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USE OF INSTANT QUESTIONNAIRES IN LECTURES AND A WORKSHOP DEVELOPED AT INTENSIVE CARE UNIT AS TEACHING INNOVATIONS IN BIOMEDICAL ENGINEERING

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Abstract: Biomedical engineering degree provides ideal training for new professionals capable of designing and managing the next generation of medical devices to improve healthcare. A solid interaction between future engineers and physicians to achieve adequate care for patients requires continuous and personal communication to facilitate proper learning. After the pandemic and returning to the classroom, the most common problems identified by faculty in higher education were low attendance and lack of student interest due to the difficulty in applying the knowledge acquired in lectures in a practical way. In order to improve this situation, this paper describes a teaching innovation implemented in the Physiology module of the Biomedical Engineering degree. Through the use of ICTs, such as multiple-choice questionnaires that provide instant results, and the implementation of teaching workshops in the hospital, where trainees can observe and interact with technological devices applied to real patients, student learning was enhanced. The use of instant questionnaires resulted in a significant improvement in the academic performance of students who completed more than 50% of these questionnaires and an attendance rate of 73% of the total students. The effectiveness of the teaching workshop in motivating the students was evaluated using anonymous surveys with five-point Likert scales and free text opinions. Regarding this evaluation, all students surveyed were satisfied (6%) or very satisfied (94%) with the implementation of this activity and its application in their studies. In summary, these teaching innovations have increased class attendance and student motivation, promoted knowledge acquisition, developed communication skills, and enhanced thinking skills. **NEW & NOTEWORTHY:** Developing teaching methods that facilitate learning and build students' confidence and thinking

skills is a priority. In this study, instant questionnaires and a workshop developed in the intensive care unit were used to improve the work of the teacher and the learning of the biomedical engineering students. The results showed increased class attendance, improved grades, and a greater appreciation of the relationship between theory and practice in those students who participated in both teaching innovations.
Keywords: ICT, intensive care unit, learning integration, physiology, teching innovation.

INTRODUCTION

The arrival in medicine of technologies such as robotics (1), 3D printing (2), virtual reality and artificial intelligence (3) requires new professionals capable of designing, installing and managing the next generation of medical devices to ensure the best quality of care with maximum safety for the patient. The Biomedical Engineering degree (BED) provides the ideal training for this profile through a solid foundation in engineering and industrial electronics, complemented by specific content in biology, human anatomy and physiology, biomechanics, biomaterials, and biosignal processing (4).

Although the pandemic brought the use of technology in education to the forefront (5), we are now returning to a hybrid format that combines face-to-face teaching with information and communication technologies (ICT). In the wake of this health crisis, we must value face-to-face teaching as a tool that enriches the learning process of students and helps them socialize (6). One of the problems currently identified by teachers in higher education upon returning to the classroom is the scarce presence in the classroom and, sometimes, the lack of attention and interest on the part of the students. Attention allows us to take in information, and our working memory helps the brain to make sense of it (7). To improve these two aspects, this paper describes a teaching innovation in which both teacher action and student learning were enhanced using ICT. We used Instant Multiple Choice Questionnaires (IM-CQ) as a tool that allows us to carry out assessments in digital environments and gives teachers the possibility to know the results immediately.

On the other hand, one of the aspects that most concerns students, especially freshmen, and can demotivate them to the point of abandoning their studies, is not clearly seeing the practical applications of the knowledge they are acquiring (8). In our case, biomedical engineers (BE) oversee the design and development of devices and products used in the medical field. Basic and advanced knowledge and management of these systems are essential for the daily care of critically ill patients. Using these systems is not an easy task. Therefore, the technology industry needs to provide adequate training for healthcare professionals. Biomedical engineers play a key role in the acquisition of knowledge about new patient monitoring and life support systems. In this way, an adequate relationship between BE and healthcare professionals is necessary to achieve full development of the daily activity and to take advantage of the technological innovation that enables better patient care. The need to teach students the real applications of the knowledge they acquire in their studies and a closer collaboration between BE and health professionals has led to the establishment of a collaboration between the Santa Lucía General University Hospital (Cartagena, Spain) and the BED recently implemented in the School of Industrial Engineering (ETSII) of the Polytechnic University of Cartagena (UPCT), Spain. The objective was to establish a feedback of knowledge in both fields that will lead to an increase in the capabilities of professionals to achieve future

advances that improve the welfare of people. Therefore, we designed the second part of this teaching innovation: the implementation of an Intensive Care Unit (ICU) Teaching Workshop (TW) on the technological systems used in this unit, taught by a specialist in intensive care medicine. In this three-hour session, students learned about the different devices used daily in an ICU and were able to see how they worked on real patients. The effectiveness of this integrated session was evaluated by collecting student feedback through satisfaction surveys.

By introducing the IM-CQ in our classes, we wanted to promote several aspects, such as increasing the presence and motivation of students in the classroom, promoting their self-learning skills, and improving their attention by focusing more on the teacher's explanations in order to complete the subsequent questionnaire satisfactorily. The ICU-TW in our study tried to achieve different objectives, such as us implementing the training of students with more specific clinical knowledge, to familiarize the trainees with the equipment routinely used in the ICU, as work on real patients and highlight the current technical limitations of these devices, to teach the students what are the real applications of the knowledge they will acquire in BED. In addition, we tried to establish knowledge feedback between physicians and BE trainees.

MATERIAL AND METHODS

The instructional innovations described in this study were delivered to a group of 33 undergraduate students enrolled in the Human Anatomy and Physiology module in their second year of BED. Students were asked to participate on an opt-out basis, and all data were anonymized. In addition, trainees attending the ICU-TW provided signed confidentiality forms to ensure patient privacy.

IMMEDIATE MULTIPLE-CHOICE QUESTIONNAIRES

The digital tool Socrative (9), developed in the United States in 2010, was chosen to implement the questionnaires. It is a tool that allows evaluations to be carried out in digital environments and offers teachers the possibility of knowing the results immediately. It can be used on the web or downloaded to a computer, tablet or smartphone. Socrative greatly facilitates the work of teachers in the area of evaluation, since it allows them to create questionnaires in a simple and attractive way for students. It is very useful because of the immediacy of receiving the test results, generating Excel documents where the results of our students are reflected individually. This method implies an important time reduction in correcting tests. It is also free and easy to use. To start using Socrative, the teacher needs to create a "room" for the class, including up to 50 students in each class. Students will then need to access the room by clicking on "Student Login": they will only need the name of the room that the teacher has previously created. Once logged in, they will be able to participate in all the activities launched by the teacher until they log out. Among the different activities available in the app (Quiz, Space Race (quiz with countdown) or Exit Ticket (quiz with scoring)), we chose Quiz. The type of answers also offered us different options (Multiple Choice, True or False and Short Answer), choosing Multiple Choice in our case. Using this digital tool, after each theoretical session, questionnaires of 10-17 multiple-choice questions were directly related to the content of the theoretical session taught. These questionnaires were completed exclusively in class and represented 10% of the final grade of the course. Because of the exclusivity of the classroom and the incentive of the score in the final grade, we hope that students will be more motivated to

attend class. The search for answers to these questions allows the students to explore their previous ideas, synthesize them and transfer the acquired knowledge to new situations, favoring the interaction between these ideas and the new knowledge they acquire, a necessary condition for their learning process. To familiarize the students with the content of the course, the presentations were available in advance through the virtual classroom. To assess the influence of IQ-MC on student attendance and grades, we calculated the percentage of attendance and compared the final grades of students who completed more than half of the questionnaires (>50%) and students who completed less than half of the questionnaires (<50%). Data are expressed as mean ± SE.

ICU TEACHING WORKSHOP

This teaching innovation was carried out in the ICU of the General University Hospital of Santa Lucía. This unit was chosen because it is a demonstration of the technological advances achieved in recent years in patient care, and because the severity of the disease presented by the users requires updated and effective technology (10). For these reasons, this unit was the most appropriate for the work to be performed by the future BE. ICU physicians and physiology faculty members collaborated to design a new TW in which students would see firsthand the various devices used in the service and how they work with real patients. The students were introduced to the different devices and concepts in a fractional manner (six students per session): monitoring of basic patient constants, invasive/non-invasive hemodynamic monitoring, monitoring of analgesia and sedation of critically ill patients, invasive/non-invasive respiratory support, and electrical therapies such as pacemakers and defibrillators. The 180-minute session focused on their technical characteristics, their application to patients admitted to the unit, and their major technical limitations. The session began with a brief theoretical introduction (30 min) in the unit's meeting room and continued with a practical demonstration (150 min) in an intensive care unit box, where the function of the technological systems in a critical patient was shown. At the end of the session, students were asked to indicate how much they agreed or disagreed with statements related to their learning and clinical understanding during the ICU-TW using five-point Likert scales. They were also asked to rate their satisfaction with the teaching session using the same scale. A five-point scale was chosen because it provided the same score but was considered less confusing and easier to use. (11, 12). The feedback assessed by the survey also included student comments as free text and allowed us to obtain documented feedback on the student experience to inform possible improvements in future activities. Data are expressed as frequencies (%).

Graphs and statistical analyses were performed using GraphPad Prism 6. Differences between groups were examined using a two-tailed, unpaired t-test. Statistical significance was defined as $P<0.05$.

RESULTS

Student Feedback on the IM-CQ and ICU-TW (Quantitative data)

INSTANT MULTIPLE-CHOICE QUESTIONNAIRES

The main data extracted from the questionnaires are presented in Table 1. Out of 33 students enrolled in the course, questionnaires with 10-17 questions were completed by an average of 25 students. Since these questionnaires could only be completed in the classroom after the lecture, this average of 25 students represented an attendance

rate of 73%. The average score obtained by the students on the different questionnaires was excellent, with a mean score of 9.3 ± 0.1, with a maximum score of 10. There was no difference between the results obtained during the course, with a score of 9.2 ± 0.3 in the first questionnaire and 9.1 ± 0.2 in the last.

This teaching innovation had a positive effect, as shown in Figure 1. We compared the score on the physiology exam between students who completed more than half of the questionnaires (>50%) and those who completed less than half (<50%). As expected, the exam scores obtained by the students who completed at least half of the IM-CQ were significantly (P<0.001) higher than those who completed less than half (<50%) (8.5±0.2 vs. 6.5 ± 0.3, respectively).

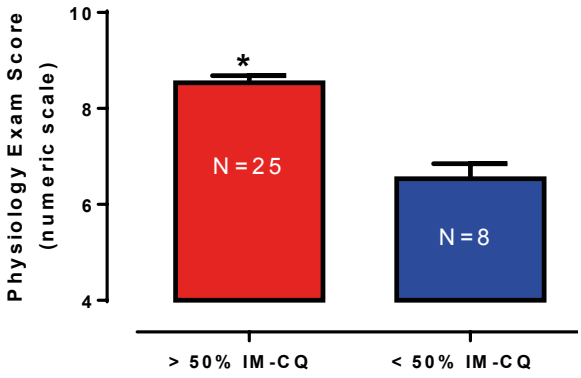

Figure 1: Physiology exam scores for students who completed more than (N=25) or less than (N = 8) 50% of the questionnaires. Data are mean ± SE. * P<0.001 vs. students who completed less than 50 % of the IM-CQ.

INTENSIVE CARE UNIT-TEACHING WORKSHOP

A total of 16 of the 23 students (7 did not respond) provided feedback on the ability of the ICU-TW to address the clinical understanding and function of the various devices used in the ICU (Figure 2A). Of 16 students, 100% strongly agreed with the knowledge provided about the devices. In addition, 81% strongly agreed or agreed (62% and 19%, respectively), and 19% neither agreed nor disagreed with the duration of the ICU-TW. Finally, 100% strongly agreed or agreed that the teaching workshop was held in the ICU because it provided a better understanding of how the technological systems work in critically ill patients (94% strongly agreed and 6% agreed) than lectures alone. The final section of the survey, completed by 16 of the 23 students (seven did not respond), was designed to determine student satisfaction with the teaching workshop (Figure 2B). One hundred percent of the students were very satisfied with the skill and presentation quality of the speakers. In addition, they were highly satisfied with the presentation design (30-minute theoretical introduction outside the treatment unit + 150-minute practical demonstration), as 100% of them would not change it. Finally, 100% of the students were very satisfied or satisfied with the usefulness of the ICU-TW for their studies (94% very satisfied and 6% satisfied).

STUDENT FEEDBACK ON THE ICU-TW (QUALITATIVE DATA)

In addition to quantitative data, trainees' individual comments were collected to obtain qualitative information. Qualitative data provided a broader picture of the students' sessions. Out of the 23 students, 16 written answers were received, most of which were brief but very positive (Table 2).

In conclusion, the students were strongly satisfied. They liked the relationship between theory and practice and the manner to integrate the learning method.

Questionnaire tittle	Number of questions (10-17)	Number of students who completed the questionnaires	Score obtained (0-10)
The body as a whole	10	28	9.2
Nervous System	17	28	8.9
Endocrine System	17	24	9.4
Integumentary System	10	25	9.7
Skeletal system	10	23	9.1
Muscle System	11	23	9.5
The blood	13	19	9.9
The heart and blood vessels	10	25	9.5
Respiratory System	10	23	9.0
Digestive System	10	24	9.3
Renal System	12	23	9.1
Results	12 ± 1	24 ± 1	9.3 ± 0.1

Table 1. Report of the main quantitative information of the instant multiple-choice questionnaires.

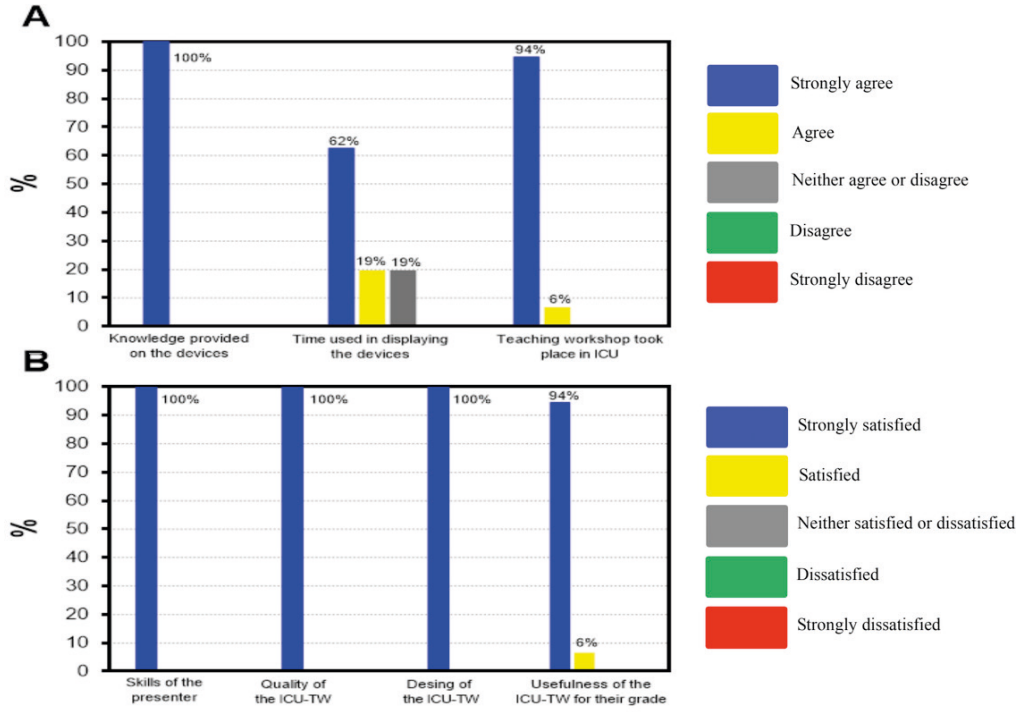

Figure 2. Feedback, using a 5-point Likert Scale from strongly agree/satisfied to strongly disagree/dissatisfied, to capture students' opinions about A) Ability of the ICU-TW to address clinical understanding and operation of the different devices (N=16) and B) Students' satisfaction with different aspects of the ICU-TW (N= 16). Data are expressed as percentages.

1.The way the doctor explained the functioning of the different devices and his professionalism
2. Firstly, the doctor explained how the devices work and then we were able to see how they are used in the daily life of a patient admitted to the ICU
3. To see the different devices working on a patient
4. The explanation of how a pacemaker works
5. To see the instruments, I will be working with in the future
6. To get a first-hand look at the different devices and see how they work
7. I was very pleased to see one of the machines being used by a student
8. The explanation received about the different instruments and seeing how they work on a patient
9. How a person's pain can be monitored via the waveform displayed on a machine
10. To see the purpose and possible application of the knowledge I am acquiring in the degree
11. To see the different devices used in the ICU and discover some that I didn't know about
12. To see individually what the equipment used in an ICU room looks like and how it is used on a patient
13. The doctor's explanations and seeing the different devices working on a real patient
14. To see the application of the different medical equipment on a real patient and to know the conditions and expenses involved in an ICU admission
15. To see the different devices, we will work with in the future as biomedical engineers
16. To see how the different devices work, which I hope to improve in the future

Table 2. Student opinions and comments on what they liked best about ICU-TW collected by satisfaction surveys via free text opinion.

DISSCUSION

All engineering curricula strive to support student learning and progressive acquisition of different expertise. The first part of this study demonstrated the utility of ICTs in education to improve learners' reactions, including attention levels, participation, and engagement (13). When ICT, as IM-CQ, was integrated into lessons, students became more engaged in their work because technology provided an opportunity to make physiology lectures more fun and enjoyable in terms of teaching the same things in different ways. This idea was supported by the fact that students who completed more than half of the proposed IM-CQ obtained significantly higher exam grades on the subject than those who did not (Figure 1). In addition, as we can find in the literature (14) the mean class attendance improving compared to the mean percentage of lecture attendance at the university (54%), with an average of 73% of the total capacity. Regularly attending classes allows students to share information with their teachers and classmates and exchange knowledge and information that you would not be able to at home. In this way, they can improve their communication, learn to work as a team, and have good coexistence (6). Furthermore, this fact is important because when relating class attendance to performance rate (ratio between the number of students passing a subject and the total number of students enrolled in it) and efficiency rate (ratio between the number of credits passed by students in a subject and the number of credits needed to pass it), it was found that, in the degrees with lower class attendance, both performance and efficiency rates were also lower (15, 16).

The second part of this teaching innovation was an ICU-TW being developed to implement the training of BE students with more specific clinical knowledge and to establish feedback on expertise between physicians and trainees. The aim was to increase the capabilities of BE students to achieve future advances that improve the welfare of people. Students scored highly in all areas in relation to clinical understanding and function of the

different devices used routinely in an ICU (Figure 2A). Student feedback reinforced the idea that real-life cases enhanced trainees' understanding of Physiology. Our perception that interest remained high throughout the entire 180 minutes long ICU-TW, supports existing evidence that the use of this teaching innovation did improve students' reactions, including attention levels, participation, and engagement (17, 18). Furthermore, students felt that the ICU-TW provided a more active learning environment and allowed them to engage better with learning outcomes. One hundred percentage of the students were agreed that the ICU-TW significantly improved their physiological understanding, and that the knowledge obtained in the session would be very useful in their professional development (Figure 2B). Evidence has shown that, in higher education, trainees' perceptions of their learning environment have a deep influence on their learning (19). In addition, an important integrative aspect of ICU-TW is the demonstration of how different devices work on a real patient. In this way, students could see the real application of the knowledge they will acquire during the degree. Furthermore, the discussion and exchange of ideas between students, teachers and physicians are considered crucial in the development of successful educational strategies focused on learning transfer (20). It has been demonstrated that cooperative integration (21) is important for linking and reinforcing connections between subject areas and is a highly effective approach for supporting student learning. Biomedical engineering education needs these teaching innovation strategies, where the objective is to bring engineers and physicians closer together. Developing the ability to make confidence in clinical ambient takes time and practice, so this kind of activity could help to establish feedback of knowledge between physicians and trainees and, in this manner, increase BE capabilities to achieve future advances that improve the welfare of people (22). Developing engineers with adaptive expertise requires various approaches, including those that promote the integration of engineering science within a clinical context (23). This type of integrative teaching session, in which physiological knowledge is delivered within a clinical context, could be adapted in various settings with the aim of facilitating and improving confidence for practice in future BE. Because of encouraging early feedback about ICU-TW, we should start to develop more TW to this format in different areas of the course to improve BE student engagement and facilitate a better understanding of the concepts explained.

In summary, meeting the challenges of a rapidly evolving healthcare system requires training and knowledge that extends beyond traditional higher education. The introduction of the IM-CQ increases the class attendance rate and the score obtained for the subject. In addition, greater inclusion of BE, from the early stages of their training, in the ranks of healthcare through this TW reinforces confidence in the knowledge they acquire in their degree and their soft skills. Both are crucial for establishing the physician-engineer communication channel needed to solve the current technical limitations and achieve better medicine.

AUTHOR CONTRIBUTIONS

V.R.* and JF.G.* conceived and designed the research, performed the teaching innovations, interpreted the results, prepared figures and tables and drafted the manuscript; V.R.; JF.G-P.; MT.LL.; JM.A.; JF.R-G. and MT.H. edited and revised the manuscript; V.R.; JF.G-P.; MT.LL.; JM.A.; JF.R-G. and MT.H. approved the final version of the manuscript. * V.R and JF. G-P are contributed equally to this study.

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