Development and Implementation of an Innovative Hybrid Mechanical Engineering Course

Salah Badjou, Ph.D.¹

Pierre-Richard Cornely, Ph.D.²

Rachid Dahmani, Ph.D.³

(2019 ASEE Zone 1 Conference, Niagara Falls, NY April 11-13, 2019)

Abstract
This paper discusses the successful implementation of a hybrid pilot course of Engineering Statics. This is a standard sophomore-level engineering course required of mechanical and mechatronics engineering majors. In a recent paper, we have shown that engineering and the sciences are lagging behind most other disciplines in integrating online and distance-learning education. For example, there are comparatively few online and hybrid programs in engineering. We have found that the main reason is that engineering and the sciences require extensive hands-on physical laboratory experiments. Traditional science and engineering education are delivered onsite, where laboratories are centralized and experiments can be cost-effectively performed. Though several creative approaches to providing adequate lab experience in hybrid programs have been tried, there is, to-date, no well-developed proven method that integrates the best practices. In Fall 2017, we developed an innovative pilot course delivered in a hybrid format. All lectures and recitations were delivered online, using the Moodle Course Management System (CMS). Lectures were available as pdf and PowerPoint files, recorded videos, and live videoconferences. The laboratory component involved onsite experiments proctored by a Teaching Assistant (a senior physics student). Three student surveys were completed, providing feedback one, two, and three months into the semester. At the end of the semester a thorough assessment of the experience was conducted, including feedback from all stakeholders; students, teaching assistant, instructor, department chair, and CMS administrator and consultant. This assessment concluded that the experience was highly successful and could therefore provide a proven model for the teaching of engineering online and through distance-learning and as hybrid programs.

1. Associate professor of electrical engineering, Merrimack College, Andover, Massachusetts. Co-principal of American Polytechnic Institute. Contact: sbadjou@ampolytech.com

2. Division Head and Chair of the Department of engineering, physics, mathematics, and computer science, Eastern Nazarene College, Quincy, Massachusetts

3. Co-principal of American Polytechnic Institute. Contact: rdahmani@ampolytech.com
1. Introduction
This paper discusses the successful implementation of a hybrid model in a pilot course of Engineering Statics at Eastern Nazarene College (ENC), Quincy, Massachusetts. This is a sophomore-level engineering course typically required of mechanical, electromechanical, mechatronics, and biomedical engineering majors.

In 2016, the co-authors conducted a study on behalf of American Polytechnic Institute (API) [1] and its college partner ENC [2] to assess the college needs and determine the feasibility of introducing a cost-effective hybrid engineering program at ENC. ENC is a small liberal-arts college. Currently, in addition to traditional liberal arts and sciences programs, ENC also offers undergraduate engineering programs in electrical and computer engineering.

API is an institution that specializes in providing cost-effective online education and training in science and engineering using the latest advances in technology and a project-based and systems approach. Currently, it offers certificates in mechatronics and mathematical modeling [1]. Online education is known to offer many advantages, and has grown considerably in the last few decades. One area of great potential for growth is in science and engineering. It is an area still subject to a subtle but not significant barrier to market entry [4].

The role of API in the partnership included the design and delivery of suitable online curricula that satisfy the needs of ENC, including:
- electromechanical/mechatronics engineering
- mechanical engineering
- biomedical engineering

According to the Bureau of Labor Statistics (BLS) [7], engineering graduates are among the most highly paid entry-level college-educated new hires. Thus, enrollment figures in engineering disciplines are higher than in most other majors. Therefore, offering new engineering programs is potentially an attractive option for liberal-arts colleges, many of which are experiencing declining student enrollment, and revenues. Our research has indicated that among the engineering fields, mechanical, electrical, and civil engineering have the largest student enrollments. This is illustrated in Fig. 1 below [3]. Even though biomedical engineering is a younger and smaller engineering field, it is among the fastest growing engineering fields and is especially popular with female students who are traditionally underrepresented in engineering [3].
The challenge for undergraduate colleges is that they are primarily tuition-based, and offering traditional onsite engineering programs is costly. This is especially due to the required infrastructure and laboratory equipment. The authors, based on their respective experience, in particular in online education [4-6], researched the issue and have concluded that an optimal cost-effective solution for introducing engineering programs that require physical laboratory experiments is a hybrid solution. They developed a cost-effective hybrid model. This approach was implemented in a pilot course as described below. The focus was to use optimally the existing and limited college resources.

Two of the co-authors have recently published a peer-reviewed paper [4] where they have shown that engineering and the sciences are lagging behind most other disciplines in integrating online and distance-learning education. For example, there are comparatively few online and hybrid programs in engineering. They have found that the main reason is that engineering and the sciences require extensive hands-on physical laboratory experiments. Traditional science and engineering education are delivered onsite, where laboratories are centralized and experiments can be performed cost-effectively. Several creative approaches to providing adequate lab experience in hybrid programs have been tried. However, there is, to-date, no well-developed proven method that integrates the best practices [4].

After they completed their study on the needs and resources of ENC, the authors wrote a proposal to the Provost of ENC. The proposal was reviewed favorably and it was decided to test the model by implementing it in a pilot course. During their extensive research of the market and of the particular resources of ENC, the authors developed and proposed programs in mechanical, biomedical, electromechanical/ and mechatronics engineering as the most cost-effective programs for ENC.

2. Course design
The pilot course, Engineering Statics, was developed and delivered in hybrid format by the authors on behalf of API in the fall of 2017. This course was chosen because it was a basic course required of the proposed engineering programs (mechanical, electromechanical, mechatronics,
and biomedical engineering). One of the co-authors, Dr. Badjou, was the course instructor. He had previously taught a similar course onsite at other colleges and universities. This co-author also published peer-reviewed papers regarding online and project-based engineering education [4-5]. Another co-author, Dr. Dahmani, had about ten years of experience teaching physics online using the Moodle Course Management System (CMS). The primary goal was to determine if the hybrid format was suitable for the delivery of new engineering and science courses and programs at ENC.

Lectures were delivered online and the lab experiments on-campus, supervised by a teaching assistant (TA), who was a senior-level physics student. Various forms of delivery were used, including live videoconference lectures, recorded video lectures, pdf and powerpoint lectures. The Moodle platform was successfully used, including a discussion forum. A term project was introduced. Quizzes were given online, homework and lab reports submitted online, and exams taken and proctored on campus. Thus, all aspects of regular onsite course delivery were tested. Based on student feedback provided in the surveys, improvements were introduced.

3. Assessment
Seven students enrolled in the pilot course and completed it. At the beginning, the co-authors developed a set of comprehensive metrics for evaluating the pilot course. Data was to be gathered from all stakeholders: Students, TA, Teacher, CMS manager (Dr. Dahmani), and Division Head and Department Chair (Dr. Cornely). The assessment involved the following:

• Three surveys were conducted, in the form of detailed carefully-designed questionnaires on a scale of 1 to 5.
  • histograms were developed for most relevant questions.
  • surveys included quantitative and qualitative data and open-ended questions.
  • surveys were conducted at the end of each month or the semester
  • questionnaire included student evaluation of lab and hybrid aspects, including lab, TA, live video lectures, individual PC and conference room, and various aspects of technology and delivery

• Evaluation by the TA. This evaluation was conducted on a weekly basis by the instructor and TA, where the TA provided regular feedback and suggestions through video conferencing and email communications

• Evaluation by the Division Head and Department Chair (Dr. Cornely)

• Support from authoritative national studies testifying to the effectiveness of the online versus the onsite model

• Development of a final report by the three co-authors on behalf of API on how the course went including discussion and integration of all aspects of deployment and recommendations
3.1 Metrics obtained from the Moodle platform:
The popular and proven Moodle platform was used to host and deliver the pilot course. Extensive and comprehensive resources and information are included in Moodle. Feedback from students, discussed below, indicates that this has been well received and appreciated by students.

The platform involves a general area containing relevant class information, and modules in the form of each week of instruction, and a detailed calendar of weekly assignments, weekly online quizzes, and exams, folders to submit homework, lab and project reports, a discussion forum, and group project forums. In addition, students and the instructor have access at anytime to the grade book of each student. This allows each student to monitor his/her progress throughout the semester. A syllabus is included at the beginning in the general area along with a tutorial on how the use the Moodle Course Management System (CMS).

As mentioned above, three student surveys were conducted anonymously, providing feedback one, two, and three months into the semester. At the end of the semester a thorough assessment of the experience was conducted, including feedback from all stakeholders; students, teaching assistant, instructor, department chair, and CMS administrator and consultant. This assessment concluded that the experience was highly successful and could therefore provide a proven model for the teaching of engineering online and through distance-learning and as hybrid programs.

3.2 Results of students’ assessment:
The following results summarize the student response:

- 5/7 = 71% of respondents found the hybrid nature of this course (lectures online and labs onsite) suitable for their learning and as effective or better than onsite. Only 1/7 = 14% disagreed.
- 6/7 = 86% of the respondents concluded that based on their experience taking this hybrid course, they would recommend similar hybrid courses to colleagues and peers. No student disagreed.
- 5/7 = 71% of the respondents believed they achieved substantial learning in this course, as much or more than comparable onsite courses. No student disagreed.
- 6/6 = 100% of the respondents found the lab part of this course suitable for their learning and as effective or better than onsite labs. This response shows that the design and delivery of the lab experiments within the hybrid format was very well received.
- 5/6 = 83% of the respondents found the introduction of a project as part of the discussion forum helpful and suitable for their learning and often as effective as onsite projects from other traditional courses. No student disagreed.
- 4/6 = 67% of the respondents found the availability of recorded video lectures and written presentations 24/7 very helpful and suitable for their learning and as effective or better than onsite lectures. No student disagreed.
Based on student feedback and the overall assessment, recommendations were made in a final report on some minor improvements and the most suitable among the tools used were recommended.

3.3 Course attrition
Attrition was minimal. Originally, eight students were enrolled. All had an interest in the proposed engineering programs which were explained to them. Only one student dropped about halfway through the semester as he had a heavier course load of required courses. This particular pilot course was taken by all students as an optional elective.

4. Summary and Conclusions
In this paper, an innovative and cost-effective method and model that were developed for teaching engineering in a hybrid format were discussed. This approach involves offering lectures, recitations, discussion, and office hours, project consultation online, and laboratory experiments, proctored by a TA, onsite. A study was first conducted to evaluate the existing resources of the college, and determine the most suitable engineering programs. Mechanical, electromechanical, mechatronics, and biomedical engineering were found to be the most suitable for ENC, in that they are more popular among students and ENC had the necessary resources to offer them.

This model was then tested by implementing a pilot course in Engineering Statics, which is a sophomore-level course typically required of mechanical, electromechanical, mechatronics, and biomedical engineering majors. An extensive assessment was conducted, involving all stakeholders, including students, teaching assistant, instructor, Department and Division Head, and CMS manager. Three student surveys were conducted throughout the semester. This assessment was highly positive, and all stakeholders recommended that future engineering courses and programs can be successfully taught following this hybrid model, at ENC and similar liberal arts colleges.

The authors conclude that the innovative method and model of teaching engineering in hybrid format can be implemented successfully in colleges and universities. They believe that this model will be especially beneficial to traditional liberal-arts colleges which typically offer no engineering programs because of their limited resources, or when they do, their programs are usually limited to a few engineering disciplines. More colleges offer 3+2 programs, whereby they partner with larger universities, such that students complete a BA or BS in a liberal arts and science major at the college and a BS in engineering at the partner university, after two additional years.

While this has worked for these colleges, the authors believe that they can increase significantly their student enrollment and revenues by implementing the hybrid model discussed in this paper. This is because in addition to the revenues from the additional two years of engineering, they will be able to offer BS programs in engineering in four years instead of the current 5-6 years. This option will be more cost-effective and attractive to students. Currently, the trend is to offer combined BS-MS programs in five years, which is more cost-effective to the students and there-
fore attractive. The authors will be happy to further discuss this paper and may be contacted at the indicated email addresses above.

Bibliographical References
1. American Polytechnic Institute website: www.ampolytech.com
2. Eastern Nazarene College website: https://enc.edu/

Biographies
• Salah Badjou is Associate Professor of electrical engineering at Merrimack College, Andover, Massachusetts. He holds in Ph.D. in Condensed Matter Physics from Northeastern University. He has academic and industrial research experience in applied physics, chemical, electrical and biomedical engineering. He taught electromechanical engineering at Wentworth Institute of Technology from 2000 to 2014. Dr. Badjou is also co-principal at American Polytechnic Institute. Contact: Email: sbadjous@ampolytech.com. Tel.: (781) 491-4219.

• Pierre-Richard Cornely, Ph.D. is Professor of electrical engineering and Division Head of engineering and science and Chair of the department of engineering, physics, mathematics, and computer science at Eastern Nazarene College.

• Dr. Rachid Dahmani has a PhD in Chemical Physics from the University of Maryland. He has over ten years of experience teaching physics online, and several decades of R&D experience in physics at national laboratories. He is co-principal of American Polytechnic Institute. Contact: rdahmani@ampolytech.com