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Improving effectiveness of teaching large introductory physics courses with modern information technology

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Abstract

We facilitated active involvement in learning of all students addressing also their individual backgrounds by carrying out diagnostic tests, offering a variety of web based resources and class activities. Elements of the flipped class and multimedia means were introduced by providing video recording of lectures and getting feedback through question-answer sessions and by administering mini quizzes. The significant cultural, educational and ethnical diversity of the class required also to address individual qualities and preferences of the students by providing a wide range of educational materials. In the future, it is important to develop quantitative statistical characteristics which can serve as metrics for the efficiency of different course components. The roles of different course components were analyzed, in particular the final grade and the completion success of homework assignments and answers on clicker questions were correlated. The emphasis was placed on comprehension of the basic mathematics concepts needed for the course that was assessed at the beginning, and the problem solving skills were tested at the intermediate exams.

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1. Introduction

The preparation of specialists able to lead the development of scientific and technological innovation as well as to teach related disciplines goes through all stages of students' education. A particular role belongs to physics

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education, which teaches such skills as critical thinking, ability to find the right approaches to solving problems and then by expressing problems with equations finally reach quantitative answers. The teaching of such classes sets challenges in implementing the most progressive methods of education and efficient instructional materials that introduce active training and achieve a successful and long lasting effect of student learning.

The goal of this effort was to develop active learning methods in a core curriculum physics class setting. We have introduced features of the flipped classroom approach that draws on such concepts as active learning, engagement of students, and employment of Internet resources, such as TAMU MediaMatrix for streaming video recordings of lectures and polling software. The availability of recording technology and the ubiquity of web-based dissemination tools make the inverted class style both timely and effective, giving in addition the benefit of evaluating and assessing student activities.

This core curriculum course covers a broad range of topics in Mechanics, Thermodynamics, Sound Waves, Oscillations and Fluid Properties with typically ~700 students per semester (mostly first-year engineers). Students are divided into lecture classes of ~125 and further subdivided into recitations of about ~25. Weekly homework problems are assigned with Mastering Physics (Pearson e-text) which encourages critical thinking using the learned material. The main two goals pursued in teaching this course are to ensure for each student: (1) the understanding of the basic laws and concepts of physics in the above mentioned areas and developing skills of applying learned concepts to solving related problems, and (2) the ability to apply knowledge of mathematics to practically relevant problems in science and engineering.

The applied teaching techniques were intended to help students in mastering basic physics skills, including: (1) understanding of terms, notions and facts as well as learning concepts and theories, (2) developing problem-solving and mathematical skills, (3) the ability to apply principles and generalizations already learned to new problems and situations, (4) fostering the ability to think creatively, (5) learning to concentrate on major factors and to disregard insignificant ones; understanding the concept of accuracy of measurements and importance of correct estimates, (6) in laboratory work and research, to develop the ability to draw reasonable inferences from observations, to synthesize and integrate information and ideas, improve skills in using materials, tools, and/or technology relevant to the subject. (7) becoming adept at turning the physical quantities into symbolic variables, translating the problem into equations, and finding both a closed-form solution and a numerical answer; the ability to identify relevant laws and formulas appropriate to solve a given task, formulate and solve engineering problems.

The direct experience of teaching such a class and literature reports (Snetinova & Koupilova, 2012; Ogunleye, 2009) reveal evidence that there are several main problems in achieving successful outcome for all students of the class: (1) students come to study physics with very different backgrounds, and therefore diagnostics and identification of the points of weakness of each individual student early in the course are of utmost importance; (2) the concepts are well learned when they are used and actively applied in problem solving, however attempts to memorize formulas instead of applying analysis and critical thinking often prevail (Kima & Pak, 2002); (3) rather often scientific discoveries made in the 18^{th} and 19^{th} centuries (which make the basis for this course) remain disconnected from the realities of the modern science and technology, and therefore the task is to relate the concepts of the course with the contemporary physics and the state-of-the-art engineering applications and discuss these modern developments in the classroom.

2. Demography of students

This study describes teaching results in one class. The demographic data of the students are listed as two charts. There were total of 110 students in the class of which 49 responded to the survey. The average age was 19.7(2) years. The gender was almost equally divided (53.1% females, 46.9% males). In ethnicity, enrolment was highest for Caucasian (67.3%), then Asian (18.4%) and Hispanic (12.2%). The majority had their education in the USA (95.9%) followed by Asia and Europe. Their majors divided into many bio- and agri-sciences and engineering specialties.