MEASURING KNOWLEDGE GROWTH FOR INDIVIDUAL BACHELOR STUDENTS AT SCIENCE COURSES OF UNIVERSITY OF LATVIA

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Abstract

The purpose of this study is to measure the development of students' conceptual understanding of basic physics concepts at introductory physics courses at the University of Latvia. The authors of the research have translated, tested and verified the Force Concept Inventory and other Concept Inventories in the context of Latvian education system. The results demonstrated a low improvement of physics understanding using present lecturing approach, which suggests the need for an active learning environment and student-centred learning approach in physics courses at University of Latvia. Due to the very small number of physics graduates from physics faculties in Latvia and especially small number of physics teachers, it becomes increasingly important that these students acquire good conceptual understanding of physics.
Keywords: *STEM education, conceptual understanding, evidence-based approaches*.

Introduction

Latvia is in a transition state with respect to the implementations of STEM education research into the study programs. On the one hand, a new, uniform education concept is being developed in the country, from pre-primary to high school. The need for reform has been demonstrated by the results of the OECD (2019, 07 May) as well as the demand of today's labour market. On the other hand, it is unclear whether university science faculties are ready for such a reform. There is scepticism among lecturers towards active-learning methods that are shown by physics education research to be more efficient than lecturing (Lasry, Watkins, Mazur, & Ibrahim, 2013). Lecturers, for a variety of reasons, avoid measuring the growth of knowledge and the growth of understanding of their students, at the same time expressing doubts about students' understanding of the basic laws of physics. However, these concerns are based only on the subjective views of lecturers, not on any measurements. The authors of this study are not aware of the measurements of student conceptual knowledge development in physics courses at Latvian universities using Concept Inventories widely used by physics education research worldwide. The Force Concept Inventory and other Concept Inventories were translated and tested, in order to measure the student's understanding of basic concepts of physics and the effectiveness of learning process during the bachelor physics courses. The results obtained are in accord with the results obtained by other physics education research groups.

Research Methodology

General Background

To compare the growth of the conceptual knowledge of students in Latvia to students elsewhere in the world, the Force Concept Inventory (*FCI*) was used. FCI was developed and first applied by Hestenes, Wells and Swackhamer (1992, March). Nowadays, the *FCI* has been administered to more than a hundred thousand students at many universities worldwide and as the research by Von Korff et al. (2016) suggests, interactive engagement teaching techniques are significantly more likely to produce high student learning gains than traditional lecturing approach.

Participants

Students of physics bachelor's course in the autumn semester of 2018 of the University of Latvia were involved in the research. 52 students participated in the study, however, only 29 students did all the phases of the test. The results presented here are for these students participating in all phases of the test.

All participants had a high-school general physics course education before being accepted to the university and all have passed the centralized exam at the end of high school. Participants were 18–20 years old, 48% were female and 52% male.

Research Design

The *FCI* test was translated and tested on faculty members for error correction. In the first physics lesson the *FCI* pre-tests were completed by all students. The translated test preserves the original *FCI* multiple-choice test format. Test conditions and time limit was set and strictly observed (Hestenes et al., 1992). Lecturers did not see the questions of the tests in order to avoid preparing the students to post-test. However, the lecturers were able to learn which students have a better or weaker knowledge of physics. Information on how students answer questions about the specific topics of the mechanics was also available to lecturers. Therefore, the pre-test was a starting diagnostic of student initial knowledge and understanding. At the end of the course, students answered the post-test questions, which were the same as pre-test questions.

The effectiveness of teaching is characterized by gain, , that is calculated as

$$<g>=\frac{<Post>-<Pre>}{100-<Pre>},$$

where *<Post>* is group average post-test result and *<Pre>* is group average pre-test result. The gain can be understood as relative increase of the student knowledge between pre-test and post-test with respect to the maximal possible increase. In other words, the gain can be interpreted as potential growth that has been achieved relatively to the maximum possible outcome. The average gain $<g>$ between 0 to 34% (Hestenes et al., 1992; Lasry et al., 2013) indicates a typical for traditional teaching approach and low student engagement.

Hestenes and Halloun, 1995 showed the level of the understanding of the mechanics is characterized by the test score. High level of understanding of the mechanics corresponds to the result in the test of 80—100% range, 60—80% range is shown by students with an understanding of the basic concepts of Newton mechanics. A third of the group with the score below 60% has a very low understanding of the mechanics.

Research Results

The calculated normalized gain of the group:

$$< g > = \frac{<Post> - <Pre>}{100 - <Pre>} = \frac{65-54}{100-54} = \frac{11\%}{46\%} = 23\% \text{ (Standard deviation 11\%)}$$

The group's average gain <g> of students at University of Latvia belongs to the group of results that demonstrate low learning effectiveness, see Figure 1. As demonstrated by other research groups (Hestenes et al., 1992; Lasry et al., 2013), our students demonstrate the gain typical to the traditional learning approach, which results in low student knowledge growth during the course.

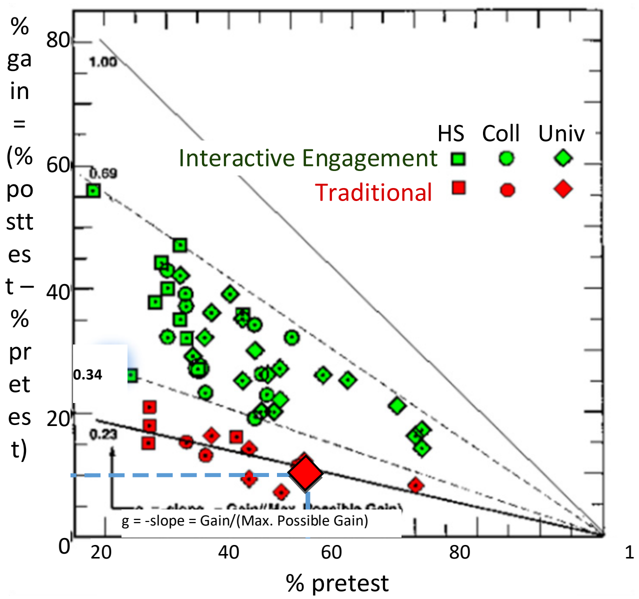

Figure 1. Test results at the University of Latvia, large red diamond, compared to the data of the research of Hestenes et. all (1992). Adapted from Hestenes et. all (1992).

To interpret the individual growth for each student, the level of the understanding of the mechanics was analysed. (Hestenes & Halloun, 1995). Only a small part of students had demonstrated high understanding of the mechanics, see Figure 2. Other students with low understanding of basic concepts of physics are not prepared to acquiring more complicated physics concepts in their further studies.

The correlation between the following parameters: enrolment exam scores at the university and whether the student continued studies in the 2-nd semester was additionally explored. No correlation between these parameters was found.

The research also yielded some unexpected results. For most of students' improvement was as expected – about 20—40 %. Surprisingly several students have shown a negative gain.

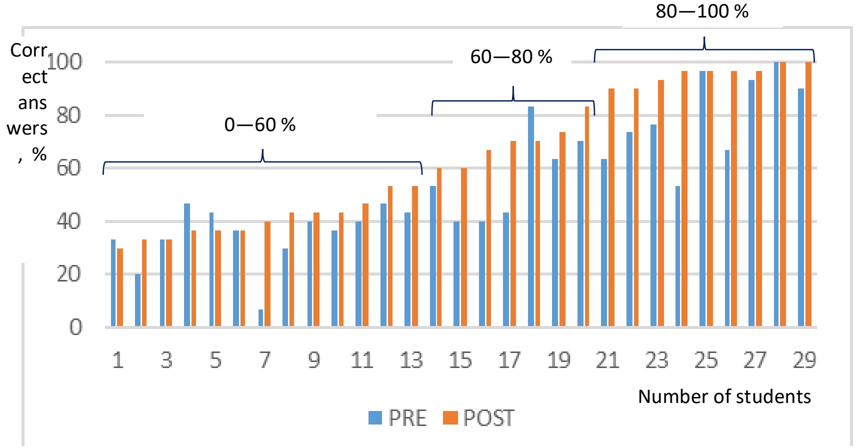

Figure 2. Individual results of students' pre and post test – only third of students have understanding of basic physics laws at the end of the course.
Data of University of Latvia, physics bachelors group, 2018 Full semester.

The research was repeated and the results were compared with a measurement in another university of Latvia – Ventspils University, a general physics course for students of the Bachelor of Electrical Engineering and Radio Electronics for the autumn semester of 2018. The result showed similar 24% gain. In addition to the Force Concept inventory test, it was also performed the gain measurement in the electrodynamics course. A measurement is currently being made for the course of the thermodynamics in the spring semester 2019.

Analysis of Results

Comparing the gain in University of Latvia to the results obtained in recent years elsewhere in the world, it can be seen that students in Latvia show a low result. For example, Georgia States Universities, US, recent study using *FCI* test included more than 5,000 students. The results show the average gain that range from 47.4% up to 71.3%. (Caballero, Greco, Murray, Bujak, & Marr, 2012). In turn in the research at the University of Toronto first year Physics course (Lasry, Watkins, Mazur, & Ibrahim, 2013) gives gains values of 45.02% for the fall session and 34.03% for the summer session. The research conducted in the Physics and Astronomy New Faculty Workshop (Lee, Manju, Dancy, Henderson, & Christensen, 2018) the average gain between 40-60% was measured. The University of Latvia's result is below these results obtained in recent years.

Conclusions and Implications

The students from the University of Latvia physics course showed the results that present challenges for the traditional lecturers. The results of the present research demonstrated the need for student engagement in the process of learning and student-centred methods (in physics and supposedly in other natural sciences) if better conceptual knowledge of graduates is expected. Particularly, taking into account the small number of physics graduates continuing to work as teachers in schools, it will be impossible to replace the retiring physics teachers by new teachers with good conceptual understanding of physics.

The *FCI* test results in the University of Latvia agree to the worldwide results described in scientific literature by several authors at different universities for the time period 1995—2014 using *FCI* and showing that traditional learning methods lead to 22% gain while interactive approach provides gain of 39% on average (Von Korff et. all., 2016). The approach presented here will be used to find the learning approach at the University of Latvia that leads to higher conceptual understanding of physics by students. The authors of this research are not aware of similar studies carried out in Latvia or elsewhere in the Baltic States. The authors call for the wider use of pre-tests and post-tests to measure the quality of physics education at university study courses.

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