Biomedical Research 2019; 30

ISSN 0970-938X
www.biomedres.info

Design, implementation, and evaluation of an introductory biomedical engineering course.

Areen K Al-Bashir*, Ruba E Khnouf, Enas W Abdulhay

Biomedical Engineering Department, Jordan University of Science and Technology, P. O. Box 3030, Irbid, Jordan

Abstract

This paper presents the design and implementation of an introductory course in Biomedical Engineering at the undergraduate level. The course was structured to give a brief introduction of all biomedical engineering knowledge areas, the bioethics that each biomedical engineer should have, and the technical writing skills the students need during their education or after graduation. The course design relied on the backward by design theory. After assessing course results; the students showed a better understanding to the meaning of biomedical engineering when comparing their opening versus closing surveys, and also had relatively good grades. The faculty members also pointed out the students' enhanced technical skills compared to previous students who did not take the course. The course with this design helped the students to receive an early understanding of biomedical engineering multidisciplinary nature with adequate ethical and technical communication skills. The course can be implemented to any other BME departments.

Keywords: Biomedical engineering, Introduction, Backward by design. **Abbreviations:** ABET: Accreditation Board for Engineering and Technology; BME: Biomedical Engineering; CAF: Course assessment by faculty; CAS: Course assessment by student; JUST: Jordan University of Sciences and Technology; OS: Opening Survey; CS: Closing Survey.

Accepted on February 12, 2019

Introduction

Biomedical engineering (BME) is one of the new fast-growing fields in applied sciences, where it has impacted medicine and the health care industry in a revolutionary manner by providing highly technical solutions and applying engineering to solving medical problems. BME includes a variety of fields such as biomechanics, biomaterials, tissue engineering, rehabilitation engineering, medical sensors, digital signal and image processing, medical imaging, etc. It provides tools for medical diagnosis and treatment, which explore wide research venues. This diversity makes it a challenging area of knowledge to both teaching and learning, where a biomedical engineer needs to master a wide range of engineering concepts and biomedical sciences.

Biomedical engineering education has started in 1959, when Drexel University in Philadelphia, PA, USA launched its master's program in BME. This program was later followed with other programs at the bachelor, master and PhD levels offered by 121 schools in the United states according to a survey collected in the early months of 1974 [1]. Due to this rapid increase in the number of BME programs, IEEE Transactions on Biomedical Engineering published a special issue on Biomedical Engineering Education and Employment [2-12]. The issue included 13 papers that discussed biomedical engineering curricula and how they can be tailored and implemented to emphasize the role of Biomedical Engineering in society and to help health care providers in planning for good health care delivery. Nevertheless, the issue's papers also focused on the biomedical engineer's contribution to Biomedical Engineering applications more than research. This issue was soon followed by many other studies, surveys and the foundation of new organizing committees to cope with BME programs' student enrolment, courses, degrees awarded, and employment. The goal of these studies was to assess the differences between many BME programs and to quantify the reduction in the engineering course work due to the inclusion of life science courses, and if this inclusion was sufficient. Programs from different academic institutions vary in their academic content and focus and cover different biomedical tracks as mentioned above. BME programs reached 704 programs around the world in 2010 [13,14]. These variations created the need to develop new BME curricula to produce innovative biomedical engineers to match the rapid advances in the field.

The Accreditation Board for Engineering and Technology (ABET) which was founded in 1932, started reviewing BME departments' curricula since early 1970 [15]. The first accredited undergraduate BME program was the BME program in Duke University in Septmber1972. Where at that time there was about 24 such programs around the world [15].

The Biomedical Engineering program at the bachelor level at Jordan University of Science and Technology (JUST) was launched in 1998 to serve the region with highly skilled, well equipped biomedical engineers with a solid engineering education and sufficient biomedical science knowledge. The Biomedical Engineering program at JUST was granted its ABET accreditation in 2007 [16]. In order to maintain its graduates with up to date technology, the BME department at JUST keeps upgrading its curriculum to cope with the new advances in the field along with the market's needs to have graduates who have a strong theoretical background along with some laboratory and field experience. Therefore, the BME department at JUST started a regular upgrade of its study plan every 5 years.

One of the most important additions to the 2013 BME study plan was the implementation of the "Introduction to Biomedical Engineering" course (BME 201). After reviewing the curriculum of most of the top schools who have undergraduate BME programs, we found that some of these schools are offering an introductory course for biomedical engineering. The introduction to bioengineering course at Massachusetts institute of Technology (MIT), USA, covers the science basis of bioengineering. The course lectures focused more on molecular cell biology and systems biology and research conducted by faculty members [17]. Another school offering a BME introduction course is the North Western University at Evanston, IL, USA. Their course is a zero credit course that covers different biomedical engineering fields of knowledge but it did not include the communication skills needed by the students [18]. The introductory course at the University of Florida also covers different biomedical engineering fields with no focus on the required communication skills and no clear evidence for team work implementation [19]. Therefore, we defined our main objectives of this second year level course to a) increase the students' understanding of biomedical engineering and its different fields of knowledge, and b) introduce them to the available career opportunities, in addition to c) introducing them to technical communication skills and subjecting them to ethical dilemmas they might face in and out of academia.

In order to achieve these pre-stated objectives of our biomedical engineering introductory course; we relied on the backward by design method in which the teacher needs to predefine the course's objectives and expected results, determine the acceptable level of student understanding of the course and then design a list of assessment tools to measure students' achievements of the predefined course objectives and expected results [20]. Accordingly, this paper will discuss the introduction to Biomedical engineering course objectives and expected results then the structure and implementation along with the course's acceptable understanding level to pass. Finally, the paper will cover the assessment tools designed to measure students' understanding level.

Material and Methods

Course design (Developmental phase)

Usually the admitted biomedical engineering students are highly scored high school graduates with a lack of knowledge of what biomedical engineering is and what biomedical engineers do. At the sometime, the BME students did not encounter any specialized biomedical engineering course until they reached the 4th year of the study program, which caused the students to feel misguided and uncertain about the purpose of the courses they have taken in their first 3 years of college. This has increased the need to clarify the meaning and the wide applications of biomedical engineering.

The introduction to biomedical engineering course (BME 201) was designed to be offered in the first semester of the 2nd year of the curriculum. The course was designed to achieve four main objectives: 1) increase the students' understanding of Biomedical engineering 2) introduce the students to the different fields of biomedical engineering and the wide range of employment opportunities available. 3) initiate the professional technical communications skills and 4) clarify career ethics in both the work place and the academic field (Figure 1). The course was offered for the first time in the fall semester of the 2014/ 2015 academic year.

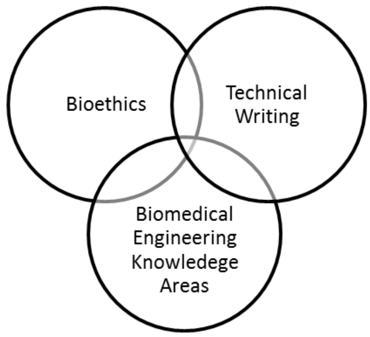

***Figure** 1. Introduction to biomedical engineering course 3-main topics.*

Course structure

In structuring the course, as mentioned in the introduction, we relied on the Backward Design method where we first defined our course objectives and desired results, then we chose our assessment tools to measure the acceptable level of students' understanding and achievement of stated objectives. Lastly, we designed a list of tasks and deliverables to achieve these objectives and desired results (Table 1).

Course objectives: The expected enrolled students in the introduction to biomedical engineering course are 2nd year BME students, who only took the college of engineering requirement courses, these courses only focused on physics, math, chemistry and biology. These students came with different personal skills in terms of reading, writing, listening. Based on that, we set our desired results and expected outcomes from enrolment in this course which include: encouraging the students to be active learners, teach them how to tackle any problems and how to look for the required information needed in solving any problem by using the available resources in the university, enhancing the reading and writing skills that we think will help them in job hunting, understanding biomedical engineering ethics and how to implement them in their career. Furthermore, being an active member within the team by exploring its advantages and challenges, this would help teach them professional socialization.

Course acceptable level of understanding: our course objectives were mapped to a number of expected results (i.e. course outcomes). Our course outcomes are shown in appendix a. passing the course's expected results or in other words course outcomes is the predetermined acceptable level of student understanding for this course.

Course assessment tools: In order to ensure achieving these desired results, passing the course is a required prerequisite for other department courses. Therefore, a list of students' deliverables and course assessment tools that would help measure the acceptable level of students' course understanding were designed and the course grades were distributed based on the given lectures.

Table 1. *Introduction to biomedical engineering course backward design.*

Identify the course objectives and results	Acceptable understanding level	Learning experience and instruction
1. Introduced students to the field of biomedical engineering and the wide range of employment opportunities available.	Passing the course outcomes*	A list of deliverables and exams were designed to measure the acceptable level of understanding.
2. Introduced students to the variety of fields and specialties in biomedical engineering		
3. Understand Biomedical Engineering Ethics		
4. Learn the basic tools for technical communication skills		
5. Encourage lifelong learning, foster teamwork		

*The course objectives and outcomes mapped to the program outcomes are in appendix a.

Course implementation

The Introduction to biomedical engineering course is a 3 credit hour (3 hours lecture weekly, preferred to be given twice a week (i.e. 1.5 hours, twice a week). The semester is 15 weeks long. Every week the course covers a lecture on a different topic in Biomedical Engineering and the other lecture of the same week is designed to introduce the students to a technical communications skill and some biomedical ethical issues (Table 2).

The course is a department centered course in the sense that each department member will be responsible to give one lecture to introduce his/her field of expertise. This is supposed to help introduce all the department members and the department research areas to the students.

Table 2. *Introduction to biomedical engineering course implementation.*

Week#	BME topics	Technical communications
1	Biomedical engineering	CV writing
2	Biosensor	Cover letter
3	Bio-instrumentation	Journal paper
4	Biomaterial	Ethics
5	Imaging systems	Referencing and citation.
6	Tissue engineering	1st exam
7	Rehabilitation engineering	Report writing 1
8	Nanotechnology	Report writing 2
9	Biomechanics	Ethics
10	Signal processing	Oral presentation
11	Physiological modeling	2nd exam
12	Regulations and FDA process	Posters
13	Frontiers in biomedical engineering	Group presentation
14	Group presentation	Group presentation
15	Group posters	

The technical writing part of the course includes introducing the students to the meaning, the goals, the styles, the content and some good and bad examples of the Curriculum Vitae (CV), cover letter, journal papers, problem statements, report writing, presentation and academic posters.

In the bioethical part of the course, we introduce the students to ethical practices in engineering, citation and referencing, ethics in practice and research, and considerations for clinical engineers. The ethics lecture includes some bioethical case studies and discussions.

Team work implementation: To implement engineering problem solving and team work; the students were asked to form a number of teams in the first week of the semester. Each team consists of ~7 students. The teams were also asked to form a virtual biomedical engineering company with an up-to-date topic of interest. The selected topic was discussed with the course instructor. After confirming the topic by both the course instructor and the team members; each team starts working on their project according to the following project plan:

1. All the companies introduced by the students have a specific well defined structure (Figure 2). All students need to understand the job description for each position, and each team member needs to apply to a specific job title in the company, and tailor a cover letter and a CV that matches the selected job opportunity he/she wants to apply for.

2. After accepting their applications; each team needs to define the problem that they will work on, and provide a written problem statement.

3. A number of journal papers related to each topic should be reviewed, and the team should revisit their problem statement, and start to write their suggested proposal.

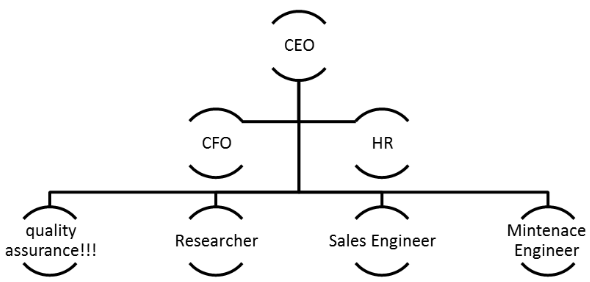

Figure 2. The Biomedical company organization for BME 201 course project.

During this time; and according to the lecture schedule in Table 2, faculty members cover different biomedical engineering topics specific to their research areas. This is meant to introduce the students to different BME areas of knowledge and to know who they can ask in case they have specific questions regarding their companies' pre-selected topic. After finishing all the lectures on different BME fields of knowledge as listed in the course description; the students are taught how to write a technical report, to present a scientific presentation, and to prepare an academic poster.

Ethics lectures are given to the students after the technical writing lectures, and need to be applied to their reports, presentations and posters when needed. Group meetings will take place at least once a week, therefore, every group will catch up with all members' wok; gather it, discuss it and assign new tasks for all members for the week after.

4. A technical report needs to be submitted at least 4 weeks before the end of the semester. The technical report will have the following format: abstract, introduction, procedure, results, discussion, conclusions and recommendations.

5. The team needs to present their work to the other teams in the class and should show willingness to answer the class's questions: the abstract along with presentations schedule of all submitted reports will be posted online to all students enrolled in the course. For any team presentation; other students from other teams are required to read the presenters' abstract and form questions about it. The reason behind asking the students to read the abstract is to facilitate their understanding of the presented topic and enrich the presentation with valuable questions. Each presentation is 30 minutes long with 10 minutes for questions.

6. Finally, in the last lecture, every team is required to prepare a poster presentation of their work and present it to the department's academic members and student.

Figure 3 summarizes the course work flow during the semester. This format of the course project is supposed to: Introduce the students to different job categories a biomedical engineer might encounter after graduating, teach the students team work, teach technical writing skills, and address any ethical issue the students may encounter.

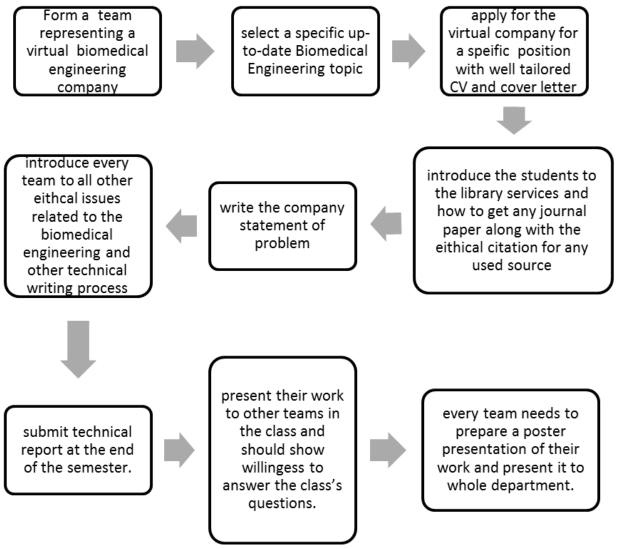

Figure 3. The introduction to biomedical engineering course work flowchart.

Course assessment

Several methods were followed to evaluate the acceptable level of students' understanding of the course material. This includes distributing the course grades on the list of deliverables as well as the course exams. Other course assessment tools were the course opening and closing surveys and the department ABET course assessment by the students (CAS) and course assessment by the faculty (CAF), plus graduating class assessment survey.

Course opening and closing surveys: To quantify the course outcomes and desired results; a survey was distributed to the students twice. One at the first lecture of the course and the other one in the last lecture of the course (Figure 4). The survey was structured to reflect the students' reasons behind choosing BME as their major as well as their understanding of BME meaning along with its different fields of knowledge before and after taking the course.

Metric	
1. Do you know what Biomedical Engineering is?	a. Yes b. NO c. Not Sure
2. Are you familiar with the courses you have to take?	a. Yes b. No c. Some of the courses
3. Are you happy with your major so far?	a. Yes b. No
4. Was Biomedical Engineering your first choice of major?	a. Yes b. No
5. Would you change your major if you had a chance to?	a. Yes b. No

Figure 4. The BME 2013 class survey.

Course grading: students were asked, as mentioned above, to write a CV, cover letter, a journal papers summary, problem statement, and a technical report, and to prepare and present a presentation and academic poster. Furthermore, students were given short quizzes and exams on different biomedical engineering topics and biomedical engineering ethical issues. The grades were carefully distributed to measure the students' performance in every task they have to do during the semester. Table 3 shows the grade distributions.

Table 3. Table of deliverables and exams with its grades distribution totalling a hundred points.

Assessment tool	Weight
Quizzes	10
CV	5
Cover letter	5
Paper summarizes	5
Statement of problem	5
Proposal	5
Report	10
Presentation	10
Posters	5
1st and 2nd exam	20
Final exam	20

ABET course assessment by the faculty (CAF): the BME department at JUST have a number of outcomes that each student should pass in order to graduate. Therefore, every course offered by the department should match some or most of the program outcomes; Table 4 shows the program outcomes. Course assessment by the faculty (CAF) measures to what extent should the course address the outcome. In other words, the number of points that should be assigned to of the course intended outcomes. For example, if the outcome X is not essential in the course, it should be assigned a smaller number of points compared to outcome Y because the content focuses on Y concepts [21].

Table 4. Identified and adopted program outcomes of the biomedical engineering program at JUST.

Program outcome	Definition
A	Graduates must have the ability to apply knowledge of mathematics, science and engineering.
B	Graduates must have the ability to design and conduct experiments, as well as to analyse and interpret data.
C	Graduates must have the ability to design a system, its components or processes to meet the desired needs.
D	Graduates must have the ability to function within multi-disciplinary teams.
E	Graduates must have the ability to identify, formulate, and solve engineering problems.
F	Graduates must have an understanding of professional and ethical responsibilities.
G	Graduates must have the ability to communicate effectively.
H	Graduates must have the broad education necessary for understanding the impact of engineering solutions in a global and societal context.
I	Graduates must recognize the need for, and the ability to engage in, life-long learning.
J	Graduates must have knowledge of contemporary issues.
K	Graduates must have an ability to use the techniques, skills, and modern engineering tools necessary for engineering practices.
L	Graduates must demonstrate adequate knowledge of biology, physiology, and the capability of applying advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology.
M	Graduates must demonstrate an ability to make measurements on, and interpret data from, living systems, addressing the problems associated with the interaction between living and non-living materials and systems.

Results

The results from all course assessment tools were collected over the 4 times the course was offered. Figure 5 below shows the students response to the survey questions before and after taking the course. The results were normalized to the number of the students attending the lecture when the survey was distributed.

Figure 6 shows students' grades for two semesters; Fall 2015, and Fall 2016 respectively. Note that the students get higher grades in the HW (i.e. list of deliverable) compared to the course theoretical part (theoretical exams and quizzes).

The last method used to evaluate the output of our introductory course was CAF analysis. In Figure 7, the instructor checks if he/she was successful in using the tools (assessing the student performance by the course activities such as exams, HWs, quizzes, projects, etc.) with the same weights as the intended CAF for course outcomes. The tool value is the highest number of points assigned for the outcome based on the exams and activities. The tool should therefore be as close as possible from CAF. A maximum of 30% deviation is accepted. The course assessment program checks also if the class has satisfactorily passed each outcome. A passing mark would be achieved when at least 60% of students (or overall average) score 60% mark or better based on Tools used. In other words, (Score/tools) should be higher than 60% in order to say that the outcome is met. If the value is less than 60% then a WARNING is displayed as in Figure 7 [21].

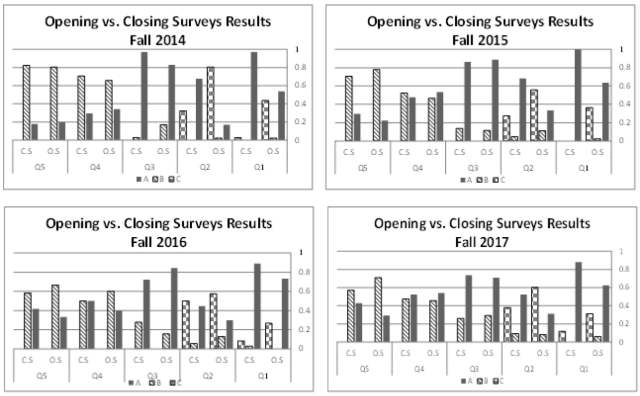

Figure 5. Students response to the survey questions before and after taking the course. OS: Opening survey; CS: Closing survey.

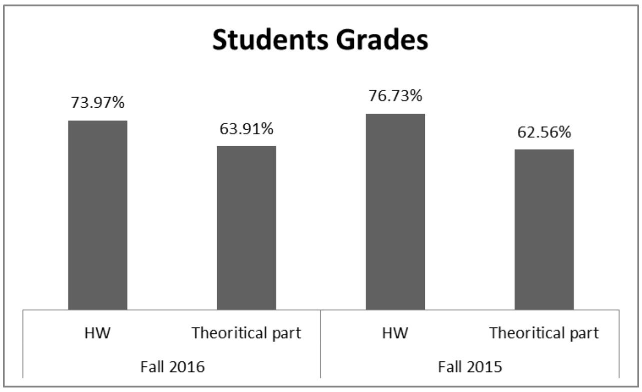

Figure 6. Comparison of students' average grades between the theoretical part of the course compared to the HW assigned during the semester.

Discussion

Undergraduate programs in biomedical engineering are relatively new programs with a special challenge namely integrating engineering concepts in medical and biological applications and in coping with the rapid development in health care systems and industrial technology. There is not enough literature that discusses the educational curricula of biomedical engineering at the undergraduate level. Therefore, in our new study plan we proposed the inclusion of the introduction to biomedical engineering course in order to help the students to fathom the meaning of its multi-disciplinary nature, as well as, gaining technical communication skills to facilitate their work for the coming course and their future work. To quantify the course's outcomes many assessment tools where applied, including the course opening and closing surveys, course grading and course assessment by the faculty member who teach the course. Comparing the results from the course opening survey to that obtained from course closing survey, as shown in Figure 5, we noticed that the course has increased the students' knowledge in the meaning of BME and the upcoming courses, made them more satisfied about choosing it as their major. The student response was almost the same over the 4 times the course was given.

BME-201		3		
Introduction to Biomedical Engineering				
Program Outcome[1]	CAF	Tool	Score	Comment
A	3.57	6.36	4.79	Warn
B	3.57	3.61	2.64	O.K.
C	3.57	3.61	2.64	O.K.
D	14.29	10.29	7.85	Warn
E	3.57	6.36	4.79	Warn
F	14.29	13.56	9.81	Warn
G	14.29	13.58	10.07	O.K.
H	10.71	12.23	8.81	O.K.
I	10.71	10.49	7.85	O.K.
J	10.71	9.08	6.69	Warn
K	3.57	3.61	2.64	O.K.
L	3.57	3.61	2.64	O.K.
M	3.57	3.61	2.64	O.K.
N	0.00	0.00	0.00	N/A
O	0.00	0.00	0.00	N/A
Sum	100.0	100.0	73.9	

Figure 7. The course assessment by faculty (CAF) results for the introduction to biomedical engineering course.

Looking through the second assessments tools, students' grades, the grades were relatively good for most students, however, after taking a closer look into the obtained results; we noticed better performance in course HW rather than their theoretical part through the course exams and quizzes. These results came in agreement with our pre-stated objectives where we focused on enhancing the students' technical communications skills and team work Compared to other introduction to Biomedical Engineering courses offered by other schools [17-19].

Moreover, based on the CAF results shown Figure 7, we noticed that CAF and TOOL assessments are close to each other within a max 30% deviation for program outcomes B, C, G, H, I, K, L, and M, which implies that the activities of the course covers very well theses intended program outcomes. However, for program outcomes A, D, E, F, and J the CAF and TOOL deviation exceed the 30% accordingly the course instructor should improve the activity and provided material related to these outcomes. To measure the students' understandings of each program outcomes related to this course we compared their scores with the required percent of the students passing the course (i.e. 60%* Tool) [21]. Interestingly, the students' scores in all program outcomes related to the course was higher than 60%* Tool. This implies that the students achieve very well the intended program outcomes through taking this course. These results from the three designed assessment showed that the students achieved a good understanding level of the course objectives.

To assure the course long term advantages on the students for the next four years after taking the course; another survey was distributed to the graduating students who took the course when it was first introduced, see appendix b. The survey was constructed to evaluate the students' technical skills and their feedback about the course in general. Figure 8 below shows the results for 49 students. As expected the survey showed agreement from the students that the course enhanced their writing, presentation, resource search and introduce them to job hunting skills, it help them also in choosing their BME focus track and knowing their future professors and their field of research.

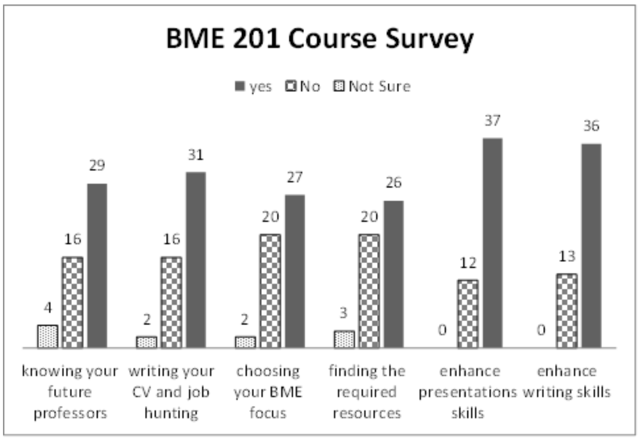

Figure 8. *Graduating students survey results.*

Also the students were asked about what part of the course they benefit from more. 24 students found the technical communication part is more useful whereas 17 students found the different BME fields of knowledge is more useful and 7 students found the ethical part is more useful. This distribution came in agreement with the lecture weight for each of the 3 parts the course involved.

Finally, faculty members of the department were asked about their experience with students who had taken the course, they were also asked to compare students who have taken the course as part of the new curriculum with students who had not taken it and were studying the old curriculum. Most faculty members, especially those who have taught classes requiring technical communication skills, reported that they have clearly noticed improvements in the students writing, formatting and presentation. Furthermore, the faculty noticed that the student's' confidence and presence when presenting was drastically enhanced which is probably a result of them having gone through the experience of team work and oral presentation.

Conclusion

The paper presented here includes a structure and design along with implementation for an introductory course to the relatively new education field of biomedical engineering. Based on the description and the results obtained; the course with this content and method of implementation helped the students as well as the faculty members in the BME department. For the students it helps them in enhancing their understanding of the multidisciplinary nature of BME at early year during their undergraduate studies, improved their technical communication skills, rational understand of their study plan in terms of the upcoming courses and the time scheduled of it. Nevertheless, it helps them to know each other through the implemented team work. On the other hand, it helped the students to plan ahead for their graduation project and know the faculty member who can help them the best in their project according to the faculty member research line. For the faculty members; the course helped in introducing the students to different BME field of knowledge helped in better selecting the different offered BME elective courses and graduation projects ideas which as results enhanced their results in these courses and better output for the graduation projects. Finally, we recommend implementing this course at other BME departments.

Compliance with Ethical Standards

Declarations

No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The datasets used and/or analysed during the current study available from the corresponding author upon request.

Acknowledgement

The authors of the work would like to thank the course TAs.

Authors' contributions

AA and RK contributed to the concept design and implementation, drafting and approval of the manuscript. EA contributed to the numerical analysis of collected results.

Ethics approval and consent to participate

The assessment process has been approved by J.U.S.T BME Department. The students and faculty members, who participated, signed the collective consent form list.

Consent for publication

All authors read and approved the final manuscript.

References

1. Requena-Carrion J, Leder RS, Beebe M, Geselowitz M. The educational value of teaching biomedical engineering history. Conf Proc Annu Int Conf IEEE Eng Med Biol Soc 2010; 2010; 316-318.
2. Schwartz MD, Long FM. A survey analysis of biomedical engineering education. IEEE Trans Biomed Eng 1975; 22: 119-124.
3. Cox JR, Pfeiffer RR, Pickard WF. Experience with a training program in technology in health care. IEEE Trans Biomed Eng 1975; 22: 129-133.
4. Detwiler JS, Sanderson AC, Vas R. A clinically oriented bioengineering program for undergraduates. IEEE Trans Biomed Eng 1975; 22: 140-144.
5. Harmon LD. Biomedical engineering education: how to do what, with which, and to whom? IEEE Trans Biomed Eng 1975; 22: 89-94.
6. Moritz WE, Huntsman LL. A collaborative approach to bioengineering education. IEEE Trans Biomed Eng 1975; 22: 124-129.
7. Torzyn NT, McKinney WD, Abbott ELJ, Cook AM, Gillott DH. Biomedical engineering program to upgrade biomedical equipment technicians. IEEE Trans Biomed Eng 1975; 22: 145-147.
8. Jacobs JE. The biomedical engineering quandary. IEEE Trans Biomed Eng 1975; 22: 100-106.
9. Weed HR. Biomedical engineering-practice or research? IEEE Trans Biomed Eng 1975; 22: 110-114.
10. Kahn AR. Biomedical engineering education for employment by industry. IEEE Trans Biomed Eng 1975; 22: 147-149.
11. Brown JH. The biomedical engineer and the health care system. IEEE Trans Biomed Eng 1975; 22: 95-100.
12. Peura RA, Boyd JR, Shahnarian A, Driscoll WG, Wheeler HB. Organization and function of a hospital biomedical engineering internship program. IEEE Trans Biomed Eng 1975; 22: 134-140.
13. Ziad OAF. Handbook of Research on Biomedical Engineering Education and Advanced Bioengineering Learning. Interdisciplinary Concepts 2012; 59.
14. Valentinuzzi ME. 50 years a biomedical engineer remembering a long and fascinating journey. Biomed Eng Online 2012; 11: 1.
15. Hart RT. Biomedical engineering accredited undergraduate programs: 4 decades of growth. Ann Biomed Eng 2015; 43: 1713-1715.
16. ABET Accreditation 2007. Available: http: //www.just.edu.jo/FacultiesandDepartments/FacultyofEngineering/Departments/BiomedicalEngineering/Pages/ABET.aspx.
17. M. I. of T. Biological Engineering Department, Introduction to Bioengineering (BE.010J). Available: https: //ocw.mit.edu/courses/biological-engineering/20-010j-introduction-to-bioengineering-be-010j-spring-2006/.
18. N. U. Biomedical Engineering Department, McCormick School of Engineering, BME 101: introduction to biomedical engineering. Available: http: //www.mccormick.northwestern.edu/biomedical/courses/descriptions/101.html.
19. Crayton Pruitt Family J. Introduction to biomedical engineering. Available at https://www.eng.ufl.edu/academics/schools-departments/bme/
20. Wiggins G, McTighe J. Understanding by design (2nd Edn.). Association for Supervision and Curriculum Development 2005.
21. Abdulhay E, Khnouf R, Haddad S, Al-Bashir A. Improvement of medical content in the curriculum of biomedical engineering based on assessment of students outcomes. BMC Med Educ 2017; 17: 1-22.

*Correspondence to

Areen K. Al-Bashir

Biomedical Engineering Department

Jordan University of Science and Technology

Jordan