. Whereas, the proposed topic *transcranial Doppler ultrasound* was about the imaging instrument itself (a device). This topic was coded first as Biomedical Imaging and Instrumentation. Then, since this topic met this study's definition of a device, the proposed topic was also coded with the DTBR subtrack Biosensors.

Each student's topic proposals were coded by both co-authors. A novice-led analysis, similar to that described by Johnson-Glauch and Herman [12], was employed to challenge researchers' biases in coding. The novice in qualitative data analysis but with expertise in biomedical engineering and teaching the introductory biomedical engineering course (the second author) was better able to classify topics using the BMES tracks. Whereas, the novice in biomedical engineering but with expertise in qualitative data analysis (the first author) was able to draw attention to potential instances of over-interpretation of students' descriptions of their proposed topics. When the co-authors' codes for a given topic proposal differed, the codes were negotiated for 100% agreement.

Results

Table 5 shows the results from coding the students' proposed topics as Device and Non-Device topics with the BMES tracks. In 2016, the percentage of Device versus Non-Device codes were 53% and 47%, respectively. Whereas, in 2017, the codes were split 66% Device and 34% Non-Device.

Table 4. Sample proposed term paper topic with coding.

Sample Author Interpreted Proposed Paper Topics[a]	Device?	BMES Track(s)	BMES DTBR Subtrack(s)
Fluorescence-guided Surgery for Cancer (emphasis: imaging strategy)	No	Biomedical Imaging and Instrumentation	NA
Mucosal Cell Transplant (emphasis: stem cells)	No	Stem Cell Engineering	NA
Artificial Ligaments (emphasis: tissue engineering)	No	Tissue Engineering; Orthopaedic and Rehabilitation Engineering	NA
Transcranial Doppler Ultrasound	Yes	Biomedical Imaging and Instrumentation	Biosensors
Bionic Eye	Yes	DTBR	Assistive Technology; Implantable Devices and Implantable Electronics
Pacemaker	Yes	Cardiovascular Engineering	Cardiovascular Devices
Modular Prosthetic Limb	Yes	Neural Engineering; Orthopaedic and Rehabilitation Engineering	Design and Control of Prostheses and Exoskeletons

[a] topic focus is not listed for Devices since the focus of each of those proposal topics is the device

In 2016, the Device related codes centered on neural and cardiovascular applications as well as imaging and instrumentation. Additionally, there were a number of codes indicating other types of Devices only classifiable in the DTBR subtracks (e.g., Bionic Eye, Table 3). Codes used for the Non-Device related topics also centered on imaging and instrumentation but also on stem cell and tissue engineering.

In 2017, a large percentage (39%) of the Device topics could not be coded in any track other than DTBR. Cardiovascular and Orthopaedic and Rehabilitation devices constituted just over 10% of the codes. Non-Device BMES track codes that with just greater than 10% representation were related to Cancer Technologies and Cellular and Molecular Bioengineering topics.

Table 6 shows the BMES Device subtracks that were coded when a topic proposal was coded as a Device. In both years, Other was a common code, meaning a specific BME topic that could not be coded using the DTBR subtracks. The code Non-specified was used as a separate code to mean a topic proposal was too vague to code. Assistive Technology, Biosensors, Prostheses, and Implantable Devices were the most common codes in 2016 and 2017. Cardiovascular Devices had a 10% representation in 2016, but declined slightly in 2017.

Table 5. Frequency of Device and Non-Device BMES track codes derived from students' proposed topics submissions.

Tracks	2016			2017		
	Device (topics[a] = 39)	Non-Device (topics = 33)	Overall Percent	Device (topics = 36)	Non-Device (topics = 19)	Overall Percent
Bioinformatics, Computational and Systems Biology				1	2	5%
Biomanufacturing						
Biomaterials	2		3%	1	1	3%
Biomechanics	1		1%	2	2	7%
Biomedical Imaging and Instrumentation	5	8	17%	1	2	5%
Cancer Technologies		1	1%		4	7%
Cardiovascular Engineering	7	2	12%	4		7%
Cellular and Molecular Bioengineering		1	1%	1	4	9%
Device Technologies and Biomedical Robotics (DTBR)	7	NA	9%	15	NA	26%
Drug Delivery	1	1	3%	2	2	7%
Nano and Micro Technologies	3	2	6%	3		5%
Neural Engineering	9	3	16%	3	1	7%
Orthopaedic and Rehabilitation Engineering	3	3	8%	4		7%
Respiratory Bioengineering						
Stem Cell Engineering		7	9%		1	2%
Tissue Engineering	3	8	14%	1		2%
Other (no BMES code fit)					1	2%
Total	41	36		38	20	

[a] topics refers to the number of topic proposals. Each topic proposal could receive more than one BMES track code.

Table 6. Number of BMES DTBR subtrack codes derived from students' topic submissions coded as a Device

DTBR Subtracks	2016 (topics = 39)		2017 (topics = 36)	
	No.	Percent	No.	Percent
Affordable Health Devices and Frugal Innovation			1	3%
Assistive Technology	5	12%	5	13%
Biosensors	4	9%	4	11%
Cardiovascular Devices	4	9%	3	8%
Design and Control of Prostheses and Exoskeletons	6	14%	4	11%
Implantable Devices and Implantable Electronics	8	19%	7	18%
Interventional Devices and Robotics	1	2%	1	3%
Implantable and Wearable Sensors			3	8%
Musculoskeletal Robotics and Biomechatronics in Rehabilitation				
Point of Care / Mobile Devices	2	5%	1	3%
Surgical Robotics	1	2%		
Translation of Devices from the Lab to the Clinic/Market				
Wearable Sensors and Devices	1	2%	1	3%
Other	10	23%	7	18%
Non-specified	1	2%	1	3%
Total	43		38	

Discussion

The research question for this study was concerned with the breadth of students' interest in the BME field as expressed through their proposed topics for a term paper. These interests are a snapshot in time that likely reflect not only actual interest but other mediating factors such as time in the semester, design of the assignment (e.g., references to devices in the wording of assignment), guidance provided by the instructor on topic selection, ease of access to literature on potential topics, current events, and personal experience. A few of these mediating factors will be touched on in this discussion of the results.

As can be seen in Table 5, the number of Device tracks for which at least one code was assigned changed from 10 in 2016 to 12 in 2017. The number of Non-Device tracks for which at least one code was assigned changed from 10 in 2016 to 9 in 2017. In Table 6, the number of DTBR subtracks for which at least one code was assigned changed from 9 to 10. Overall the number of tracks coded in students' topic proposals is not very different from 2016 to 2017. What is perhaps more interesting than the outright number of track and subtrack codes used is the popularity and the shifting popularity of some codes and the non-existent use of some codes.

Not surprising, in 2016, was the relatively high number of codes issued for topic proposals related to Stem Cell Engineering and Tissue Engineering (Table 5) and Prostheses (Table 6). Similarly, the Neural Engineering code was a common code in 2016 and was often related to topics concerning neural-prostheses interfaces. It has already been pointed out that these are topics highlighted in media defining biomedical engineering and are regularly discussed in the news. The shift away from these topics in 2017 can be explained by a concerted effort of the instructor to steer students away from these topics to eliminate topic redundancy and additional work on the part of the students to identify another topic. Cardiovascular Engineering was also a code used frequently in 2016 for topic proposals focused on things such as pacemakers, defibrillators, and stents. In 2017, Cancer Technologies was a code used more frequently than in the previous year. The popularity of cardiovascular- and cancer-related topics may relate to enjoyment of an activity in students' past, their personal connections to family members who have benefitted from these technologies, or their hope of inspiring others to find interest in the topic. One student stated in their proposal abstract, "My interest in stents stems from my fascination with the cardiovascular system. It started when I took anatomy and physiology in high school, where I loved learning about the cardiovascular system. We made a flip book outlining the flow of blood in the heart through all the different chambers, and that information is engrained in my head to this day." While another stated in their abstract, "This research is important to me. I have a family history of several cancers, and may someday get cancer myself. It is hoped that this paper will give the students in this class inspiration to work on improved radiation therapies and use their brilliance to create increasingly effective treatments."

In 2016 versus 2017, there were five versus one Device and eight versus two Non-Device proposals related to Biomedical Imaging. This difference in the number codes related to biomedical imaging may be explained by the different due dates for proposing topics or unconscious instructor influence. In 2016, the students had two lectures about Medical Imaging prior to proposing topics, while in 2017 the Medical Imaging lectures occurred after their topics were confirmed by the instructor. Additionally, in 2016, one of the co-instructor's was an expert in imaging research, while in 2017 there was only one instructor and her research focus was on nanotechnology and molecular/cellular engineering. Not surprisingly, when the instructor with more interest in nanotechnology and molecular/cellular engineering was the sole instructor in 2017, there were a few more proposed topics in the Cellular and Molecular Bioengineering area as well as the related area of Cancer Technologies. The instructor's passion for molecular and cellular engineering may have come through more in 2017 when she was teaching the course on her own. For example, during the 2017 'Sensors' lecture, and not during the 2016 lecture, the students participated in an in-class activity during which they determined the most important aspects of a molecular biosensor. The influence instructors have on students' career choices is a phenomenon that has been noted (e.g., [13]). When instructors connect course content to their own passions, perhaps students are more likely to attain the maintained situational interest phase described by Hidi and Renninger [9].

Respiratory Bioengineering and Biomanufacturing were two track codes that were never used. It is curious, with the abundance of advertising related to respiratory issues and drug delivery methods, that no topics were proposed in this category. Perhaps the fact that the class, and therefore the topics listed on the syllabus, did not cover respiratory issues is the reason that the students did not choose to look into these topics for their projects. As for Biomanufacturing, the subtracks for this category focus on issues of production at scale or scale-up. These are issues likely far removed from students' purview at the beginning of their studies in biomedical engineering.

Overall, the coding scheme based on the 2019 BMES tracks and subtracks was able to classify students' topics so that breadth of interests in a given semester and changes across semesters could be detected. That said, there were limits to the use of this coding scheme for sensing breadth and change in breadth in students' proposed topics.

Consider the large increase in the number of DTBR in 2017. Among these DTBR topics were those related to hearing aids, cochlear implants, and dental crowns. The coding scheme BMES tracks and subtracks were difficult to apply to topics related to the sensory organs (e.g., eyes, ears), skin, and teeth. Perhaps these topics are not commonly presented at BMES but rather at IEEE, so the conference tracks at other conferences might be useful to expand the coding scheme.

In addition, the coding scheme was limited in its ability to handle topics that lacked specificity or were less current technologies (e.g., a historical overview of in vitro fertilization). Topics related to mental illness and physical therapies were also difficult to code.

Implications and Future Work

The coding scheme, perhaps with some modifications to enable additional topics to be coded more easily, has potential to be used in a number of ways by instructors to broaden students' exposure to BME and monitor students' interest. The results of using the coding scheme also provides evidence for instructor reflection on their teaching practices. These two notions are discussed below along with future applications of the coding scheme.

To broaden students' exposure to BME, the coding scheme could be applied to students' proposals at the time they are submitted to ensure desired breadth in course coverage. Alternatively, the coding scheme could be provided to students and they could select a track.

The application of the coding scheme to students' proposed topics could also be used to guide the students to more specific topics early in the semester. Multiple students submitted final papers that were an overview of a topic and not an in depth look at a technology. This issue could actually be detected at the proposal stage because generic topics were difficult to code.

The scheme could be applied to students' responses to a number of assignments across the semester to track changes in interest. For instance, the instructor of the course in this study developed a short first-day-of-class survey which asked students what topics they would be interested in choosing for the term paper. By asking this question on day one, the instructor could more accurately assess students' interest in and breadth of understanding of BME prior to exposure to the course topics. Then, the instructor can consider the influence of course topics and instruction on students' (perhaps) more informed topics proposals later in the semester.

As for instructor reflection, the results of analyses conducted using this scheme can guide instructor's practices. As the results of this analysis emerged, the instructor began to consider her own biases that might have influenced students' proposed topics. She became aware that she advised the students to avoid focusing on her research areas since her in-depth knowledge of those areas would skew her interpretation of the term papers that the students submitted. Because of this advice, there were no proposals on carbon nanotubes or sensors for cellular signaling, and very few proposals dealing with any aspect of nanotechnology or cholesterol altering drugs/technologies. After consideration of the impact of this advice on students' proposals, the instructor has elected to not make this suggestion in the future.

The results of this analysis also led to informed changes in the logistics and instructions for the project. First, students are now given more time, and therefore more class periods, before they are required to propose topics. By postponing the date for which the students must choose their topic, they are exposed to more aspects of BME. Second, the assignment text was changed to make it clear to students that they need to focus on a technology or device and not perform a subject overview. The assignment was altered to increase specificity, and examples of points and questions that the students need to address were provided.

Finally, the coding scheme developed in this study could be applied in a number of settings to manage, monitor, or investigate students' understanding of the breadth of BME. At a minimum, the code scheme could be applied to students' responses to a number of activities across a course with the intention of guiding students' exposure to the lesser known sub-disciplines within BME. Within a BME program, this coding scheme could be applied across a number of activities in a number different courses to monitor change in students' understanding of the breadth of BME and ultimately inform curricular change to enhance greater exposure. To make broader claims about the breadth of BME understanding, particularly for those demographic segments that may have less access to learning about BME, the code scheme could be used as the basis for designing a quantitative questionnaire that could assess awareness of or interest in BME, much like existing career interest instruments. Such an instrument, with appropriate validity evidence, could be administered to a larger, more diverse cross section of students (beyond the course setting and university in this study). Results could inform the development of K-12, undergraduate, and other public learning opportunities to raise awareness of the various facets of BME. Further, similar coding schemes could be developed for other engineering majors based on their professional societies' meeting topics; such coding schemes may have the potential to impact students' exposure to the breadth of the a given engineering field through intentional design of course assignments and curricula as well as other programming.

Conclusion

The intention of this study was to develop a coding scheme to classify and monitor students' biomedical engineering interests and demonstrate how it could be used in a particular context to gather base-line data to which future classroom interventions to expand students' interest and understanding might be compared. The Biomedical Engineering Society's (BMES) 2019 Annual Meeting paper tracks were selected as an a priori coding scheme. The scheme was applied to students' proposed term paper topics in a junior level introductory BME course in an embedded BME program. Overall, this coding scheme was found to be sufficient for the instructor to understand the breadth of BME field coverage in a given course deployment of the term paper assignment. The results gained from using this coding scheme in a given setting could enable instructors to make decisions to improve the course assignments and course design in future course offerings or make programmatic-level decisions concerning exposure to the breadth of BME across the curriculum.

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