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# Improvement of Teaching Effectiveness in Higher Education

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## Abstract

Recently, a robust tool for assessment of different teaching methodologies in engineering education has been developed by the consortium of the iTeach project (www.iteach-chemeng.eu). The tool was initially tested for its applicability in teaching units of chemical engineering education, evaluating several educational approaches used to deliver core knowledge and employability competences in different geographical and educational contexts. After some modifications, the framework was subjected to a wider testing, including teaching units that are part of other engineering disciplines, but also, extended to other higher education disciplines. In the presented case-study, the framework, including six metrics, was used in the assessment of two pedagogical approaches, practical instructions via lab and self-instruction delivery, applied in the teaching units Microbiology and Engineering Economy, respectively. Necessary data were collected by online surveys, carried out among four target groups of stakeholders, i.e. academics, employers, graduates and students. The results of this testing will be presented and discussed.

**Key words:** Teaching effectiveness, Lifelong learning, Higher education

## 1. Introduction

Engineering education plays a key role in achievement of inclusive economic, technological and cultural growth of a society. Modifications and improvements in the field of education provide skilled and competent individuals that successfully respond to the needs, and challenges of the globalized world. Thus, an engineering curriculum, except underpinning and core engineering courses, includes disciplines addressing communication skills and basic knowledge in economics, business, management and entrepreneurship [1].

High-quality education, accompanied with a satisfying relevance, and application of an adequate pedagogical approach, is the ultimate goal of higher education institutions. Achievement and maintenance of quality in education is a continuous balance between general and narrow areas of excellence. Continuous update of the engineering curricula, reflecting the newest technological achievements, as well as involvement of new engineering disciplines, ensures a high relevance of engineering programs. For the further improvement of the relevance of the engineering disciplines, it is important to develop and maintain strong relations with industry, government, and alumni association, accompanied with a continuous improvement of teachers' reputation and public image.

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Application of appropriate pedagogical approaches, tailored to the different learning styles of students, facilitates the development of the students' full potential. On the other hand, engineering programs and the pedagogical approaches that educators apply, don't enhance just the students' knowledge and employability competences, but also introduce the principle of lifelong learning [1].

Yet, some engineering educators prefer deductive types of lecturing, such as traditional ex-cathedra teaching, where the new material taught is not presented in the context of previous knowledge. This pedagogy doesn't encourage students' learning neither promotes interest or motivation for learning [2, 3]. Poor acquired knowledge and/or knowledge transferred in professional environment, results into frustrations of students and teachers, as well. Thus, practicing inductive pedagogies in class, like problem-based, product-based learning, or any student-centered style, promotes creative and critical thinking, such that the gap between teaching and students' learning styles has been reduced [4].

Furthermore, new educational concepts, accompanied by the technological innovations, have transformed the role of teachers from simple presenters of information into facilitators of learning [5]. Recently, new teaching approaches have been accepted, among which, the model of flipped classrooms, where less lecturing and more real-world activities involved has attracted big attention [1].

Moreover, some of the innovative pedagogies suggested to facilitate the teaching and learning processes are: Learning through social media such as Twitter and Facebook; Productive failure or problem-based learning, where students use previous knowledge to find possible solution, and the professor, after receiving students' answers, explains basic concepts of the problem and methods of the solution; Teachback, when a student attempts to explain what they have understood; Design thinking applies innovative context, putting students in position of a designer, performing experiment and creating prototypes; Learning from the crowd, allows allocation of teaching resources, providing information helpful for students in projects, as well as online discussion among students and sharing their work; Gamification and game-infused learning makes the learning entertaining and interactive [6].

Despite the continuous efforts for improvement of effectiveness in engineering teaching, a robust tool for evaluation of core knowledge and competency delivery hasn't been proposed yet. Mostly, the teaching effectiveness evaluation has been related to Universities [7] and academic staff rankings [8] or evaluation of the study programs by accreditation bodies [9], and it doesn't include the evaluation of the teaching methodology used.

The objective of the iTeach project (www.iteach-chemeng.eu) supported by EU Life Long Learning Programme was to develop a robust framework, that will support the assessment of teaching effectiveness of core knowledge and competences, associated to the employability of graduates in chemical engineering. After some modifications, the framework was subjected to a wider testing, including teaching units that are part of engineering disciplines, but also, extended to the branches other than chemical engineering curricula. Part of the results is presented in this study.

## 2. About the assessment framework tool

Initial review and analyses of the learning outcomes [10] of a chemical engineering education, served as a base for development of a framework related to an assessment of a whole chemical engineering formation [11], followed by establishment of an evaluation tool, associated to the effectiveness of a single teaching unit.

This framework enables easy calculation of six metrics used to evaluate the efficiency of teaching a given course. The six metrics taken into consideration are:

1. Strategic nature of the course, related to the significance of a course for the general learning outcomes of the study programme.
2. Relevance of the proposed formation, dealing with the content of the teaching unit.
3. Relevance of the proposed pedagogy, which concerns the teaching method.
4. Perception of relevance of the pedagogical approach, oriented toward the students' perception of the course, from a qualitative and organizational point of view.
5. Evaluation of acquisitions, related to the acquired knowledge, assessed after finishing the teaching unit.
6. Evaluation of transfer, concerning both, a single teaching unit and a whole formation.

## 3. Methodology

The iTeach framework tool has been tested using several courses, among which, Microbiology, as a part of 3rd year curriculum of chemical engineering, and Engineering economy, attended by the 3rd year students of Industrial Engineering at International Balkan University in Skopje, in the academic year 2016/2017. The evaluated teaching approach applied in delivering the course Microbiology was practical instructions via lab, while self-instruction delivery was used for Engineering economy.

Necessary data were collected by survey, conducted among four target groups, academics, employers, graduates and students. Online questionnaires were distributed via e-mail, using contact channels of iTeach consortium members and associate partners in Macedonia (two higher education institutions, accreditation bodies, employers, and graduates). For the course Microbiology, surveys were distributed to 50 academics (which were specifically asked to disseminate / send to other colleagues), 94 graduates (who finished the degree between 2012 and 2017), and 50 industrialists. In the case of the course Engineering economy, the questionnaires were sent out to 95 academics, 52 employers and 73 graduates. Distribution of printed versions of the questionnaires to the students, 30 for Engineering Economy, and 52 in the case of Microbiology, resulted in a bigger number of answers compared to the other stakeholders groups. Students' replies were inserted into the online questionnaires available on the iTeach official website. All metrics, except metric 5, were quantified through a series of Likert-type scale questions. For metrics 1-4 and 6, the scale applied to rank individual statements is: (5) strongly agree, (4) agree, (3) neutral, (2) disagree, (1) strongly disagree, while for metrics 5: (5) very good, (4) good, (3) average, (2) bad, (1) very bad. The resulting data were entered into iTeach tool to calculate metrics, except metric 5, using formulas [11, 12] presented in Table 1.

Metrics 5 is calculated according Eq.1, independent of the grading system used, and it is based on the students' courses and cohort average grades and standard deviations.

$$M5 = \left( \left( \left( AM_{y}^{course} \middle/ AM_{y-1,y-3}^{course} \right) \middle/ \left( AM_{y}^{cohort} \middle/ AM_{y-1,y-3}^{cohort} \right) \right) \middle/ \left( \left( SD_{y}^{course} \middle/ SD_{y-1,y-3}^{course} \right) \middle/ \left( SD_{y}^{cohort} \middle/ SD_{y-1,y-3}^{cohort} \right) \right) \right) \cdot 3 \qquad (1)$$

where, $AM_y^{course}$ and $AM_y^{cohort}$are average marks (grades) of the students obtained for the evaluated course and cohort, respectively, in the academic year of interest; $AM_{y-1,\ y-3}^{course}$ and $AM_{y-1,\ y-3}^{cohort}$ are average grades obtained for the evaluated course and cohort, respectively, in the three previous years; $SD_y^{course}$ and $SD_y^{cohort}$ are standard deviations of the average marks of the students, for the evaluated course and cohort, respectively, in the academic year of interest; $SD_{y-1,\ y-3}^{course}$ and $SD_{y-1,\ y-3}^{cohort}$ are standard deviations of average grades for the evaluated course and cohort, respectively, in the three previous years.

**Table 1.** Metrics considered in the framework

| Metric | Formula |
|---|---|
| Strategic nature of the course/discipline | M1 = (2A+G+2E)/5 |
| Relevance of the proposed formation | M2 = (2A+G+E+S)/5 |
| Pedagogical relevance of the teaching approach | M3 = (2A+2G+S)/5 |
| Perception of relevance of the pedagogical approach | M4 = S |
| Evaluation of the acquisitions | M5 |
| Evaluation of transfer | M6=(A+2G+2E)/5 |

A, G, E and S stand for Academics, Graduates, Employers, and Students, respectively.

Measures of central tendency (M, SD, Min, Max) and frequency counts were calculated for all Likert-scale type questions.
More than 80% of students and 15% of graduates invited to participate in the survey submitted their answers, for the course Engineering Economy, while for the other stakeholders' groups the number of the respondents was significantly smaller, only 2% of the academicians and 4% of the employers submitted their answers. For the course Microbiology, again more than 80% of the students, and 40% of the employers responded to the survey, and the replies from the other two stakeholder groups (academic staff and graduated) were less than 10%. Therefore, attention will be paid mostly on the results obtained from students and graduates for Engineering Economy, as well as students and employers for Microbiology.

## 4. Framework testing results

The iTeach framework was initially tested on a core course from the chemical engineering curricula, Chemical Reaction Engineering [11, 12], taking into consideration different pedagogical approaches, like traditional lectures, problem-based learning, work-based learning, recorded lectures, practical instruction via labs.
Traditional lecturing was the predominant teaching method used for both courses, where students are passively involved in the education process. The professor explains the material, sometimes asks questions (and in the most of the cases answers them), solves some problems related to the topic, and the knowledge acquired by the students is evaluated through written exams.
In the academic year 2016 / 2017, as predominant teaching methods professors were asked to implement practical instructions via lab, for the course Microbiology, and self-instruction delivery,

for the course Engineering economy. Thus, we have used the framework tool to assess the effectiveness of both teaching methods used in the courses under consideration.
Except underpinning necessary knowledge and developing essential skills, required for graduate employment, application of laboratory instructions, in addition, stimulates interest, increases motivation for scientific knowledge, and develops open mindedness and objectivity [13, 14].
At the beginning, the professor explains the aims, objectives and the learning outcomes of laboratory session, experimental procedure, as well as expected results, in addition to the written instructions, and notebook where the results and findings of the experiments have been recorded.
Self-instruction delivery included teachers concise and narrowed explanation of given topics. Students were given some tasks, and were instructed to use the tools and materials, carefully selected and prepared by the professor. The performance of the planned activity by the students undergoes a supervision of the professor [15]. The teacher monitored the students' progress during the process. It is believed that this kind of independent study would promote skills such as self-improvement, taking initiatives, increased self-confidence, as well as time-management abilities.
Results from the evaluation of the framework metrics for both courses, are summarized in the Table 2, and Figure 1.

**Table 2.** Framework metrics for the teaching units Engineering Economy and Microbiology, applying practical instructions via lab, and self-learning delivery, respectively

| Metric | Engineering Economy / Microbiology | | | | |
|---|---|---|---|---|---|
| | Academics | Graduates | Employers | Students | Overall grade |
| 1. Strategic nature of the course / discipline | 4.5 / 4.1 | 4.2 / 4.7 | 4.3 / 3.9 | - | 4.3 / 4.2 |
| 2. Relevance of the proposed formation | 4.6 / 4.4 | 4.2 / 4.1 | 4.2 / 4.1 | 3.9 / 3.9 | 4.3 / 4.2 |
| 3. Relevance of the proposed pedagogy | 4.1 / 4.1 | 4.2 / 4.5 | - | 3.8 / 3.8 | 4.1 / 4.2 |
| 4. Perception of relevance of the pedagogical approach | - | - | - | 3.8 / 3.9 | 3.8 / 3.9 |
| 5. Evaluation of acquisitions | - | - | - | 3.3 / 2.7 | 3.3 / 2.7 |
| 6. Evaluation of transfer | 4.1 / 3.9 | 4.0 / 4.4 | 3.8 / 3.8 | - | 3.9 / 4.1 |

Assigning overall scores higher than 4.0, academics, graduates and employers consider the strategic nature of both courses, metric 1, as very important. As far as the relevance of proposed formation concerns, metric 2, academic staff gave the highest (M=4.4; 4.6), and students the smallest (M=3.9) grades for both courses. The overall grades of 4.3 for Engineering economy and 4.2 for Microbiology, respectively indicates that, generally, the content of the teaching unit has been supported by all interested parties involved in the assessment. High overall scores (> 4.0) obtained for the relevance of the proposed pedagogy, metric 3, shows that basically all stakeholder groups agree with the proposed pedagogy, where again, students (M=3.8) show slight anxiety related to the teaching approaches used in both courses. The smallest overall marks are given for metric 4, related to the perception of the course by the students from a qualitative and organizational point of view, and metric 5, associated to the knowledge acquired by students and measured by evaluation of students' knowledge after finishing the teaching unit.

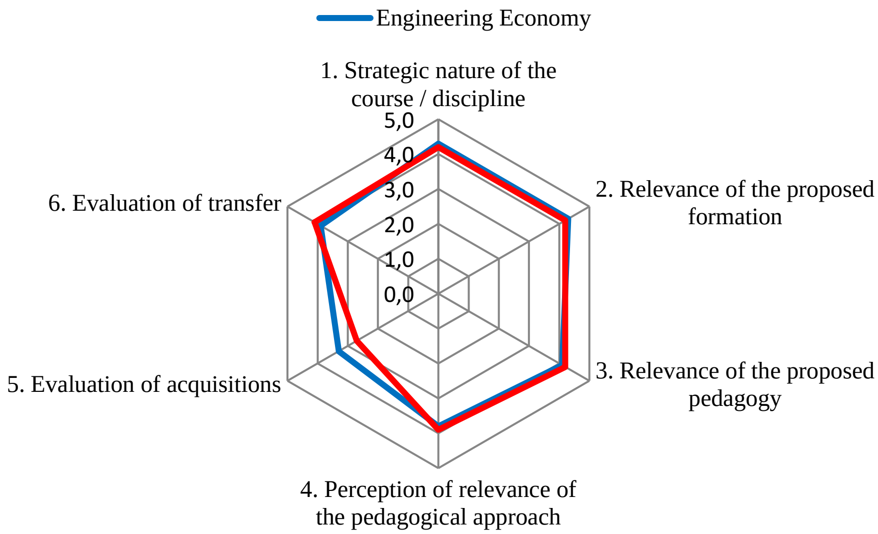


**Figure 1.** Assessment framework radar plot for the courses Microbiology and Engineering Economy, with practical instructions via lab, and self-learning delivery as teaching pedagogies applied, respectively

Assessing the whole formation, metric 6, related to the evaluation of transfer, was graded with the smallest mark by the employers (M6=3.8), the highest by academics (M6=4.1) for Engineering Economy, and graduates (M6=4.4) for the course Microbiology. All metrics assessed by the students, or influenced by the students' success in the courses under observation, were evaluated with the smallest grade. In the elaboration of each metric separately, primarily, the students' responses will be taken into consideration, accompanied by the stakeholder groups with the bigger number of responses, graduates, for the course Engineering economy, and employers, for Microbiology.

Replies of employers, for the teaching unit Microbiology, and graduates, for Engineering economy, to the questions related to the evaluation of the strategic nature of both courses, metric 1, have been presented in Fig. 2. With the values ranged between 4.0 and 4.7, graduates consider that Engineering economy is important in achievement of the global learning outcomes of the whole formation, that the course brings the needed knowledge and skills that can be applied in professional situation. Evaluating the strategic nature of the course Microbiology, with an overall grade of 3.9, employers think that the contribution of this discipline in the whole formation is very big (M=4.5; SD=0.5). On the other hand, the question related to the necessity of the future graduate profession was rated with lower score (M=3.5; SD=0.8).

Figure 3 summarizes the results for the assessment of the relevance of the proposed formation, metric 2. For the course Engineering economy, graduates, giving values between 4.0 and 4.3, agree with the content of the teaching unit, its duration, workload, ECTS, its position in the curriculum, but also with its clearly formulated learning outcomes. Students also approve the position of the teaching unit in the program (M=4.0; SD=0.8), the duration, workload and ECTS (M=4.0;

SD=1.0), but are slightly concerned with the definition of the learning outcomes (M=3.7; SD=1.2).

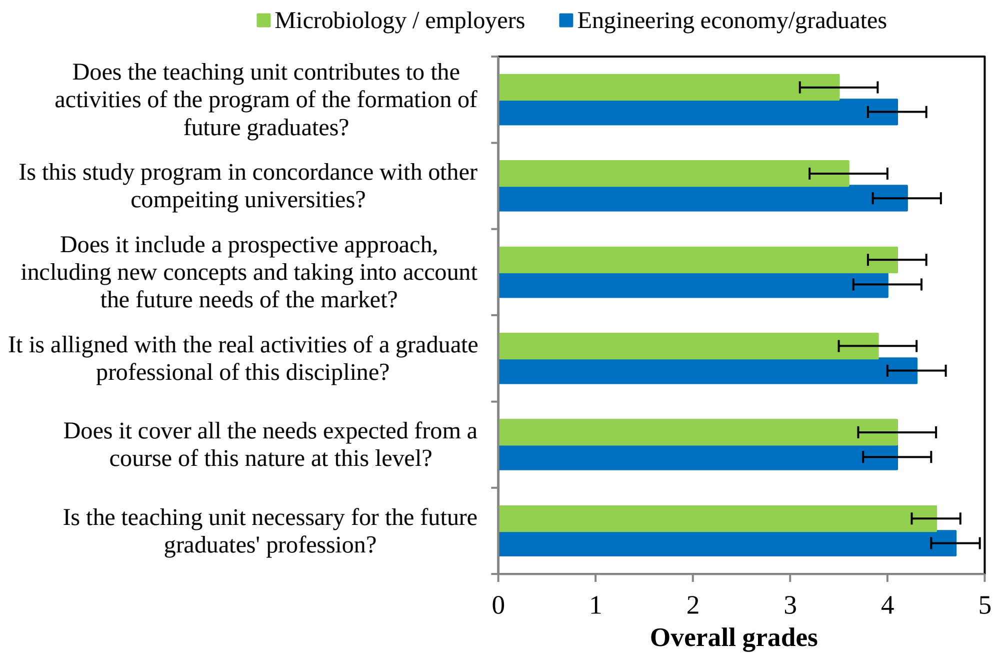


**Figure 2.** Metric 1 – Strategic nature of the course, mean values and standard deviations for both courses tested, Microbiology and Engineering Economy, practical instructions via lab, and self-learning delivery, as teaching pedagogies applied, respectively

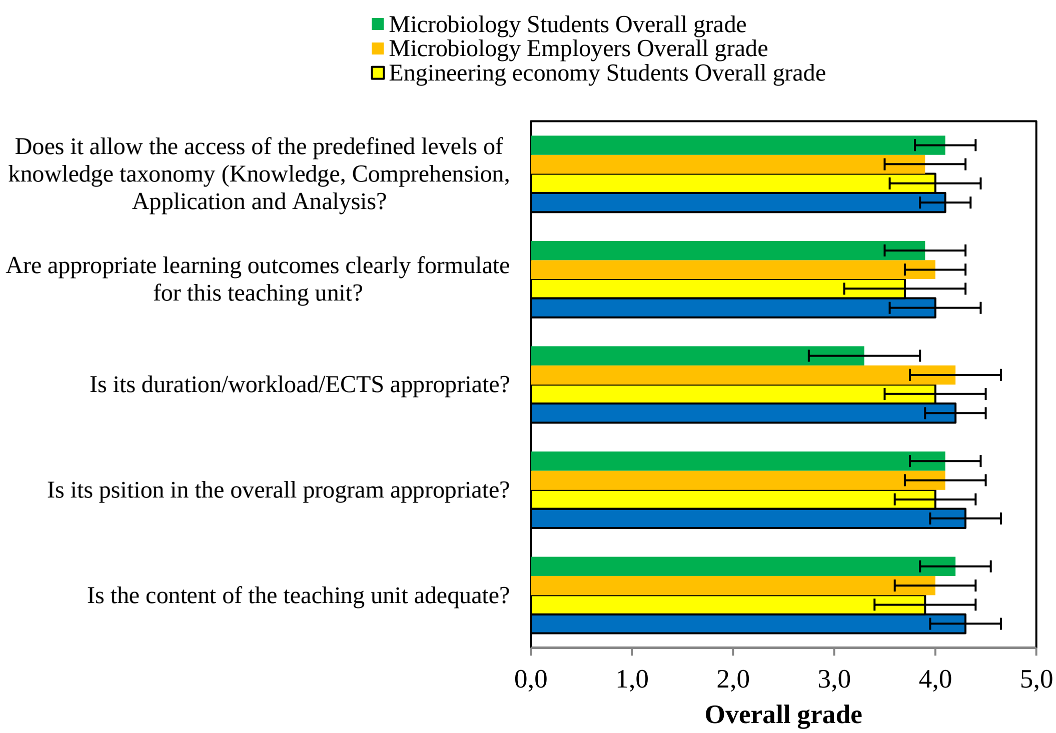

**Figure 3.** Metric 2 – Relevance of the proposed formation, mean values and standard deviations for both courses tested, Microbiology and Engineering Economy, practical instructions via lab, and self-learning delivery, as teaching pedagogies applied, respectively

Graduates, with the average score of 4.2 delivered to the metric 3 (Table 2), and grades of all questions concerning this metric ranged between 3.9 and 4.7 (Fig. 4), consider that the proposed pedagogy (self-learning delivery) in delivering the course Engineering economy, allows efficient acquisition of the skills taught and knowledge. Also, students feel that they learned something valuable (M=4.0; SD=1.1) from the course Engineering economy, and that this discipline is intellectually stimulating (M=4.0; SD=0.7), when self-learning delivery is applied. But, they have experienced that the group interactions are not encouraged in bigger extent (M=3.4; SD=1.4). As far as practical instructions via lab is concerned, students, also, learned something valuable in the course Microbiology (M=4.5; SD=1.6), but again, they think that the group interactions are not stimulated (M=3.3; SD=1.0).

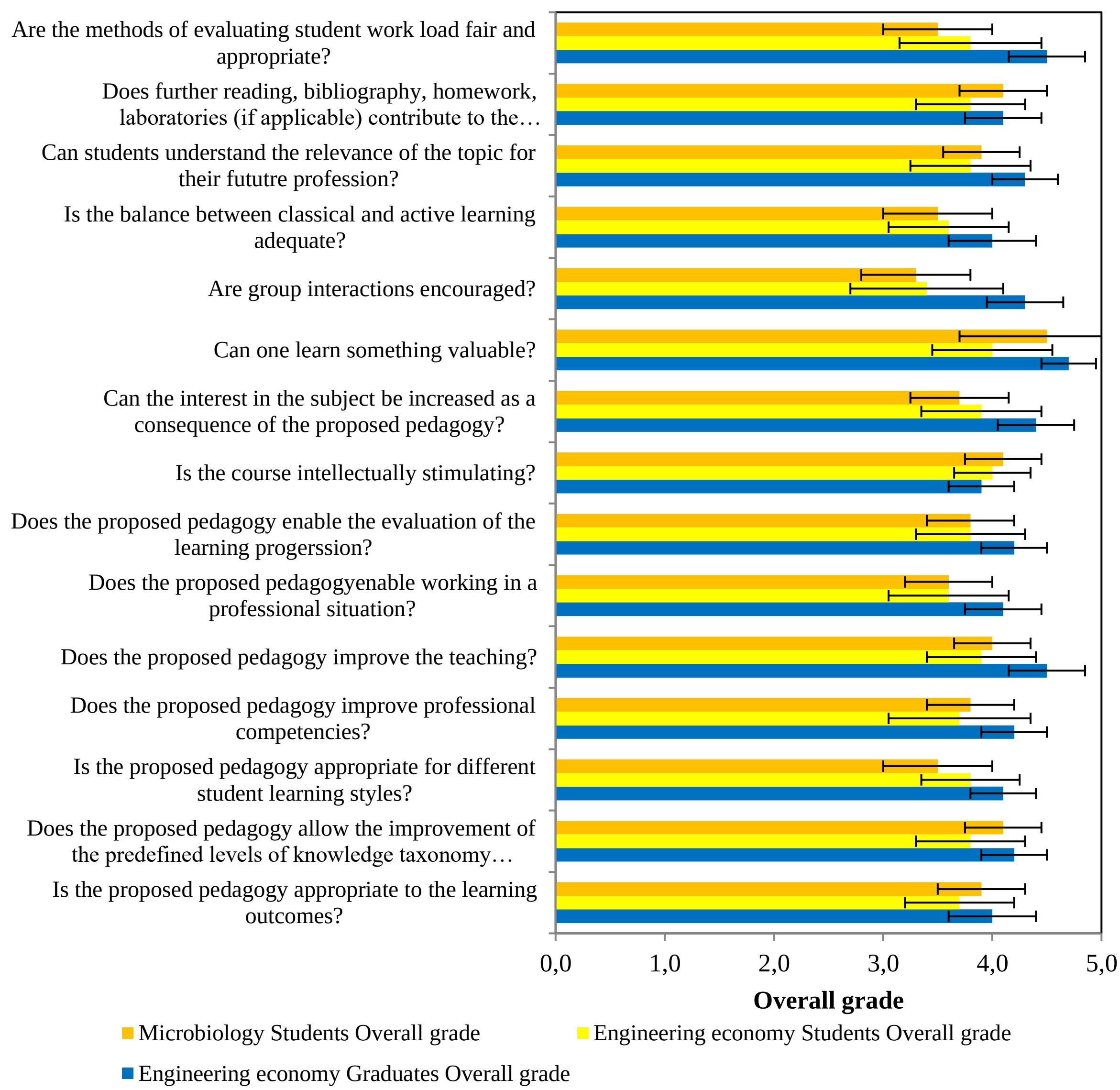

**Figure 4.** Metric 3 – Relevance of the proposed pedagogy, mean values and standard deviations for both courses tested, Microbiology and Engineering Economy, practical instructions via lab, and self-learning delivery, as teaching pedagogies applied, respectively

Fig. 5 presents the results of the students' perception of the relevance of pedagogical approach, metric 4. Students express their satisfaction with the applied pedagogical approach, self-instruction delivery, for the course Engineering economy, that it promotes their interest, and regarding the clear explanation of the teacher, allows better understanding of the subject (M=4.0; SD=0.8-1.1.2), but they do not completely agree with the appropriateness of the teaching material and resources (M=3.6; SD=1.1). With an average grade of 3.9, the students' opinion is that the practical instruction via lab has been a relevant teaching methodology in delivering knowledge and competences in Microbiology. Teacher's explanation is considered to be very clear (M=4.3; SD=0.7), but they don't fully agree that the grade obtained reflects the level of their effort, as well as their understanding for this course (M=3.5; SD=1.2).

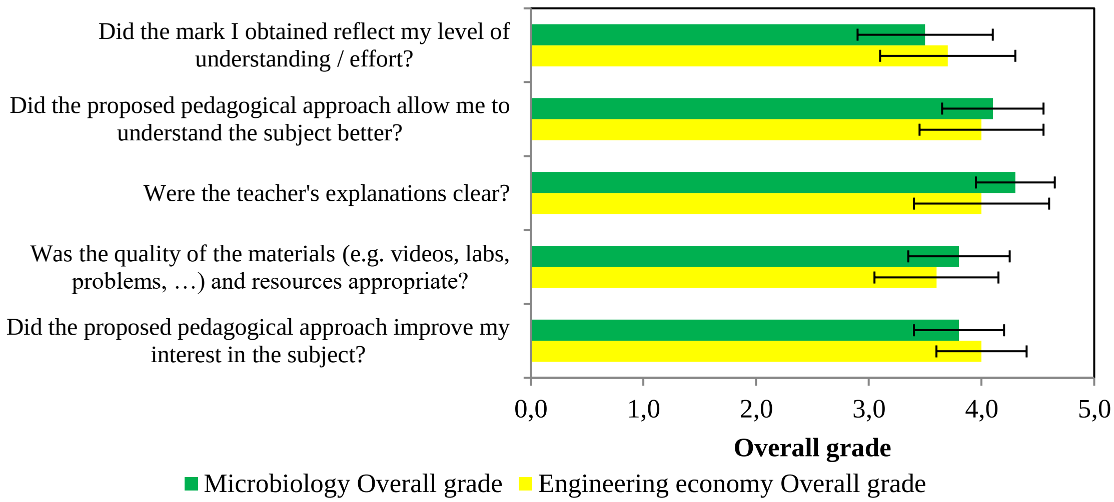


**Figure 5.** Metric 4 – Perception of relevance of pedagogical approach by the students, mean values and standard deviations for both courses tested, Microbiology and Engineering Economy, practical instructions via lab, and self-learning delivery, as teaching pedagogies applied, respectively

The lowest marks of 2.7 and 3.3 for Microbiology and Engineering economy, respectively, were obtained for metric 5 (Table 2), dealing with an evaluation of the knowledge acquisition by students, and measured by the assessment of that knowledge, using Eq.1, as soon as teaching unit ends. The value of metric 5 would be increased once students' grades would be higher than those of the cohort, but also with the decrease of standard deviation, resulted from a more uniform understanding of the cohort, or the absence of students who were lost in some parts of the course.
Students' average grades for both courses, in accordance with the Macedonian grading system, (from 5 to 10, where 5 is the failing, 6 - minimum and 10 - highest passing grades), as well as the success of cohorts in the academic year 2016 / 2017 and three years before, including standard deviations, are presented in Table 3.
Higher average grade of students in the academic year 2016 / 2017, compared to the previous year, for the course Engineering economy is observed, while the cohort' average grades in the last two years are lower compared to the previous two years. Enhancement of the students' performance in

Engineering economy, for the observed academic year (2016 / 2017), might be ascribed to the changed teaching methodology applied – self-instruction delivery. On the other hand, the increase in the average grade of students for the course Microbiology in the academic year 2016 / 2017 might be considered not just as a result of implemented methodology (practice via lab), but the improvement of the whole cohort, as well.

**Table 3**. Average grades for the courses Engineering economy and Microbiology and cohorts, with standard deviations, for the academic year 2016 / 2017, and three years before

| Academic year | Engineering economy | | | | Microbiology | | | |
|---|---|---|---|---|---|---|---|---|
| | Avg. grades | SD course | Cohort avg. grades | SD cohort | Avg. grades | SD course | Cohort avg. grades | SD cohort |
| 2016 / 2017 | 7.14 | 1.43 | 6.75 | 1.19 | 7.00 | 1.43 | 7.67 | 1.04 |
| 2015 / 2016 | 6.64 | 1.54 | 6.78 | 1.02 | 6.35 | 1.27 | 7.04 | 1.00 |
| 2014 / 2015 | 7.00 | 1.72 | 7.47 | 1.14 | 6.90 | 1.32 | 7.29 | 1.02 |
| 2013 / 2014 | 7.27 | 1.61 | 7.56 | 1.16 | 6.71 | 1.47 | 7.44 | 1.21 |

Students were asked to suggest the teaching pedagogical approach that would be more effective in delivering the knowledge and practical skills in both, Engineering economy and Microbiology. Most preferable methods of delivery for the students of Engineering economy is practical instructions via lab and traditional lectures, and part of the students are in favour of recorded lectures and work-based learning, Fig. 6. Problem-based learning and work-based learning are the choice of the students of Microbiology, accompanied by practical instructions via lab and traditional lecturing, Fig. 6.

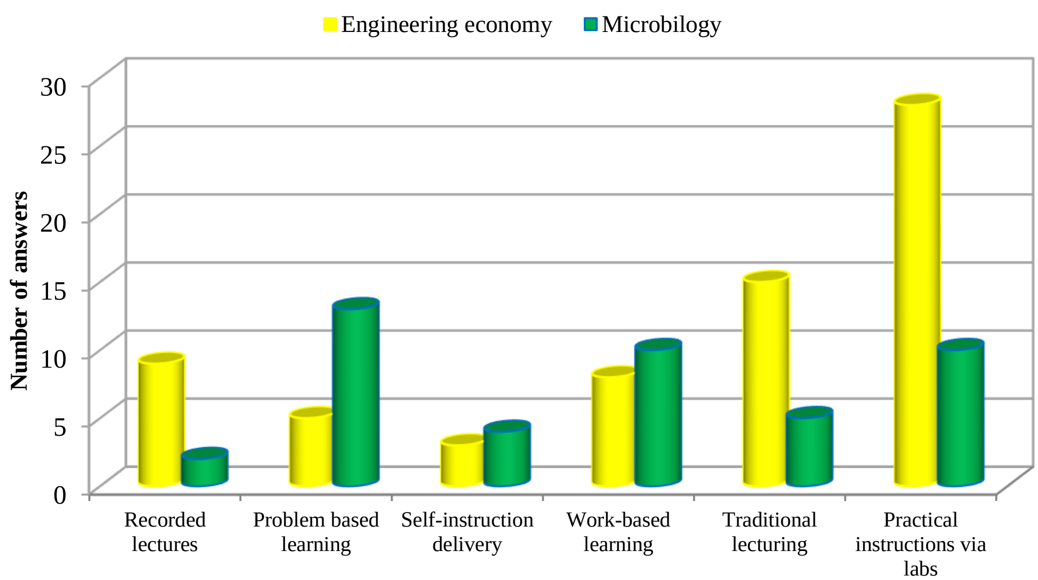


**Figure 6.** Suggested teaching and learning methods by students

As previously defined by the consortium of iTeach project, in collaboration with the stakeholders parties, academics, graduates and employers have been involved in the assessment of evaluation of the transfer, metric 6. Regarding the number of the responses received, in the elaboration of the particular questions defining metric 6, only the employers', for Microbiology and graduates opinion, for Engineering economy, is taken into consideration, Fig. 7.

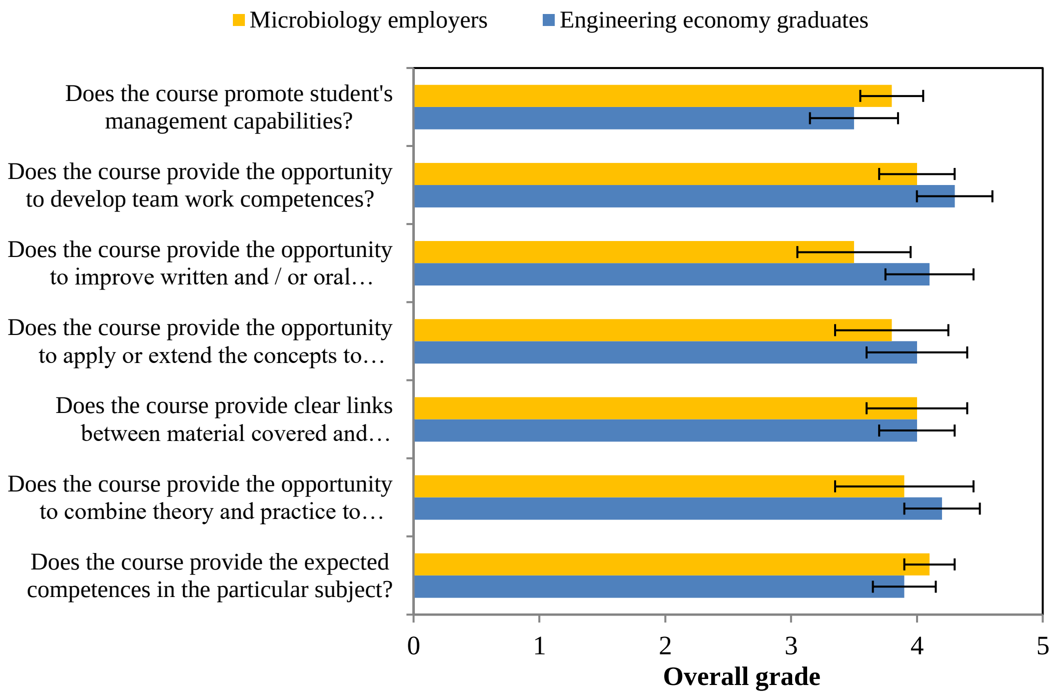


**Figure 7.** Metric 6 – Evaluation of transfer mean values and standard deviations for both courses tested, Microbiology and Engineering Economy

One of the significant characteristics of education is its flexibility and the possibility for adaptation to the requirements and changes imposed by the new modern world [16]. In addition, with the introduction of new up-to-date teaching methods, accompanied by introduction of advanced information and communication technologies in teaching and learning processes, the role of the educators has been changed from "chalk and talk" paradigm into a model of facilitators of education [17, 18].

Despite many advantages of the implementation of virtual labs and computer simulation in classes [19, 20], as well as application of teaching and learning mobiles' and smartphones' platforms [21, 22], some concerns, connected to the appearance of some negative repercussions on learners, like selfishness and wasted time, occur when online communications replace traditional face-to-face interactions between learners and educators [17, 23]. Therefore, a constant need of evaluation of teaching styles exists. In that regard, the framework tool supported by iTeach project should be of big importance in the process of assessment of teaching approaches applied, not just in the engineering education, but in other branches too.

## Conclusions

A framework tool, directed toward assessment of teaching effectiveness in the context of delivering not only core knowledge, but also employability competencies in the chemical engineering formation, has been developed and piloted [11]. An assessment tool has been applied in evaluation of diverse disciplines delivered in universities in Europe, whereas in this study, an assessment of two teaching units has been performed.

The effectiveness of self-instruction method, mainly implemented in delivering the course Engineering economy has been marked by average values of 3.7 by students' and 4.2 by graduates, while the evaluation of pedagogical approach, practical instructions via lab, has resulted with average grades of 3.6 and 3.9 assigned by students and employers, respectively. Mark 1 has been accepted as the worst and 5 as the best mark, within this evaluation. Some deficiency in the acquisition of the knowledge by students has been observed in both courses under consideration, Engineering economy and Microbiology. As suggested by students, teaching effectiveness, except with the application of practical instructions via lab and self-instruction delivery, might be improved by practicing some other methodologies, such as: recorded lectures, work-based learning, and traditional lecturing.

Even though the assessment tool developed within iTeach project has been primarily concerned with the evaluation of education in chemical engineering, the models and tactics could be applied to other areas of higher education as well.

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