Ready to Study Engineering Physics in University?

Comparison of mechanics skills between two European universities connected with engineering education

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INTRODUCTION

This manuscript gives an overall picture of freshmen students' prior knowledge in basic mechanics under the concept of force, which slightly improves after first elementary physics course. The results are compared between two universities, University of Zilina in Slovakia and Tampere University of Applied Sciences in Finland. It is presented that traditional lecturing which focuses on quantitative calculations and analysis does not improve qualitative understanding enough, if the students enter the university with light or none scientific background. It is also shown that the strongest wrong preconceptions are very difficult to correct and tend to remain misconceptions despite of teaching. Some misconceptions even got stronger after the teaching. More modern methods of teaching improve students' learning outcomes more than traditional lecturing, but the improvement in the researched student population is still too low compared to ideal.

1 MECHANICS SKILLS AND FCI TEST

Traditional methods of lecturing in front of large student group, in which students have a passive, listening role, are a tradition on university teaching. In the large-scale study (6000 students) by Hake, reported in 1998, it is shown that teaching methods including active engagement of students receive better learning results especially what comes to conceptual understanding, compared to traditional methods [1]. The study used Force Concept Inventory (FCI test) [2], which contains 30 multiple-choice questions on mechanics, to measure students' learning outcomes on Newtonian mechanics. In the Hake's study learning outcomes were seen as dependent on the teaching method, independent on gender or pre-test score. Learning outcomes were measured as average of student's fraction of possible gain in FCI test [2]. The calculation of the fraction of possible gain is presented in *eq.* (1).

$$G = \frac{\text{postscore\%} - \text{prescore\%}}{100 - \text{prescore\%}} \tag{1}$$

In Hake's paper [1] the gains lower than 0.30 were considered as low gains, gains between 0.30 and 0.60 were considered as medium gains and gains over 0.60 were considered as high gains. In Hake's study, the average gain on traditionally taught courses was 0.23 and the average of the gains from interactively taught courses was 0.48. Gains of the student groups using traditional teaching methods were all under 0.30.

Similar results have also been reported elsewhere. Schmidt's study has shown that using teaching method of Peer Instruction, the students performed in the same level in computational problems, but achieved better conceptual understanding compared to traditional method [3]. Of course engineering physics cannot concentrate purely on qualitative-level understanding, but it is worth of questioning that should the students still understand the qualitative meanings of concepts appearing as symbols in their calculations.

FCI test has also been used in comparison of entering engineering students' understanding of basic mechanics [4]. In order to study students' conceptions more precisely, the test has been used as improved test so that each of the questions also included the confidence evaluation. This means that with each question the student also answers between if (s)he is sure about the answer' correctness or if the answer is just a pure guess in a four-level Likert scale. Similar test has been used before in a study concerning the development of students' confidence when using interactive teaching methods [5, 6]. The idea is to see also behind the plain multiple-choice test result to students' awareness that if their answers are correct or not.

In the context of the improved FCI test, students' learning should be seen as increasing number of correct answers and also increasing confidence on student's correct answers and hopefully lower confidence on those answers that are non-correct.

The aim of the study is:

- To compare entering students' initial mechanics skills between two universities
- To compare the change of the skills after the first physics course.
- To compare how the students' confidence towards the answers changes after teaching and between universities

2 DATA GATHERING

The students' in the study were all first year students, just entered to the university. The students of the University of Zilina were students of the Faculty of Electrical Engineering (FEE), aiming at the academic master's degree in engineering. Students of Tampere UAS were studying either ICT Engineering, Mechanical engineering, Vehicle engineering or Building Services engineering, aiming to professional bachelor's degree in engineering.

The same FCI questionnaire including confidence evaluation to each question, translated in students' native language, was given to students as GoogleForms format before (pre-test) and after (post-test) the first elementary physics course in autumn semester 2015. In the University of Zilina the course was entitled as "The Introduction to Physics", which is organized at first term, during 13 weeks. Weekly hours, 2- 1 - 0 (lectures-exercises-labs), were implemented as presence study. The course is focused on repetition of knowledge from secondary school – preparation for the study of university course of physics. The main objectives of the course are

1. Acquiring knowledge of basic physical principles, quantities, phenomena and their simple description with use of mathematical apparatus at the level of the secondary school.
2. Applying of obtained knowledge at solving simple physical problems. Learn how to use appropriate mathematical apparatus in physics.

The contents of the "The Introduction to Physics" course includes not only mechanics contents but also contents from thermal physics and electricity. The course is followed by the courses "Physics 1" and "Physics 2" on the next semesters. Following "Physics 1" –course includes also the contents of mechanics.

In the Tampere UAS the course between pre- and post-test was entitled as "Mechanics". The contents of the course include the rigid body dynamics of translational and rotary motion, energy principle and impulse-momentum principle. The course lasted 6 weeks with total contact teaching time of 36 hours.

The total number of students' answers is presented in *Table 1*. Because answering was voluntary and the some of the answerers had left some questions unanswered, the number of answers in results calculations may be less than presented in the *Table 1*.

Table 1. The number of answers

University	Pre-test	Post test	Paired
University of Zilina	252	214	172
Tampere UAS	120	101	86

The total number of answers that could be paired (same person has made both pre- and post-test) was 172 in Univ. of Zilina and 86 in Tampere UAS. Between tests, the students in the University of Zilina were taught using traditional methods and students in Tampere UAS were taught in a way that included some, but not substantial amount of active engagement methods.

3 RESULTS

3.1 Initial mechanics skills and improvement

The number of the correct answers improved in both universities, but the improvement was smaller than expected. The percentages of correct answers in pre- and post-tests in Univ. of Zilina and Tampere UAS are presented as boxplot in *Fig.* 1.

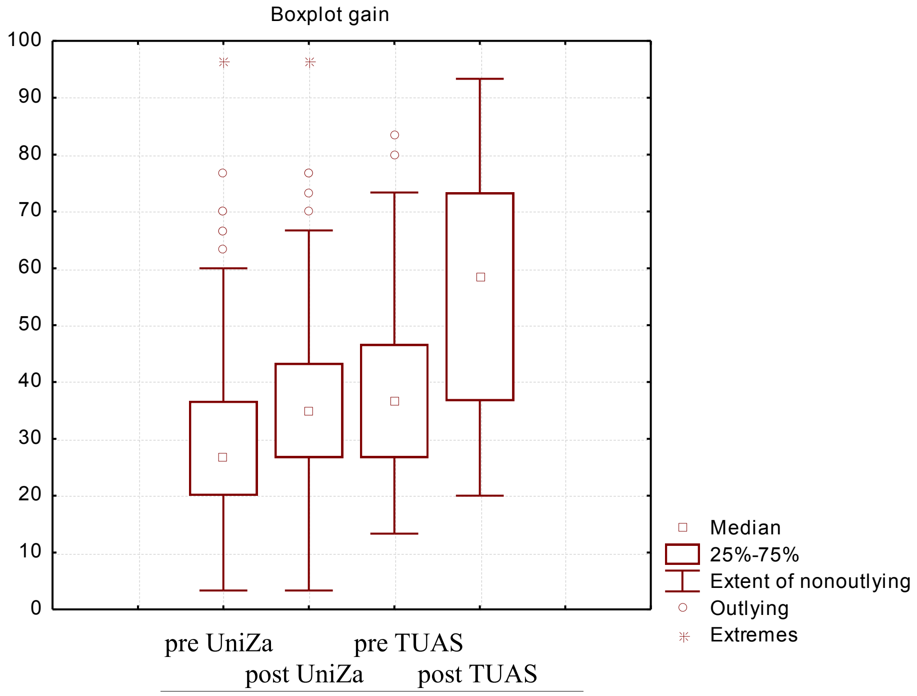

Fig. 1. Box-diagram of pre-test and post-test FCI results

From the *fig.* 1. it is seen that the percentages are slightly higher in University of Zilina, but not as high as expected. The students of the Tampere UAS start with slightly higher prior knowledge of mechanics. Their knowledge also increases more during teaching than one of the students of the Univ. of Zilina.

The other way to compare the learning outcomes between universities is to calculate the fractions of possible gains. They are presented in table 2.

Table 2. Average gain in %

University	Gain
Univ. of Zilina	10 %
Tampere UAS	27 %

As it is seen in *Table* 2 the achieved gains remain under 30 % and can be considered as low gains [1]. The gain in the Tampere UAS is higher than in the University of Zilina. The low growth of successful students from University of Zilina can be caused by the fact that only one third of the total number of students attended lectures. It is also remarkable that the course contents in the Tampere UAS is much more concentrated on the mechanics concepts than in the Univ. of Zilina

As the authors claim it is necessary to point out that 60 % of FCI test, for empirical reasons, is minimal threshold so that a student could continue in understanding Newtonian mechanics effectively. Below this threshold, a student's grasp of Newtonian concepts is insufficient for effective problem solving. Otherwise a student is not able to overcome difficulties which caused him/her misconception and thus (s)he learns physics by heart. 80 – 85 % FCI score represents the mastery level when a student thinks in terms of intentions and Newtonian physics. As the authors state such an outcome does not depend on what teacher, in what country and what kind of school (s)he teaches [2].

3.2 Confidence distributions

It is necessary to analyse not only the amounts of correct answers, but also students' confidences with their answers' correctness. Ideally thinking teaching should not only increase the amount of the correct answers, but also lead towards better confidence that the answer that is given is correct or not. The students' pre- and post- confidence distributions from both universities are presented in *Fig.* 2 – 3*.* In the following figures the sureness means students' own sureness towards the answers' correctness.

Fig. 2. Confidence distribution, Tampere UAS Pre-post

The pre- and post- confidence distributions of the Tampere UAS presented in Fig. 2. reveal that in pre-test the distributions are quite similar despite of the answers' correctness. However, in the post-test the confidence distributions are different. The correct answers collect much higher confidence evaluations compared to the wrong answers. In terms of learning, this points that the students are mora aware of their correct thinking.

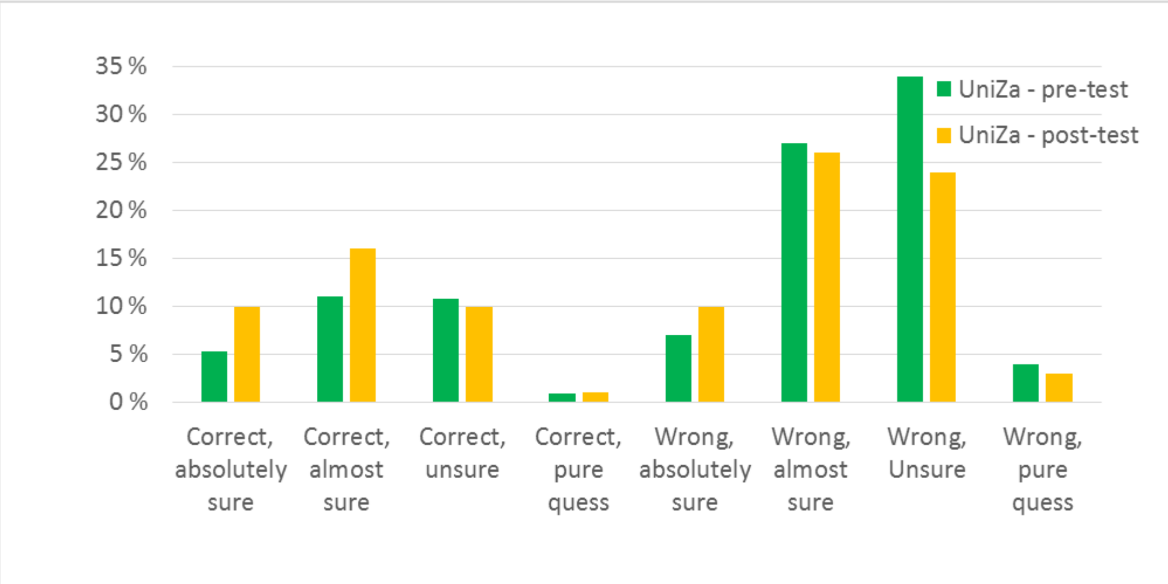

Fig. 3. Confidence distribution, Univ. of Zilina Pre-post

The pre- and post- confidence distributions of the Univ. of Zilina presented in *Fig*. 3. show that in pre-test the confidence distributions are very similar despite of the answers' correctness. As a difference from the Tampere UAS, the similarity in the confidence distributions still remains in the post test.

To compare confidence distributions between universities, in *Fig*. 4. pre-test confidences of both universities and in *Fig*. 5 post-test confidences of both universities are presented.

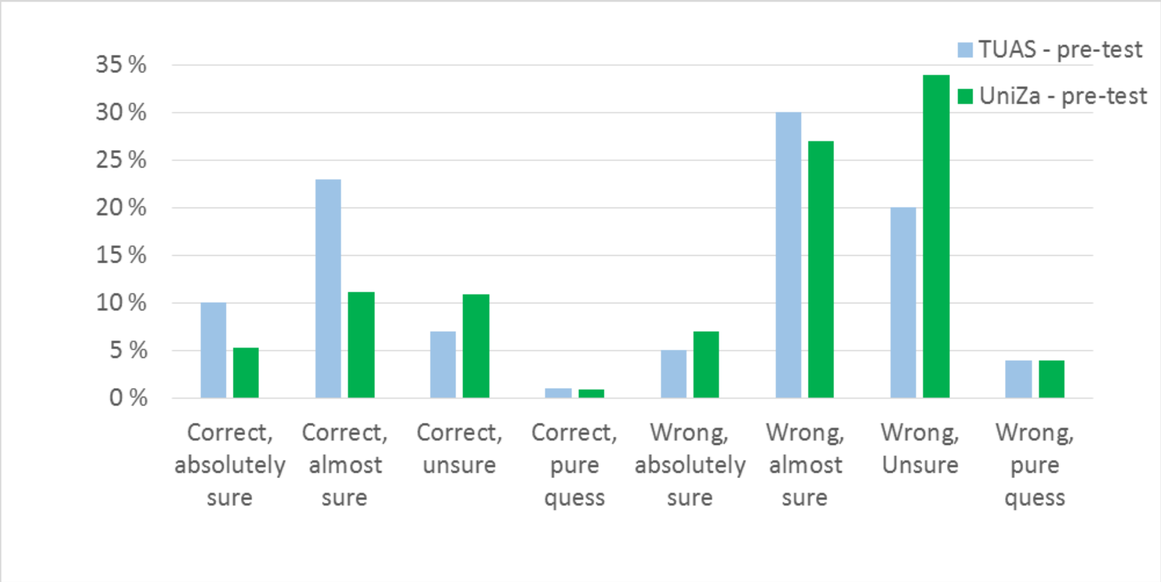

Fig. 4. Confidence distribution, Univ. of Zilina and Tampere UAS Pre

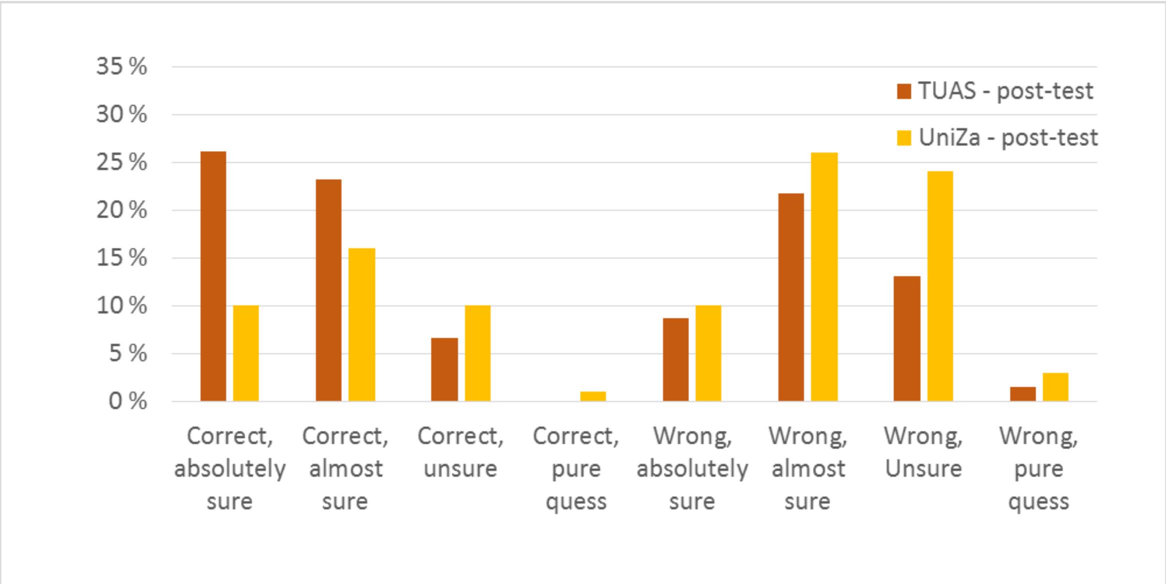

Fig. 5. Confidence distribution, Univ. of Zilina and Tampere UAS Post

In *Fig*. 4 it can be seen that the confidence distributions of both universities are almost alike in the pre-test. The students of the Tampere UAS assess their confidence towards their answers' correctness slightly higher than the students of the University of Zilina, despite of the real correctness of their answers.

In *Fig*. 5 it can be seen that the confidence distributions of the students' correct answers are different between the universities. The distribution of the Tampere UAS is definitely skew towards better confidences, while the same distribution from the Univ.

of Zilina remains more normally distributed and quite alike compared to the wrong answers. The confidence distributions of the wrong answers are similar between universities.

4 CONCLUSIONS AND FURTHER DEVELOPMENT

The students of the University of Zilina achieve slightly higher learning results compared to Tampere UAS. This may be partially explained by the use of active engagement methods at the Tampere UAS, but there may be a lot of other explaining things, like the course in the Tampere UAS is more concentrated to concepts of mechanics. It is also remarkable that the attendance to lectures in the Univ. of Zilina was low. The suggestions as interventions in order to improve the situation are similar or parallel to suggestions presented in [7]. The better results of students' conceptual understanding in mechanics can be achieved using more activating methods in introductory physics education [8].

The confidence evaluation in which students assess how sure they are that their answer is correct, gives another perspective to students' skills. In pre-test it reveals how deep the student's preconception is and in post-test it tells the student's self-assessment of the depth of his/her knowledge. The confidence assessment is seen as important tool to enhance the students' ability to assess the correctness of their knowledge and also stop the student to think his/her reasoning during the multiple choice test.

Our research has pointed to the fact that students do have difficulties with understanding basic concepts of mechanics at the entering stage to university. Knowledge of relationships between concepts, physical principles and real world is also often weak. In the future it could be worth of comparing answers and confidences of individual questions. It is assumed that it would show that there are some questions, in which students have a lot of erroneous preconceptions and still after semester misconceptions. In this case, the use of conceptual pre-tests, which include the confidence evaluation, may help the lecturer to re-schedule the contents of the course. More lecture or activity time can be used with the contents of which students have the most non-correct preconceptions. Especially on those in which students are absolutely sure that their wrong answers are the correct ones.

In the future colleagues from Univ. of Zilina would like to prepare Introductory Summer Course of Physics which would deal with the students' lack of knowledge from secondary schools and prepare them for studying at the university [9]. We assume that with the help of this course and interactive way of teaching physics, it would be possible not only to eliminate the dropout of first year students, but also to improve their level of knowledge in the course of general physics, mainly in the field of mechanics as it was confirmed in Tampere UAS.

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