Designing a Hybrid Engineering Course combining Case-Based and Lecture-Based Teaching*

Neda M. Bassir Kazeruni, Andre Laboy, and Henry Hess, *Member, IEEE*

Abstract— **Traditional engineering and business school courses have different pedagogical emphases. Engineering courses are perceived as technical, dense and require students to provide definitive answers to problems. On the other hand, business school courses aim to increase students' knowledge by confronting them with real-world cases and by encouraging both in- and out-of-the-classroom teamwork, thinking in groups and problem solving. In business school courses, the teaching is directed towards the thought process rather than the final answer itself. These two approaches to learning are both valuable and give the opportunity to develop complementary skills. Combining both approaches in a single course is however challenging. We tackled this challenge by designing the semester-long "Introduction to Nanobiotechnology and Nanobioscience" course for senior undergraduate and first year graduate students as a hybrid class. Our objective was to design an engineering course of standard length, which incorporates key elements of the business schools' case study approach to learning while retaining essential elements of the traditional engineering education.**

I. INTRODUCTION

Active learning can be up to twice as effective as traditional lecturing[1]. As a result, research studies regarding active learning methods have multiplied in the past two decades[2-5], and active learning has been introduced in college classrooms, in subjects as diverse as medicine[6,7], political science[8], business[9] and engineering[10,11]. We adopted a multi-leveled active course incorporating a hybrid active learning approach based on introducing, in an engineering course, the active elements that are traditionally used in business school curricula.

The course we designed, "Fundamentals of Nanobiotechnology and Nanobioscience" was targeting the higher levels of learning as described by Bloom's taxonomy. The learning objectives of the course are summarized in Table I. By getting students more involved and engaged in the learning process, we aimed to address the broader range of learning objectives described below.

TABLE I. LEARNING OBJECTIVES OF THE "FUNDAMENTALS OF NANOBIOTECHNOLOGY AND NANOBIOSCIENCE" COURSE

At the end of the course, we aimed for the students to be:	
1	Able to define nanobiotechnology in the context of modern science and engineering
2	Capable of understanding and interpreting concepts such as intermolecular bonds, adsorption and binding/unbinding processes, nanoscale transport mechanisms, and degradation mechanisms at the nanoscale
3	Comfortable in estimating orders of magnitude of objects that relate to engineering
4	Capable of comparing and evaluating research papers related to nanobiotechnology with a critical mind
5	Able to take a position towards an engineering-related question and defend their position in front of others
6	Able to describe examples of applications and outline the state of the art in nanobiotechnology
7	Able to contribute to and build upon team ideas through discussion

II. METHODS

To reach these learning objectives, the course "Fundamentals of Nanobiotechnology and Nanobioscience" was designed and taught in Spring 2017 as an integral part of the semester course schedule in the School of Engineering and Applied Sciences at Columbia University. Seven students from different backgrounds enrolled in the course.

Since our perspective was to differentiate the teaching method from the one of traditional, lecture-based engineering courses, a new course format was introduced, dividing the class-time around three different types of activities:

1. Lectures
2. Case studies
3. Case histories

In-class participation was also encouraged and relevant comments or in-class discussions were rewarded with extra points in the course's final grade.

1. Lectures

Lectures made up less than half of the overall class time. They were meant to provide the students with enough background material to be able to address the issues raised in case histories and case studies. An essential redesign element of the course consisted in the partial "flipping" of these lectures: the foundational material of each lecture series was recorded and divided into several short videos. The students were asked to watch the videos in preparation for the class, and take a quiz consisting of a few short questions online. These short quizzes emphasized the main take-away points of the online lecture and acted as a continuous formative assessment

* This research was supported by the National Science Foundation under award number NSF-ENG1662329, and by Columbia University's Office of the Provost grant on Hybrid Learning Course Redesign and Delivery.

N. M. Bassir Kazeruni is a PhD Candidate at Columbia University, 116th Street and Broadway, New York, NY 10027, USA (e-mail: nmb2163@columbia.edu).

A. Laboy, is a Learning Designer at the Columbia University's Center for Teaching and Learning. (e-mail: al3429@columbia.edu).

H. Hess is a Professor of Biomedical Engineering at Columbia University and the editor-in-chief of *IEEE Transactions on Nanobioscience* (corresponding author: 212-854-7749; fax: 212-854-7749; e-mail: hhess@columbia.edu).

tool for the instructors. Thus, by analyzing the outcome of the quizzes before the beginning of the next class, the instructors were able to implement methods of Just-in-Time Teaching (JiTT) by adjusting the material to the students' needs and to take into account their potential difficulties. For instance, if a specific concept was misunderstood by the students, the instructors would become aware of it thanks to the quizzes. As a result, they would dedicate a few minutes of the next class to explain that concept more in details.

Thanks to the flipping of the lectures, the in-class lectures were more active and consisted more of discussions: the instructor will draw the students' attention on the main "take-home messages" of the flipped lecture, while the students had the opportunity to ask for clarifications regarding the topic. All these activities aim to bring the students not only to a higher level of understanding, but also to teach them to develop, formulate and justify their ideas.

2. Case Studies

Collaborative learning improved learning outcomes in a broad range of aspects from academic achievement[12,13] over students' attitude, to students' retention of the material[14,15]. In order to take advantage of that, we designed business school-inspired case study classes to encourage collaborative learning by making students think about research questions related to the previous lectures' material. In groups, students were asked broad and open-ended questions about the most interesting research direction to follow from then on, the feasibility or the implementation of research ideas, or the economical or societal pay-off of research in the field of interest. Throughout this process, the instructor aligned the students' perspectives and ideas towards the learning objectives of the course, and generated longer class discussions. Since these classes exclusively consisted of discussions about the empirical applications of the material, they turned the classroom into a more interactive and active environment in which the material was taught in a more personalized way.

Another element that we introduced was to repeat the first case study, whose theme was "What are the future prospects in nanobiotechnology?" as the last case study of the course. The second time we went through the exercise, we presented the students with the answers they themselves had come up with at the beginning of the course and asked them to critique them. Thus, we wanted to make the students realize how much they had progressed throughout the semester.

3. Case histories

The case histories consisted in the reading, understanding and critiquing of papers that could be considered as responses to the previous case study. Case histories presented what actual research has been done in relation to the preceding lecture material and case study, thus giving a conclusion to the three or four classes spent on a specific subject. By showing how the course's material is currently used and looked upon by researchers, the case histories were intended to give the students an idea of all the different ramifications of the field of nanobiotechnology. In a few cases, we also interviewed a subject expert (who was the first author of a case history paper) in order to make the material gain a more applied sense in the students' eyes.

4. Assessment of the effectiveness of the implemented measures

The results of this study are derived from an end-of-course optional survey in which the students were asked to self-assess their progress.

In addition to the survey, the students were also given the option to anonymously send their feedback to the instructors about the courses' features such as the online and in-class tools that where implemented.

III. Results

1. Post-course survey

All students responded to the survey. Figure 1 presents the relevant outcomes of the survey.

2. Student feedback

Five out of the seven students seized that opportunity. Representative comments are reproduced in Table II.

TABLE II. STUDENTS' FEEDBACK ON THE COURSE, GROUPED BY THEME

Comments about the course in general:
I thought it was a good course. Active participation was very encouraged, and the lecture videos before the class discussions allowed for a more productive class session.
I really enjoyed the class. I think it will only work in a class size of below 20 though.
Very interesting and inspiring course! After taking the class, it has clarified many questions that I previously had about the field of nanotechnology.
I would love to see the presentation of the results. [Students knew that the educational outcomes of the course would be studied and presented as research]
Comments about the lecture videos:
I think they were good. Posting maybe lecture notes would have helped to review the material.
[They] suited the information we were learning. Video lectures produced very well by Neda.
[I would have] made the flipped lessons a little bit more application based so that we didn't learn the material twice but rather worked through hypothetical situations, not just case studies.
Comments about the case studies:
They were enjoyable.
Comments about the case histories:
I liked all of the kinesin/microtubule papers, as the system was easy to understand once I knew the concept.
I enjoyed the heat-triggered PNIPAM tracks paper in particular. It seemed concrete, brief, and promising without requiring much technical knowledge to interpret.
I liked the catch bonds paper.
Some were useful, some were very dense, and some very boring. I'd prefer to work through solving their problem rather than just talking about the paper.
Comments about the repeating the first case study as the last one:
It helped a lot by connecting the topics that we have discussed together and offering a clear overall summary of nanotechnology.
I thought it was useful because it showed how much we had learned about the field, and we were able to contextualize it better.
Helped show progress and development over the semester.
I think it was a fun exercise. I think more structure when doing the first one would have yielded more positive results. Our ideas then were pretty misinformed.

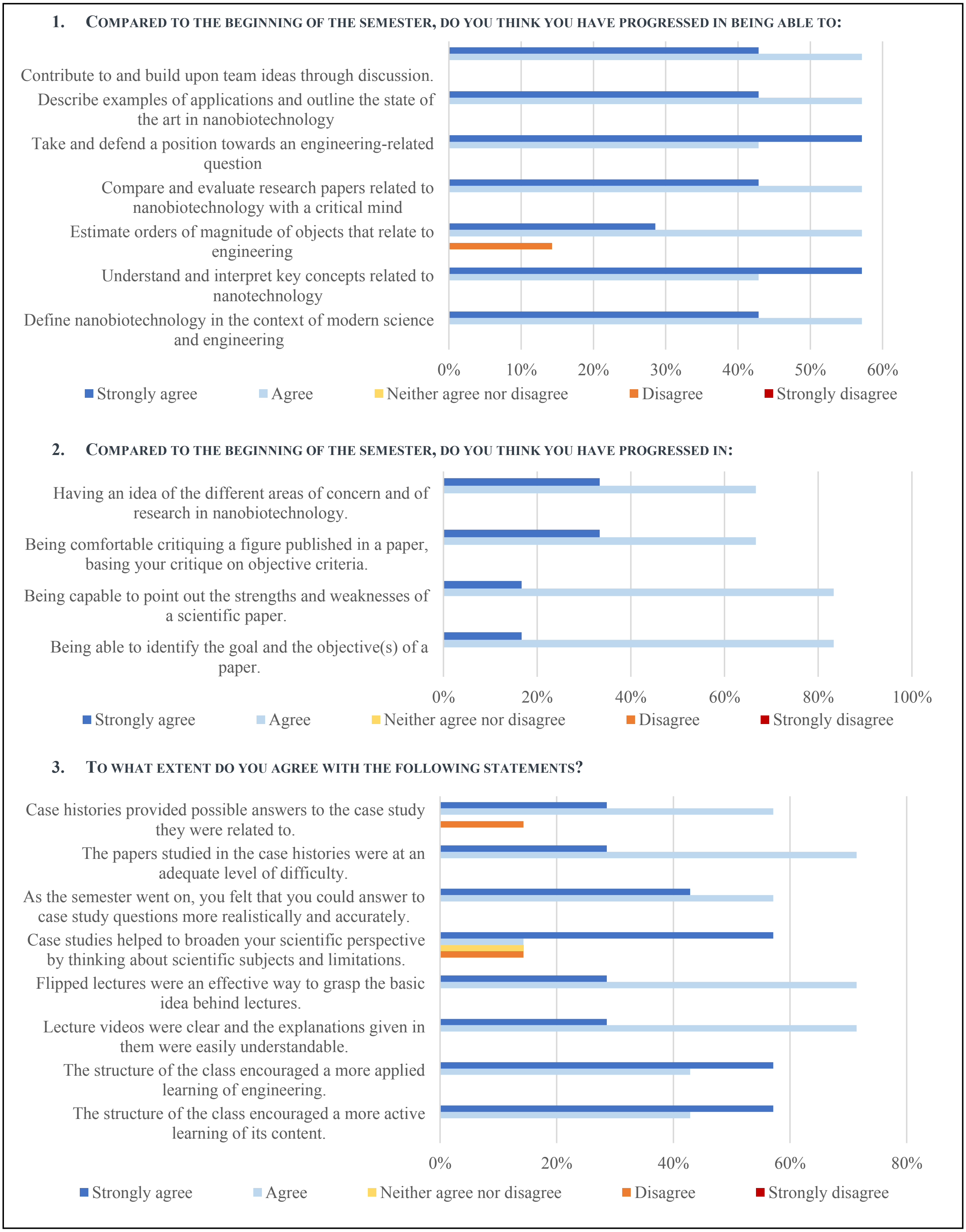

Figure 1. Students' answers to two of the end-of-course survey questions. In both questions, students self-assess their progress. The first questions is geared toward the course's learning objectives, the second question evaluates the students' ability to critique a scientific paper, and the third one assesses how effective the active learning methods were. The x-axis represents the percentage of students falling within each category.

IV. Discussion

Interestingly, the very fact that all students answered to the end-of-course survey is a proof of their active engagement with the course.

The survey and student feedback reveal that even though some concerns were raised about the execution of the course, the participants were overall very satisfied with it (Fig. 1). They found the course at an adequate level of difficulty, and all of them believed that the course had reached its learning objectives (Fig. 1, Question 1). After the course, students were able to place nanobiotechnology in the current context of science and engineering, and they were more comfortable with reading and critiquing scientific papers (Fig 1., Question 2). They were also able to benefit from the active elements introduced in the course, and they strongly agree that the use of flipped lecture and in-class collaboration and group work enhanced their learning (Fig. 1, Question 3; and Table II).

Students' feedback comments corroborate the results discussed above: student were overall eager to learn using the technological tools that were at their disposal, and they enjoyed to learn using the new methods that were introduced in the course.

Lastly, it is interesting to notice the variety of comments given about the case histories. While the answers to question 3 show that students believed the case studies to be at an adequate level of difficulty, their comments prove that the papers were diverse enough to match different students' taste: most students refer to papers that they liked, but all the mentioned papers are different. Meanwhile, a student expresses his or her discontentment about the exercise altogether, being thus a further proof that no exercise can meet everybody's needs and learning preferences.

V. Conclusion

Even though the obtained results of this project are positive and encouraging, we intend to further deepen this research by designing a robust and objective method of assessment of the active learning elements of the course. To do so, two new measures will be implemented. First, a pre-course survey will provide the instructors with information about the students' baseline knowledge regarding the course's learning objectives. Secondly, students' in- and out-of-classroom participation will be evaluated qualitatively and quantitatively throughout the semester, letting the instructors assess the evolution of their engagement and active interaction with the course material. Thus, we aim to improve the students' learning and retention of information using methods derived from Just in Time Teaching.

Acknowledgment

We thank Columbia University's Center for Teaching and Learning for their in-kind support and collaboration in developing the technological elements of this project and acknowledge financial support through a Provost Award for Hybrid Learning Course Redesign and Delivery and NSF grant number NSF-ENG1662329.

References

[1] Hake, R. R. "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *American journal of Physics*, 66(1), pp. 64–74, 1998.

[2] Novak, Gregor M. "Just-in-Time teaching," *New Directions for Teaching and Learning*, 128, pp. 63–73, 2011.

[3] Hung, W., Jonassen, D. H., & Liu, R. "Problem-based learning," *Handbook of research on educational communications and technology*, 3, pp. 485–506, 2008.

[4] Prince, M. "Does active learning work?" *A review of the research. Journal of engineering education*, 93(3), pp. 223–231, 2004.

[5] Prince, M. J., & Felder, R. M. "Inductive teaching and learning methods: Definitions, comparisons, and research bases," *Journal of engineering education*, 95(2), pp. 123–138, 2006.

[6] Graffam, B. "Active learning in medical education: strategies for beginning implementation," *Medical teacher*, 29(1), pp. 38–42, 2007.

[7] Barrows, H. S. "Problem-based learning in medicine and beyond: A brief overview," *New directions for teaching and learning*, 1996(68), pp. 3-12, 1996.

[8] McCarthy, J. P., & Anderson, L. "Active learning techniques versus traditional teaching styles: Two experiments from history and political science," *Innovative Higher Education*, 24(4), 279-294, 2000.

[9] Wright, L. K., Bitner, M. J. and Zeithaml, V. A. "Paradigm shifts in business education: Using active learning to deliver services marketing content," *Journal of Marketing Education*, 16(3), pp. 5–19, 1994.

[10] Freeman, S., et al. "Active learning increases student performance in science, engineering, and mathematics," *Proceedings of the National Academy of Sciences*, 111(23), pp. 8410–8415, 2014.

[11] Kvam, P. H. "The effect of active learning methods on student retention in engineering statistics," *The American Statistician*, 54(2), pp. 136–140, 2000.

[12] Johnson D., Johnson R. and Smith, K. "Cooperative Learning Returns to College: What Evidence is there that it Works?" *Change*, 30(4), pp. 26–35, 1998.

[13] Johnson D., Johnson R. and Smith, K. D, *Active Learning: Cooperation in the college classroom*, 2nd Ed., Interaction Book Co., 1998.

[14] Springer, L. Stanne, M., and Donovan, S. "Effects of Small-Group Learning on Undergraduate in Science, Mathematics, Engineering and Technology: A Meta-Analysis," *Review of Educational Research*, 69(1), pp. 21–51, 1999.

[15] Berry, L. Jr. "Collaborative Learning: A program for Improving the Retention of Minority Students," U.S. :Virginia, ED384323, 1991.