

Combining online and face-to-face tutoring to enhance learning physics concepts

Gomez Puente, S.M.¹

Education Development Policy Advisor & Quality Assurance Officer
Dept. of Applied Physics, Eindhoven University of Technology
Eindhoven, the Netherlands
E-mail: s.m.gomez.puente@tue.nl

Engeln, R.

Associate Professor, Group Plasma & Materials Processing
Dept. of Applied Physics, Eindhoven Univ. of Technology
Eindhoven University of Technology
Eindhoven, the Netherlands
E-mail: r.engeln@tue.nl

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INTRODUCTION

Enhancing learning concepts in physics courses and motivating students to attend instructions are the two main goals of the pilot conducted in the first-year *Applied Natural Sciences* (ANS) Physics course. This pilot has been conducted both at the Applied Physics (AP) and the Electrical Engineering (EE) departments at the Eindhoven University of Technology in the Netherlands. The motivation to improve the educational approach is two-fold: first of all, the low percentage of students' attendance to the instructions at the physics department; secondly, the low pass rates at the electrical engineering department in the past two years.

In this paper we present the results of the use of blended-learning, i.e. a combination of an online platform and tutor groups, to enhance students' conceptual learning. Despite the positive results in the use of online a small-scale tutoring groups, there is still room for improvement. Likewise, opportunities to further experiment with blended-learning methods are still explored.

¹ Corresponding Author
Gomez Puente, S.M., s.m.gomez.puente@tue.nl

1 BACKGROUND

1.1 Educational framework in the Applied Natural Sciences (ANS) course

The Applied Natural Science (ANS) is a compulsory course which is given to all freshman engineer students at Eindhoven University of Technology. The content of this course focuses on teaching the concepts of mechanics, flow, waves, energy and momentum, heat transfer and collisions. The ANS course provides a fundamental basis for these basic concepts in physics. Because of the differentiation of students in terms of prior knowledge, educational background and discipline, tailor-made teaching and learning methods must be developed. These developments are also necessary also to educate the *Engineers of the future* [1].

Two central pillars have supported the rationale to improve the conditions of learning in the ANS course. First of all, there was a need to upgrade the e-learning platform in order to accommodate the methods to the current policy regulations at the University. Secondly, the vision on education regarding intensifying small-size group education has been taken as a starting point to adjust the instructions [2]. Following this vision, quality of education focuses on providing learning opportunities in small groups, specially for large courses with groups up to 179 natural science students and some 173 electrical engineering students, both electrical engineering and automotive students.

To meet the educational challenges set by the two main goals of the pilot, the pedagogy to teach physics was modified. One of the major changes was the upgrading of the online system. In order to do that, firstly, the Mastering Physics (MP) e-learning platform was replaced by Oncourse [3], an in-house developed e-learning environment. The two main reasons for this adjustment were 1. MP seems to be less appropriate to give feedback on students' answers [4]; and, 2. it is sensitive to fraud with this computer system. Moreover, Oncourse fits better the outcomes of the course as it is requested by the students to work with symbols instead of with numeric values. Secondly, as part of the implementation of the small-group education vision of the university, we introduced tutor groups with up to 10 students per group [5]. The tutor groups are to replace the independent learning setup and approach in which students, up to 30 to 40, work independently on solving exercises while the teacher walks around and answers punctual questions.

2 FROM TRADITIONAL TEACHING TO THE ENGINEERS OF THE FUTURE EDUCATION

2.1 Educating the Engineers of the Future

Eindhoven University of Technology has developed an educational vision to educate the *Engineers of the Future*. Considerations for a radical change both in the content of the curriculum within the study programs as in the teaching and learning methods is caused by a number of facts. First of all, there was a need to make significant and innovative contributions to society and therefore, the curriculum needed to be adjusted to comprise a strong disciplinary basis, skills and entrepreneurial attitude [6]. Furthermore, there was also interest to reduce drop-outs and attract more different types of engineer students. Within this framework of radical transformations, the vision of education 2030 was started up. The vision consisted of, among others, the following core elements:

- Excellence by connecting education and research;
- Small-scale education and master apprentice interaction;
- Internationalization and a greater diversity of students;
- Student-demand teaching and tutoring role of teaching staff;
- ICT and blended-learning in teaching large groups;
- Professional development of faculty staff;
- Multidisciplinary;
- Output qualifications and educational quality assurance;
- Lifelong learning and involvement of the business world.

Transforming this vision in a realistic scheme [7], the curriculum for the different study programs therefore comprised the following (see also *Fig. 1*):

- Major disciplinary courses (90 EC) specific to each study program;
- Elective courses (45 EC);
- Basic compulsory courses (30 EC) for all engineer students;
- USE (User, Society and Enterprise 15 EC) courses for all engineer students;
- Professional Skills (Communication, written and presenting; Reflection; Planning and organization; Dealing with scientific information; and Collaboration – 5 EC).

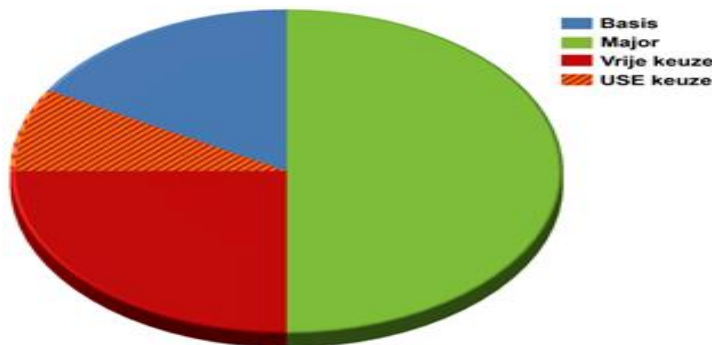


Fig.1. Overview structure bachelor curriculum for all TU/e study programmes

2.2 Transformations in the design of the ANS course

The challenge in putting in practice the Bachelor College study programs did not only involve the structure of the curriculum but also the pedagogy and educational approaches. Within this framework, the introduction of blended-learning, i.e. ICT tools, such as e-response system devices, i.e. clickers, online feedback platforms, e-books with animations and digital assignments, or weblectures, were introduced in courses as active learning methods, to reach large amounts of students and focus on feedback and specific needs.

The ANS course is not an exception and the redesign of this course is not a stand-alone action. It is part of a complete transition of the curriculum to the so-called Bachelor College. Over the past three years, this course in particular was subject to, not only adjustments in the content, but also in the didactical forms. First of all, the instructional design consisted of lectures and supervised independent learning; the latter to have students work on problem-solving assignments in groups of 30 to 40 students. Clickers were introduced to activate students and an online platform was used to practice but also test students' knowledge. The didactical setup of ANS has been transformed to respond every time to new students-driven requirements, e.g.

differentiation in learning styles and prior knowledge on the one hand; and, policy demands, e.g. fraud and vision on small-scale learning. We provide in *Tables 1, 2, and 3*, an outline of the ANS adjustments over the past three years.

Table 1. First year Bachelor College (2012-2013)

Educational/instructional design	Assessment
-4x45 min. Interactive lecture • Clicker questions and demonstrations -4x45 min. supervising independent learning -Self-study online book/assignments Mastering Physics	60% final written exam 20% written interim exam 20% weekly quizzes
Analysis of results - Pass rate is low in some study programmes - Some concepts remain difficult	Improvement - 'Live' demonstrations' for conceptual understanding

Table 2. Second year Bachelor College (2013-2014)

Educational/instructional design	Assessment
-2x(2x45) min. Interactive lecture • 30 min. demonstration • Clicker questions (2nd. lecture of week no demonstration) -2x(2x45) min. supervising independent learning -Self-study online book/assignments Mastering Physics	60% final written exam 20% written interim exam 20% weekly quizzes
Analysis of results - Mastering Physics is not an optimal assessment instrument - High absence in supervising independent learning	Improvement - Pilot: Small-scale education (1x 1 hour tutor groups) in natural sciences & Electrical engineering study programs - Feedback and assessment tool: Oncourse

Table 3. Third year Bachelor College (2014-2015)

Educational/instructional design	Assessment
-2x(2x45) min. Interactive lecture • 30 min. demonstration • Clicker questions -2x(2x45) min. supervising independent learning -Self-study online book/assignments Mastering Physics	70% final written exam 20% written interim exam 10% Oncourse homework (average best 5 of weekly quizzes)
Analysis of results -Positive experience with Oncourse & tutor groups but not optimal (symbols & frequency) - Content more challenging - Conceptual understanding of old & new physics concepts - Link between lectures/homework quizzes/tutor groups not yet optimal	Improvement - Pilot: Small-scale education (1x 2 hours and up to 16 students in tutor groups) in natural sciences & electrical engineering study programs - Feedback and assessment tool: Oncourse: more symbols - Professionalization of faculty staff in didactics - Weblectures and pencasts to improve conceptual understanding

3 RESEARCH METHODOLOGY

3.1 Instruments and data collection

To analyse this pilot we collected both students' and teachers' perceptions on Oncourse and on the tutor groups. N = 13 applied physics and electrical engineering tutors took part in this experiment. The tutors' response consisted of N = 11. Regarding the students' participation, a total of N = 861 students followed the ANS course in 2014/2015, of which N = 179 natural science students and N = 173 electrical engineering students (both electrical engineering and automotive). The response of the natural science and electrical engineering students consisted of N = 66 students who filled out the questionnaire.

In addition, we also analysed the students' pass rates of both AP and EE departments and compared these with the results of two consecutive generations of students, namely, 2013/2014 & 2014/2015.

The research instruments to collect students' and teachers' perceptions consisted of a structured questionnaire including both close and open questions. The survey comprised a Likert 0 to 5 scale (0 (totally disagree) to 5 (totally agree) structured questionnaires.

3.2 Results on tutors' perceptions on Oncourse and tutor groups

With regards to tutor's perceptions on Oncourse, both from applied physics and electrical engineering tutors, results indicate a general positive experience with the Oncourse online platform. We present tutors' opinions in *Table 4*.

Table 4. Tutor's perceptions on Oncourse

Question	Mean	Standard deviation
1. Students work weekly on Oncourse homework assignments	3.60	1.02
2. During the tutor groups students ask relevant questions in relation with the Oncourse homework assignments they have done before the tutor meeting	2.70	0.78
3. You, as a tutor, have a good overview of students' weekly progress with Oncourse	3.00	1.10
4. Oncourse supports you, as a tutor, to know that students' mistakes are so that you can give feedback and address those problems during the tutor meeting	3.50	1.20
5. I find Oncourse a useful tool to support students' learning	3.60	1.20

An analyses of these results show that there is only one item, the level of satisfaction regarding *the relevance of students questions on Oncourse homework assignments before the tutor group meetings* that scores lower (mean 2.70). This result needs to be further analysed in the context of the content of the course but also in terms of students' motivation.

With respect to tutors' opinions in the open questions, tutors mentioned that from a technical point of view the Oncourse assignments still need to be improved to include more symbolic questions rather than numeric ones.

Table 5. Tutor's perceptions on tutor groups

Question	Mean	Standard deviation
1. Students work actively during the tutor meetings	3.80	0.75
2. Students work more actively during the tutor meetings than during the 'Supervision of independent learning' from previous years?	3.14	1.25
3. Students come more often to the tutor meetings than the 'Supervision of independent learning' from the previous year?	2.86	1.25
4. As a tutor you observe that the tutor groups support better students to understand/learn better concepts/problems, etc., than with 'Supervision of independent learning'.	3.14	1.46

The tutors' perceptions regarding the newly implemented approach for small group instruction, i.e. small-scale tutor group, as a replacement of the supervision of independent learning has also been experienced as positive. Looking at the results, we perceive a general level of satisfaction regarding the active involvement of the students during the tutor group meetings. Furthermore, comparing the students' involvement with this in the previous traditional instruction form of 'Supervision of independent learning' tutors is also positive. In addition, this new small-group tutoring type of instruction was perceived as a good supporting method that helps students to understand and to better master the concepts and problems to be solved.

However, tutors' remarks in the open questions point out that the attendance of students to the tutor meetings was relatively lower in general but also after the interim tests. Moreover, tutors mentioned that the number of weekly meetings, i.e. 1 hour, is not enough to handle problems, on the one hand. On the other, it has little motivation for the students to come and be prepared for the weekly assignments.

Suggestions for improvement are to increase the number of hours per week for the tutor-groups, from 1 to 2 hours. In addition, the feedback system will be improved so that students having questions on the exercises do not have to wait one week to get an answer.

In this regard, suggestions on increasing the number of students, from 8-10 to 16 maximal, were also made. Similarly, the level of complexity of the assignments has been recommended during open discussions with the tutors as a mean to motivate students to make the weekly assignments and join the tutor group meetings where they can get an answer to their problems.

3.3 Results on students' perceptions on Oncourse and tutor groups

Students, both from the applied physics and electrical engineering departments, were surveyed regarding their perceptions on Oncourse and tutor groups. According to the survey, 37.9% participated in a tutor meeting more than 6 times. In *Table 6* we summarize the students' opinions regarding these two new elements of the ANS experiment.

Table 6. Students' perceptions on Oncourse and tutor groups

Question	Mean	Standard deviation
1. Are you satisfied with the tutorials? (for example, alignment with lectures, level, supervision).	3.9	0.9
2. During the first tutor hour, you were told what was expected from you when participating in a tutor group.	4.0	0.9
3. By making the Oncourse weekly quizzes and practice quizzes you were enough prepared for the tutor hours?	3.6	1.2
4. There was enough time to discuss during the tutor hours questions and problems you encountered while studying the material and making the Oncourse quizzes?	3.4	1.2

The general observations of the students in the open questions with respect to the tutor groups are that the tutor groups were supportive meetings to ask questions and get a throughout explanation of problems and difficult exercises in order to get a better understanding of lecture topics. Some remarks and suggestions for improvement were made in order to increase the number of tutor hours a week, but also to intensify the level of complexity in the content.

3.4 Comparison of the Applied Physics and Electrical Engineering students' pass rates

In order to gain an overview of whether this pilot with the use of an online platform, i.e. Oncourse, and the support of tutor groups has had an effect on students' study success, we compared students' pass rates of applied physics and electrical engineering students regarding 2013/2014 and 2014/2015. We observed differences among applied physics and electrical engineering students (electrical and automotive students). In *Table 7*. we present the overview of two different cohorts of students.

Table 7. Comparison of applied physics and electrical engineering students' pass rates 2013/2014 and 2014/2015

Students' groups		2013/2014		2014/2015
	N= students	Pass rate	N=students	Pass rate
Applied Physics	135	71.5	179	80.6
Electrical Engineering	123	66.2	120	64.5
Automotive	48	42.5	53	62.0

Comparing the pass rates of the applied physics and automotive students in these two cohorts, results show an increase, while the pass rate for the electrical engineering students has not changed significantly.

We are careful in making statements to claim that the introduction of Oncourse as an online platform, and the tutor group system, has not had immediate impact on electrical engineering students. Higher rates might be linked to the didactical methods, although we don't have an explanation yet on why this is not the case for the electrical engineering students.

4 CONCLUSION AND FUTURE PERSPECTIVES FOR THE INSTRUCTIONAL DESIGN OF THE APPLIED NATURAL SCIENCE COURSE

This pilot has served to get an insight on to what extent blended-learning, a combination of an online e-learning platform, i.e. Oncourse, and a small-scale tutoring system, may have enhanced students' learning and motivation. Although the results are promising regarding the online feedback system and the tutorial approach there are still some areas for improvement. First of all, Oncourse options need to be upgraded to test students' understanding by creating more symbolic assignments but also through multiple choice questions. This, along with more challenging content may lead to a higher level of motivation as students will attend the tutor groups with relevant questions. Moreover, despite the fact that the tutoring system has been positively appreciated by the students, the form (groups of 8 students) and the frequency (only 1 time a week) needs to be modified into groups of up to 16 and two-hour meeting.

Blended-learning seems to be a promising tool to focus on students' conceptual understanding. Although blended-learning has been used in the instructional design of the ANS course for over the past three year, we are now exploring areas to fine-tune this approach. *Weblectures*, as short and focused pieces of lectures on specific topics, theory or concepts, and *pencasts*, as a step-by-step work-out of problem-solving approaches on physics elements, are developed at this moment as study material for the self-study time of the students.

New perspectives for a more tailor-made implementation of blended-learning are still being investigated. The firsts steps towards building a *Roadmap* for blended learning are already under construction. The implementation, careful monitoring and evaluation of this newly developed blended-learning approach will bring about new insights on teachers' roles as coaches, on the effectiveness of lectures as the red-line for the self-study time, but also on students' conceptual understanding and motivation.

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