# Comparison of the Entering Students' FCI Results – Tampere UAS and University of Žilina

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## INTRODUCTION

The Force Concept Inventory (FCI-test) is largely used conceptual test concerning introductory mechanics concepts [1]. It can be used to measure the effectiveness of different models of teaching [2] or to monitor the preconceptions, misconceptions and development of the students' conceptual understanding on introductory mechanics.

The students entering the engineering studies have very heterogeneous background in physics. In Tampere University of Applied Sciences (Finland) a student may enter engineering studies either from the upper secondary school (3 – 4 years at the age of 15 - 19) having secondary school physics studies between 1 to 10 courses, meaning the maximum amount of 5 hours a week during 2,5 years. Students can enter engineering studies also from the vocational school (about 3 years at the age of 15 - 19), having merely no obligatory physics at all.

In the University of Žilina (Slovakia), entering students enter the university studies either from secondary "professional" school, e.g. "Secondary School of Electrical Engineering", or from grammar schools. Physics background between schools is very different; in grammar school, students have the opportunity to attend 5-11 classes a week per 4 year studies (1-2 lessons a week in each grade, plus extra optional laboratory lessons mostly in the last two grades of studies) while students at secondary "professional" schools may have only 2 classes a week per 4 year studies

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or no physics at all. Therefore it is very important to recognize the students' prior conceptual knowledge of physics before entering the engineering physics studies.

In the paper, the results of the FCI test scores measured before the start of the engineering studies between the student group of Tampere UAS and the student group of University of Žilina, are presented. The results of the test show that the conceptual understanding varies a lot between students inside the universities, but mainly the results between university students of the same educational history are the same. Some other similarities and differences are studied and discussed.

## 1 PURPOSE OF THE STUDY

This study aimed to investigate the entering engineering students' prior knowledge in key concepts of mechanics in introductory physics and to find the similarities and differences between countries and students' educational background. Results can be used to help students to improve their performance in Physics (kinematics of particle, dynamics of particle, Newtonian mechanics, work and energy, momentum, impulse, etc.). At the beginning, we have to identify existing misconceptions using conceptual pre-test - FCI test.

The teaching process in Žilina after the pre-test, is performed in the traditional way, i.e. the students at the first year of the Faculty of Operation and Economics of Transport and Communications (FOE) (first semester) and of Faculty of Civil Engineering (FCE) and Faculty of Electrical Engineering (FEE) (second semester) (aged 19–20) took part in 13 lectures and 13 seminars within a semester. The lectures focused on individual physics topics and were subsequently followed by the seminars aimed at quantitative task solving.

The teaching process in Tampere, after the pre-test, is performed in a period of 7 weeks including 36 hours of activating lectures including weekly assessed measurement assignments or week exams, following the ideas of study method described in [3]. The contents of the lectures included both conceptual- and quantitative problem-solving elements. The quantitative elements are performed mostly in algebra-based level, not in calculus-based level, because the studentsof the study aimed to professional, non-academic bachelor-level degree in ICT-engineering.

## 2 FCI TEST AND DATA GATHERING

The FCI test consists of 30 multiple questions assessing the concept of force and Newton laws that highlights the common misconception about motion and force through 6 dimensions: kinematics, Newton's Three Laws of Motions, types of forces and superposition principle [1]. It has been widely used as a practical way to test learning and teaching methodologies in physics. The FCI is available online in many languages (http://modeling.asu.edu/R&E/Research.html).

The pre-test in Žilina was carried out at the beginning of the winter (FOE, FEE) and summer (FCE) semester of 2013 and 2014. 117 (FOE), 97 (FCE) and 25 (FEE) students (about 20 % from grammar schools and 80% from secondary schools) took part in the test during the introductory seminar; the test took about 30 - 40 minutes (it depended on individual students). Students were answering by means of printed version of tests, each student solving the same number of questions. Test results were collected and subsequently stored for further processing.

The pre-test in Tampere was carried out at the beginning of the autumn semester 2014 at the first physics lecture on two different student groups. The students answered using paper form of the test. The test took about 40 minutes. 81 students studying ICT engineering answered the test. The 36 of the answered students came from vocational school background and 45 of the answered students came from secondary school background. The test results were collected and stored for further processing.

## 3 RESULTS AND ANALYSIS

The percentages of the students' correct answers to individual questions are presented in *Fig. 1* and *Fig. 2*. There are some questions, in which students have a lot of erroneous preconceptions. The answers give the impression that students could have serious problems with elementary physics at the very beginning of their studies.

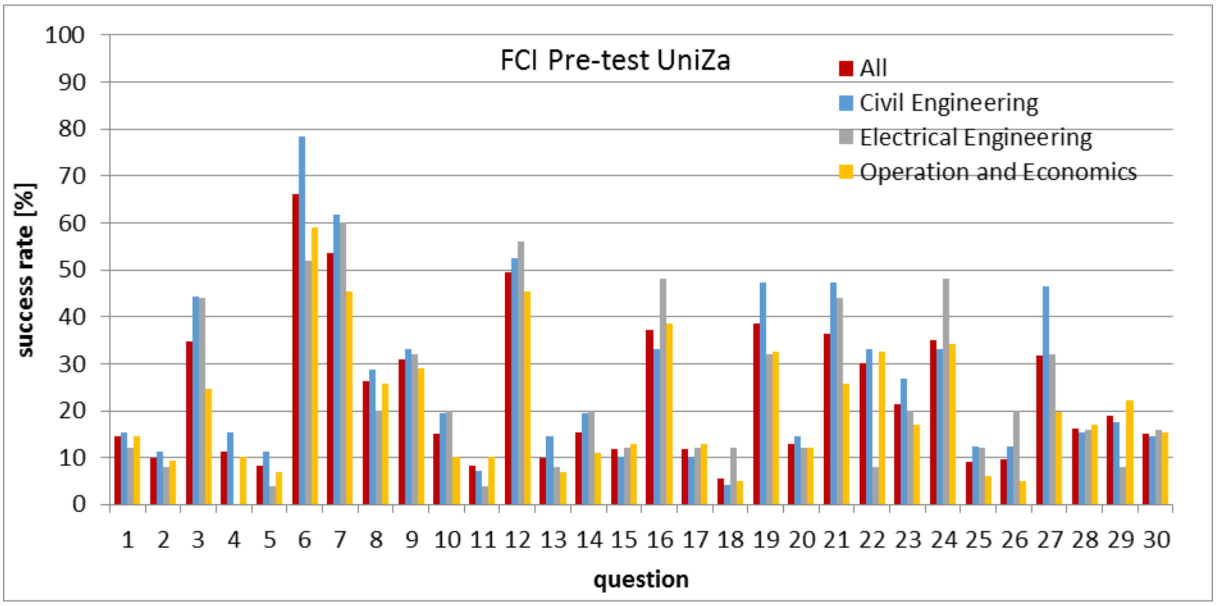


*Fig. 1. FCI – Pre-test (Žilina)*

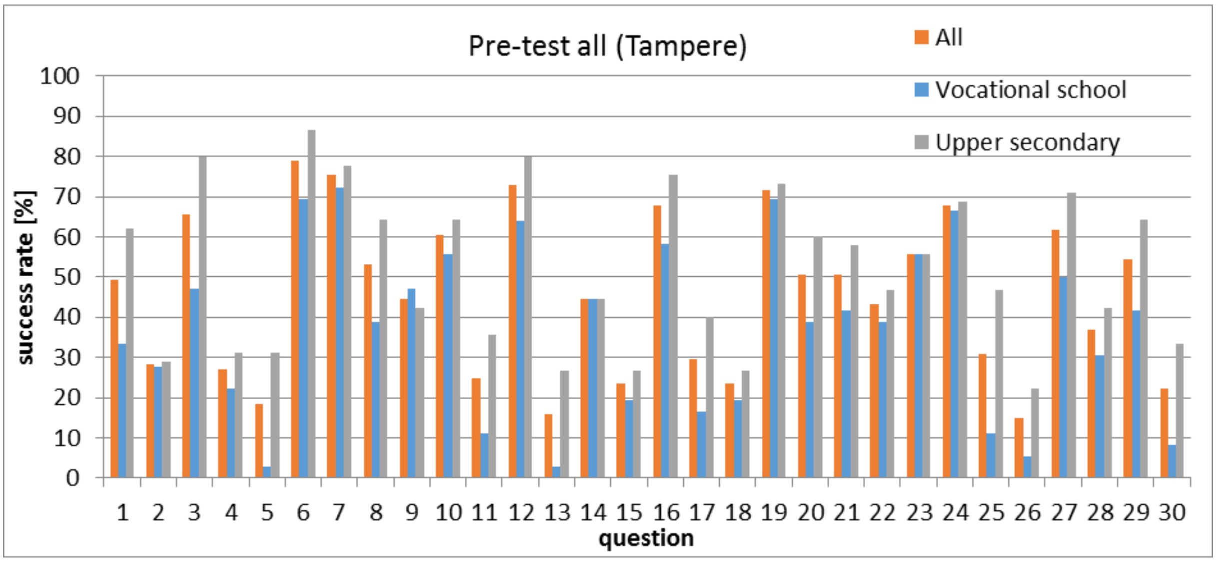


*Fig. 2. FCI – Pre-test (Tampere)*

In comparison with the results of the individual questions between University of Žilina and Tampere UAS, the distribution of the percentages of the correct answers in *Fig. 1* and *Fig. 2* is quite similar. Students of the university of Tampere have slightly higher percentages overall, but the same questions seem to cause difficulties to the students of the both universities. This confirms the observation that the commonsense beliefs about mechanics are relatively similar in different countries.

In *Fig. 1* (Pre-test in Zilina) it is shown that there are differences in FCI-test performance between students who have different educational backgrounds. Students from the Faculty of Operation and Economics of Transport and Communications have not had any obligatory physics course in vocational school. Students from Faculty of Civil Engineering have had 2 classes of physics in a week for 1- 2 years).

In *Fig. 2* (Pre-test in Tampere) it is shown that there is a clear difference in FCI-test performance between students who have different educational backgrounds, vocational school or upper secondary school, on almost all of the questions, especially 5, 13, 26 and 30.

The questions in which students encounter more difficulties in both universities seem to be questions 2, 4, 5, 11, 13, 15, 17, 18, 25, 26, 30. The subjects of the questions are presented in *Table 1*.

*Table 1.* Subjects of the difficult questions

| Subject | Questions |
|---|---|
| Recognition of the forces acting in given situation | 5, 11, 13, 17, 18, 25, 30 |
| Newton's third law | 4, 15 |
| Movement under given forces (Newton's second law) | 2, 26 |

As it is seen from *Table 1*, seven of these questions in which students encounter major difficulties and are getting less correct answers are connected with recognizing the forces acting in a described situation. The common misconception connected to these questions is that movement always requires a force acting to the direction of movement. Low scores in the question 13 reveals the misconception of force persistence after contact. In the questions 17 and 30 the misconception is typically an idea that upward movement is determined by stronger force in that sense. In the questions 25 and 26 misconception is typically related to problems with the Newton's Second Law in a situation in which acceleration is zero. The other questions showing major difficulties also deal with very elementary principles of introductory physics.

In *Fig 1.* and *Fig. 2* is seen, that questions 6, 7, 12, 19, 21 and 24 get more correct answers than the others. Common to these questions is that most of their subject consist the movement of the object in certain condition and they are more connected to kinematics than the other questions.

As authors of FCI test declare, the Force Concept Inventory as a whole is a very good detector of Newtonian thinking. But "errors" on the Inventory are more informative than "correct" choices [1]. This leads to idea to analyse students' misconceptions through their incorrect answers to the test in the future.

Students' overall success in FCI pre-test (University of Žilina and Tampere UAS) is presented as boxplot in *Fig. 3.* From the *Fig. 3* it is seen that the students of the Tampere UAS have slightly higher scores on the FCI pre-test. In comparison to the results reported by Hestenes [1] it can be seen that the results given the study may vary between 27% and 73% for the pre-test application of the FCI.

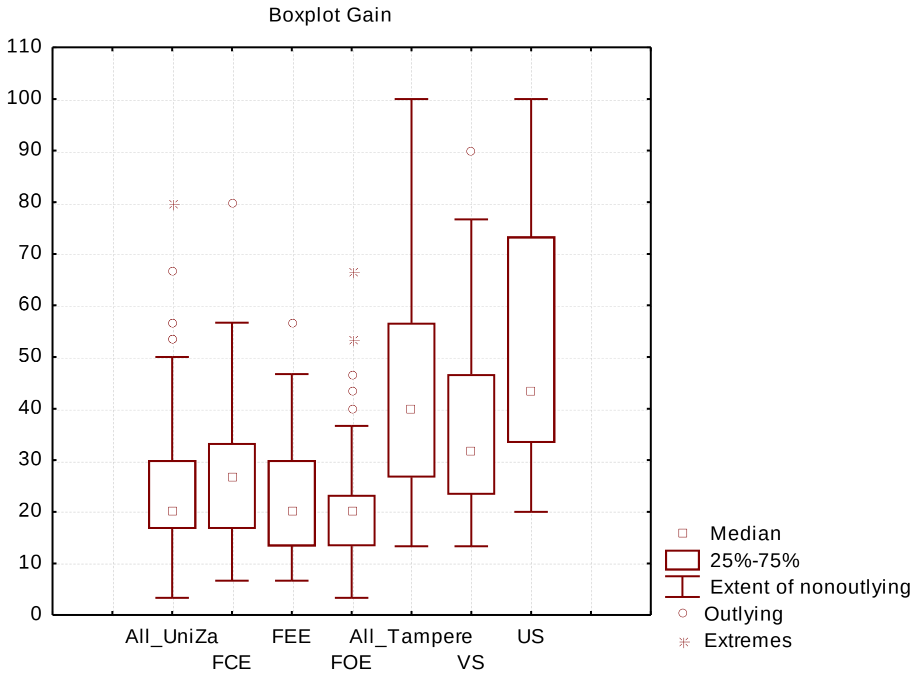


*Fig. 3. Boxplot Gain of Pre-test results (FCE – Faculty of Civil Engineering, FEE – Faculty of Electrical Engineering, FOE – Faculty of Operation and Economies of Transport and Communications, VS - vocational school, US – Upper secondary)*

We suppose that for the students with lower level of FCI score, it is necessary to prepare academic intervention in order to encance students' expertise concerning physics, the underpinning subject, the basis in technology. Next year's freshmen in University of Žilina from FOE will start with Physics in second semester and in first semester they can improve their physics background by attending the course „Introduction to Physics". Similar posibilities are prepared for students in FCE and FEE already, on academic year 2014 - 2015 year they can choose the course – „Introduction to Physics" on the first semester.

## 4 DISCUSSION

Our research has pointed to the fact that students do have difficulties understanding basic concepts of mechanics at the entering stage to university on both countries. Knowledge of relationships between concepts, physical principles and real world is also often weak.

As Hestenes [1] concluded, it has been established that

(1) Commonsense beliefs about motion and force are incompatible with Newtonian concepts in most respects,

(2) Conventional physics instruction produces little change in these beliefs,

(3) This result is independent of the instructor and the mode of instruction.

Authors further note that the first impression of most physics teachers is that the FCI questions are too trivial. This turns to shock when they discover how poorly their own students perform on it [1].

If we want to achieve better results with current student quality, it is seems to be necessary to use more effective, interactive methods and to focus more on active and creative, more conceptual approach in order to enhance the students' expertise rapidly in the beginning of their studies. The approach is also supported by many other authors [2], [4 - 6]. Presented results suggest that problem-based learning, project-based learning, internet-supported learning, video-based problems, P&E method, conceptual question application, interactive engagement methods, model-based introductory physics curriculum, and other inquiry-based teaching methods enhance higher order cognitive skills and that students do better than those attending traditional lecture-lab type instruction.

There are many studies that widely apply computer animations and simulations, Physlets, and other computer-assisted tools in science education [3], [5], [7 - 16]. As Akpınar [8] has proved by his study, the use of animation in education increased conceptual understanding by promoting the formation of dynamic mental models of phenomena. Williamson and Abraham [17] reported in their study that computer animation had a more positive effect on students' conceptual understanding than traditional instruction. Kelly and Jones [18] showed that animations improved some students' concepts scientifically; however, some prior misconceptions of the students sustained. And moreover, new misconceptions appeared. Zacharia and Constantinou [9] used Physlets to investigate the effects of experimenting with physical or virtual manipulatives and found out that both modes of experimentation were equally effective in enhancing students' conceptual understanding. Chen et al. [19] explored the effects of predict-observe-explain (POE) method and simulation-based learning strategies on correcting misconceptions and improving learning performance. The study proved improvement in learning performance and abatement of misconceptions.

Video analysis and simulations (VAS method) of problem tasks using interactive programme Tracker is one of the methods that considerably helps to form conceptual thinking and at the same time eliminating misconceptions, to develop manual skills and intellectual capabilities of students [20, 21].

In the study, a post-test was not carried out. In the future, the influence of using different teaching methods to enhance students' conceptual knowledge in introductory physics will be tested using pre-test – post-test setup.

## 5 SUMMARY

The results of the study can be summarized as following:

- Similar types of misconceptions in elementary mechanics are found from both countries.
- The prior knowledge of introductory physics of the students entering the universities is heterogeneous and weak.
- The prior educational background seems to be one of the major explanations to heterogeneous level of knowledge. The students entering the engineering studies without secondary school physics studies (no obligatory physics) achieved lower scores on the FCI pre-test.

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