

# How do our students learn clinical engineering? A pilot study

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**Abstract**—This paper aims to measure what are the students' perceived learning outcome achievements after finishing their clinical engineering major courses. This is a pre- post-test with no control group study design. Forty students were involved in this pilot study. A paper-based survey composed of a demographic section and a 5-point Likert ("1" is strongly disagree and "5" is strongly agree) section measured the students' perceived learning outcome achievements after exposing them to clinical engineering major courses. A Wilcoxon signed-rank and Mann-Whitney U test statistics were conducted to test the two hypotheses of this study. Our analysis showed statistically significant results between the pre-survey mean and SD: 21.10 SD 3.54; and between the post-survey mean and SD: 22.75 SD 3.68 ( $Z=-2.12$ ,  $p<0.033$ ), indicating that overall, students' perceived learning outcome achievements after exposing them to clinical engineering major courses had significantly improved by the end of the major. Also, statistically significant results were found between the post-survey mean and SD: 3.94 SD 0.61 learning outcome perceptions and between the students' actual marks mean and SD: 4.53 SD 0.22 ( $-5.00$ ,  $p<0.000$ ), indicating the students had low confidence in their learning outcomes after completing their clinical engineering major.

**Keywords-component:** clinical engineering, biomedical engineering, engineering education

## I. INTRODUCCIÓN

### A. Clinical engineering roles and training methods: a brief state of the art

According to the American College of Clinical Engineers "a Clinical Engineer is a professional who supports and advances patient care by applying engineering and managerial skills to healthcare technology" [1]; this definition is also adopted by the International Federation for Medical and Biological Engineering [2] and by the U.S. Board of Examiners for Clinical Engineering Certification [3]. Simply put, a clinical engineer is a biomedical engineer settled in the clinical environment that serves as a "facilitator" between medical technology and its users by providing operational and technical support.

Although there is an indisputable need for the presence of clinical engineers in healthcare organizations gained across the years, legitimate concern on the part of the consumers (i.e. patients/clients) has arisen. Since most of the time these consumers are interacting with medical technologies, they want to be confident that the professionals providing the servicing (e.g. maintenance) for their medical devices are properly

qualified. Therefore, universities and non-governmental bodies of countries (e.g. the U.S. led by the ACCE) and international federations (e.g. the International Federation for Medical and Biological Engineering (IFMBE), and the European Alliance for Medical and Biological Sciences (EAMBES)) are putting special emphasis on the development of guidelines containing protocols for professional education and training clinical engineers. For example the EAMBES released its own protocol for training clinical engineers in Europe. According to the EAMBES's protocol, 3 years of education and training are needed to be a certified clinical engineer. Students' core training areas include management (32 %), technology assessment (15%), regulatory/QA issues (11 %), repair/systems thinking (6 %), risk management/safety issues (9%), education (8%), (product development (8 %), and miscellaneous topics (11 %). These core training areas are in conjunction with the ACCE [1]. The training and education protocol should be conducted in either specialized "Training Centres" or in "Institutions" that must be accredited with the national or the European Clinical Engineering Professional Development Panel CEPDP [2]. In the U.S. similar efforts have been made. One example is the cooperative training course offered by Trinity College, the Hartford Graduate Center, Hartford Hospital, the University of Connecticut Medical Center in Farmington, the Baystate Medical Center in Springfield, Massachusetts, and NOVAMED. This is a hospital-based two-year program in which students have to take a clinical engineering internship program followed by a normal Master's degree program in biomedical engineering.

Despite the advantages of the training protocols of the European Union and the U.S., for low-income countries such comprehensive, structured, and integrated programs rarely exist. As a result, the main responsibilities in the education and training of future clinical engineers are under the umbrella of the biomedical engineering programs of higher education centers/universities. For example, this is the case of the biomedical engineering program (BEP) offered in a partnership between the School of Medicine and Health Sciences at the Universidad del Rosario and the School of Engineering Julio Garavito in Bogotá. In brief, this program has 154 credits<sup>1</sup> and 9 semesters (4.5 years). To obtain a degree, the students have to do a major in any area of biomedical engineering covered by the program, and to have a certificate at B2 proficiency level in a foreign language (English) [4]. One of the majors is clinical engineering.

The authors of this pilot study carried out a rapid review of academic studies in both undergraduate and graduate programs aimed at measuring the impact of clinical engineering programs' implementation in terms of either the achievement of the students' intended learning outcomes, or employers' perceptions of program graduated skills. Unfortunately few studies exist [5, 6], indicating a gap in the knowledge in this area.

### B. Clinical engineering training method: our proposal

The teaching method of the clinical engineering major on the BEP follows a well-structured and balanced number of courses and credits, the teaching methods and learning strategies with the course content. This is the so-called "constructive alignment" teaching philosophy [7]. Simply put, in the tasks of designing and implementing a particular course, a relationship must exist between the *intended learning outcomes (ILOs)*, the *teaching and learning activities (TLAs)*, and the *assessment of the actual students' learning (AL)*. In our experience, when this alignment exists, the students' anxiety decreases, while their perceived competence, motivation, and satisfaction with learning increases, because they know in advance what they have to learn and how they will be assessed. In addition, the above-mentioned alignment facilitates the process of accountability of the teacher to his/her audience: the students. Therefore, under the conditions of a constructive alignment teaching philosophy, this study proposes two hypotheses:

*Hypothesis 1 (H<sub>1</sub>): There are statistically significant differences in students' perceived learning outcome achievements after putting them through clinical engineering major courses.*

*Hypothesis 2 (H<sub>2</sub>): There are no statistically significant differences between students' perceived learning outcome achievements and the actual students' marks after putting them through clinical engineering major courses.*

Tables I, II, and III show the course's structure, the intended learning outcomes, and the constructive alignment of the clinical engineering major of the BEP.

Table I. Clinical engineering training major courses

Course name	Course id	Cr	Total hours	Type
Maintenance Management	MTM001	3	48	M
Clinical Engineering	CE001	3	48	M
Medical Devices I	MD001	3	48	E
Medical Devices II	MD002	3	48	E
Medical Devices III	MD003	3	48	E
Hospital Engineering	HE001	3	48	E
Thesis or Internship	GRADOPT	4	640	M

E: Elective course, M: Mandatory course. MD001: Cardiovascular system devices; MD002: Respiratory system devices; MD003: Imaging devices

To obtain the major in clinical engineering the students have to take at least MTM001 and CE001 mandatory courses, one elective course (see Table II) and Thesis or Internship course either in a healthcare institution or in an enterprise in the area of

clinical engineering (e.g. maintenance, biomedical metrology, etc.)

Table II. Learning outcomes.

ILO code	Learning outcome (Name/code)
C13	Student is able to schedule the life cycle medical technologies, proposing a more feasible option for their introduction into the healthcare system.
C14	Student is able to conduct an economic analysis of health.
C15	Student is able to conduct an economic analysis of medical technologies during acquisition processes (cost benefit analysis).
C16	Student is able to perform scheduled and unscheduled maintenance tasks.
C17	Student is able to schedule and implement scheduled and unscheduled maintenance programs.
C18	In general student is able to design and implement the full process of technology management.

Table III. Constructive alignment on the clinical engineering track courses biomedical engineering program.

Course code	Learning outcome (Name/code)	Teaching and learning activities	Assessment method
MTM001	C16-C17	Lectures (20%) Laboratories (80%)	Theory test Practical test in labs Rubrics
MD001, 002, 003	C16, C18	Lectures (20%) Laboratories (80%)	Theory test Practical test in labs Rubrics
CE001 HE001	C13-C15, and C18	Lectures (20%) Collaborative learning techniques (Colts) (80%)	Theory test Collaborative learning (Rubrics) test

## II. MATERIALS AND METHODS

### A. Study design

Pre- post-test with design with no control group.

### B. Participants.

All students that enrolled on MTM001 and CE001 mandatory courses and the students that chose at least two elective courses in their clinical engineering major.

### C. The instruments

In this study, a survey was designed to measure the students' perceived learning outcome achievements. The survey was composed of a demographic section (section A, 10 items) and a 5-point Likert (section B, 6 items) "1 is strongly disagree and 5 is strongly agree" section measuring the students' perceptions of their learning outcome achievements when passing the courses of the clinical engineering major. Also, the students' average marks on the clinical engineering major courses were recorded.