Work in Progress: A Hybrid Engineering Course Combining Case-based and Lecture-based Teaching

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Designing a hybrid engineering course combining case-based and lecture-based teaching

Traditionally, engineering and business school courses have had different pedagogical emphases. Engineering courses were perceived as technical, dense, and provided definitive answers to problems. On the other hand, business school courses increased students' knowledge by confronting them with real-world cases and by encouraging both in-class and out-of-the-classroom teamwork and problem solving. The teaching was directed towards the thought process rather than the final answer itself. These two approaches to learning are valuable and give the opportunity to develop complementary skills. Even though many efforts have been made to introduce active elements in traditional engineering courses[1-3], combining both approaches in a single course is still 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 incorporated key elements of business schools' approach to learning while retaining essential elements of the traditional engineering education.**

Our hypothesis is that our hybrid approach to learning will make students more involved and engaged in the learning process, which will allow us to address a broader range of learning objectives in the course.

Completed work

The course BMEN4580 – "Fundamentals of Nanobiotechnology and Nanobioscience" has been designed and taught in Spring 2017 as an integral part of the spring semester course schedule in the School of Engineering and Applied Sciences at Columbia University. This course was targeting the higher levels of learning as described by Bloom's taxonomy. At the end of the course, we aimed for the students to be:

a. Able to define nanobiotechnology in the context of modern science and engineering,
b. Capable of understanding and interpreting concepts such as intermolecular bonds, adsorption and binding/unbinding processes, nanoscale transport mechanisms, and degradation mechanisms at the nanoscale,
c. Comfortable in estimating orders of magnitude of objects that relate to engineering,
d. Capable of comparing and evaluating research papers related to nanobiotechnology with a critical mind,
e. Able to take a position towards an engineering-related question and defend their position in front of others,
f. Able to describe examples of applications and outline the state of the art in nanobiotechnology,
g. Able to contribute to and build upon team ideas through discussion.

Active learning can be twice as effective as traditional lecturing[4], which is why active learning was at the core of our design of this course. Indeed, the class-time was structured 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.

Lectures made up less than half of the overall class time. They provided 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. The short quizzes emphasized the main take-away points of the online lecture and acted as a continuous formative assessment tool for the instructors: by analyzing their outcome before the next class, we were able to both implement methods of Just-in-Time Teaching (JiTT) by adjusting the material to the students' needs, and to take into account their potential difficulties.

Partially flipping the lectures opened up time for in-class discussions: the instructor could 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 aimed to bring the students not only to a higher level of understanding, but also to teach them to develop, formulate and justify their ideas.

Collaborative learning improves learning outcomes in a broad range of aspects going from academic achievement[5,6] to students' attitude and retention of the material[7,8]. 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. These classes exclusively consisted of discussions about the applications of the material, which turned the classroom into a more interactive and active environment in which the material was taught in a more personalized way.

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 three or four classes spent on a specific subject (Table 1). 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 in 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.

Subject: **Biomechanics of cytoskeletal structures**

Type of class	Learning objectives	Class description
Lecture	a., b., and c.	Flipped lecture and lecture on the biomechanics of cytoskeletal structures.
Case study	c., e., and g.	Class discussions on how to increase the lifetime of biomolecular devices.
Case history 1	a., d., e., and f.	Study of the paper: Brunner, C., et. al. "Lifetime of biomolecules in polymer-based hybrid nanodevices", *Nanotechnology*, 15(10), S540, (2004).
Case history 2	a., d., e., and f.	Study of the paper: Kabir, A. M. R., et. al. "Prolongation of the active lifetime of a biomolecular motor for in vitro motility assay by using an inert atmosphere", *Langmuir*, 27(22), 13659-13668, (2011).

Table 1. Cycle of classes on the topic of cytoskeletal structures and their lifetime

As taught in Spring 2017, this course introduced an innovative type of teaching in both the fields of nanobiotechnology and active learning. The end-of-course survey also emphasized the effectiveness of this new method in terms of addressing the learning objectives of the course (Figure 1).

Future developments

To further deepen this research, we plan to (1) maintain and further develop the active learning aspects of the course by enriching the teaching with other voices and perspectives and (2) design a robust and objective method of assessment of the active learning elements of the course.

To address our first objective, we will update the papers that are studied on a regular basis to keep them current. We will also introduce new perspectives by developing a system of online annotation of the papers. The instructors will use annotations to draw the students' attention on the ideas of interest that will be discussed in class. The students will hence have a better idea of what to look for in a paper, which will in turn serve the higher objective to teach them to be more effective readers when provided with a scientific paper. The annotation of the course material will open the door to online and out-of-classroom interactions both between the students, and between the students and the instructors. The commented files and their associated discussions will also serve as a formative assessment tool for the instructors. Hence, this measure can facilitate the students' independent work while encouraging them to learn more.

Compared to the beginning of the semester, do you think you have progressed in being able to:

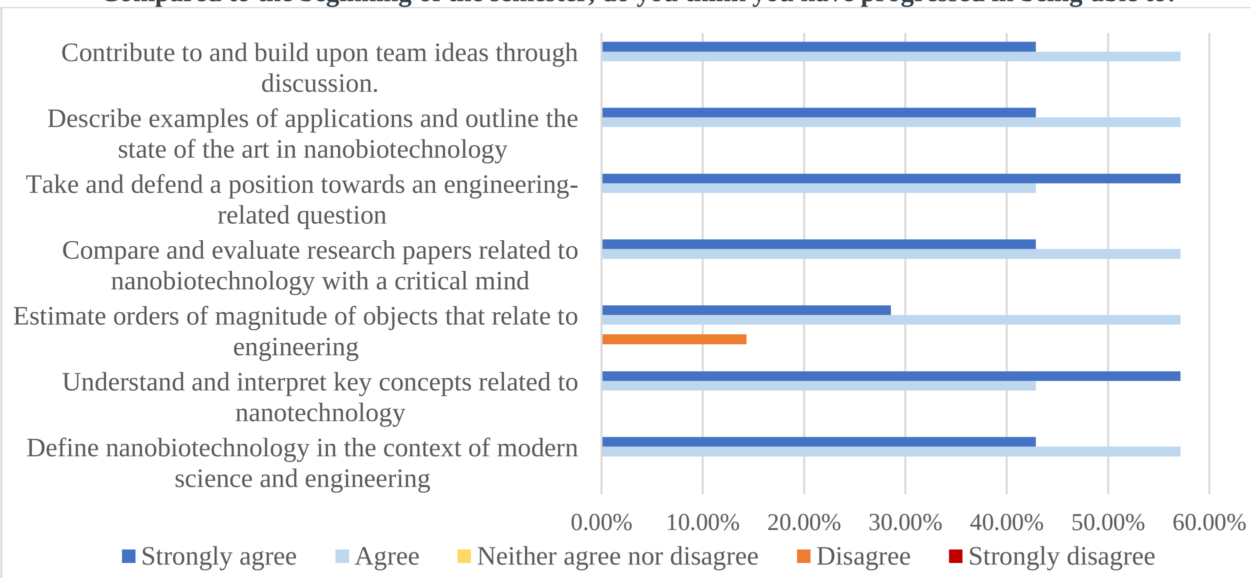

Figure 1 – Students' answers to one of the end-of-course survey questions about their progress regarding the course's learning objectives.

Secondly, to assess the effectiveness of the active learning measures, new measures will be implemented. First, a pre-course survey will provide the instructor with information about the students' baseline knowledge regarding the course's learning objectives. Intermediary assessments will be designed to gauge the effectiveness of each active element. Lastly, 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.

Altogether, we aim for this course not only to be remembered as novel, but also for its content to be learned and assimilated more efficiently by students.

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