THE INFLUENCE OF INTERACTIVE LECTURES ON STUDENTS’ CONCEPTUAL UNDERSTANDING IN STEM EDUCATION

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Abstract

Using specific interactive learning activities with the aim to motivate and activate freshmen to study can positively influence students’ attitudes towards learning and increase the chance of students’ success in the STEM (Science, Technology, Engineering and Mathematics) study programme.

In paper, we deal with the results that we gained from the students’ knowledge testing before and after the course of physics using traditional and interactive way of teaching this course using video analysis with the program Tracker (video analysis and simulations (VAS) method of problem tasks). We used a standardized FCI (Force Concept Inventory) pre and post-test in order to find out the prior and output of knowledge of physics in the experimental and control group.

We also used a Student t-test to evaluate statistical differences between the means of the pre and post-tests. Our results indicate that there is no statistical difference in the mean of pre-test score of the experimental and the control group.

Furthermore, based on the p-values observed, we rejected the hypothesis that there is no significant difference between the post-test means, our results confirmed that there is significant increase in conceptual understanding after the successfully completed the course of physics in both control and experimental group. Moreover, the significant difference between the post-test means was confirmed by using t-test at the end of the semester in the experimental group in comparison with the control group. Watching and analysing video recordings of the process of motion in an attractive way forms correct students’ conceptions and also positively influences students’ attitudes towards the importance of study for their future.

We point out the importance of interventions such as interactive lectures and their integration into STEM study programme because thanks to them we can manage to reduce the lack of students’ knowledge.

Keywords: STEM education, video analysis and simulations (VAS), Student t-test.

1 INTRODUCTION

In recent years, a regional education reform has been implemented in Slovakia with two main aims, firstly to enhance humanistic and creative teaching approaches and secondly to concentrate upon the development of the student’s self-concept in order to achieve higher efficiency of learning. However, looking back at the outcomes of this reform, it seems that humanities and social science subjects were more or less knocking STEM and technical subjects down because the number of their lessons increased whereas physics and mathematics suffered from the reduction of lessons. Another outcome of this reform was that higher education was transformed to a three-level system, which triggered the need to adjust the study programs of individual departments as well as the content of the relevant subjects. And again the reduction affected mainly physics and mathematics and their number of lessons even so that the importance of these two subjects for technical study programmes is indisputable.

Another aim of the education reform was to increase the number of people with degree. In other words, to get as many students as possible to apply and enrol at universities, no matter whether they are prepared for it or not. As a result, vast majority of technical universities are attended by students who come from the whole spectrum of schools - secondary grammar schools or secondary technical schools - and a glaring gap in their readiness for university-level work is breathtaking. Furthermore, there was also a change in the system of the secondary school leaving examination. Students attending secondary technical schools can choose physics or mathematics only as an optional fifth subject! This is one of the reasons why students’ theoretical knowledge, skills and key competencies
are at very low level when they enrol at university. As a result, universities across our country are forced to spend time, money and energy to solve this disconnect. We must determine who is not prepared for university and attempt to get those students up to speed as quickly as possible or we risk losing them altogether.

The long-term intention of the Ministry of Education, Science, Research and Sport of the Slovak Republic is to motivate young generation to study technical and natural sciences. At the same time, the Minister of Education feels the need to modernize the education system. He sees the way in strengthening mathematics, physics and natural sciences at all levels of the education system with the aim of enhancing graduate employability. Improving the quality and attractiveness of technical education and the analysis of key elements is also the aim of European Commission for Education, Youth, Science and Research. The European Council Communication entitled “A New Impetus for European cooperation in Vocational Education and Training (VET) to support the Europe 2020 strategy” highlights the key role of VET in lifelong learning and mobility. Therefore, the key competences and the development of our students is more and more up-to-date topic in recent years.

Problems start at primary and secondary schools what is visible from the results obtained from the testing in 2006, 2009, 2012, 2015 and 2016, which showed that Slovak pupils significantly lag behind the OECD average (e.g. in the OECD PISA survey, which focuses on three main areas: assessing scientific, reading and mathematical literacy of 15-year-old pupils).

The analysis of the partial results showed that Slovak pupils have declarative knowledge, but cannot apply it in practical situations. They have problems with reading the charts, they have big problems with the tasks that require the usage of evidence, or when they have to choose the most important information and facts. Slovak pupils have difficulty while solving the tasks, in which problem needs to be specified and which can be later investigated with appropriate scientific procedures. Moreover, they have problems to identify these scientific procedures and use them as a tool for acquiring new knowledge. Unfortunately, these conclusions have also been confirmed by researchers at technical universities, the aim of which was to find out the prior knowledge level of freshmen. Based on the analysis of the tests results, it can be generally assumed that the most significant reason for Slovak pupils lagging behind is that they do not show interest in science. This is true not only for Slovak pupils, but also for other pupils living in the EU. Moreover, Rocard’s report, one of the outcomes of the expert group set up by the European Commission, points out that pupils do not like the way how STEM subjects are taught. Despite the Slovak school reform which took place in 2008, both the deductive way of teaching and significant overcapacity of the subject content predominate in most schools (at all levels and school types). Another problem is insufficient number of experiments done during physics lessons, which is closely connected with material and equipment deprivation of schools. At the same time, there is also a problem with requirements that pupils have to fulfill in these subjects. Moreover, pupils’ theoretical knowledge is still preferred to the ability to apply their theoretical knowledge into practice.

Today more than before, education should meet the needs of practice and the content of it should be based on professional high-level expertise, which can be applied in a wide range of disciplines. Universities should have the leading role in preparing graduates who will follow new development trends in their field of study and whose knowledge will be supported not only by field-specific knowledge, but also by a broad range of skills and knowledge in mathematics and physics. Therefore, if we want to prepare graduates who are able to work independently with a high degree of creativity, then apart from well-educated teachers, devoted scientists, study materials of high quality and scientific laboratory equipment, we should keep in mind that university teachers of mathematics and physics must take into account the specific needs and requirements of each faculty and prepare specific study materials supporting the specialization of these faculties.

Therefore, we place the emphasis on the synthesis of theoretical knowledge and practical experience in the given field when teaching mathematics and physics in new accredited study programs of both the first and second level of higher education. So the graduate is able to conduct research and use evidence-based analysis, to gain in-depth knowledge in the major and analytic, problem solving, and to apply the knowledge of mathematics and physics in real-world settings either in production technologies, in the process of production management, or in quality control of the final products. Moreover, we try to prepare our students for teamwork and collaboration with scientists and engineers, so they are able to work in interdisciplinary fields at the interface between physics and technical departments. As a result, we consider theoretical training not as the goal but as a means to an end, and therefore it should always be followed by practical application.
2 METHODOLOGY

We decided to support freshmen by interactive lectures using video and video analysis and find out whether interactive lecture are more effective in increasing students prior knowledge level of physics than traditional lectures.

Our previous research using FCI tests [1] reveal that the input knowledge level of students attend Faculty of Operation and Economics of Transport and Communications of University of Žilina (FOETC) concerning force, mass point kinematics and dynamics is at lower level in comparison with the students from chosen university abroad (Mean(FOETC)= 23 %, Mean(TAMPERE) = 45 %) [2]. Next FCI testing of students from Faculty of Electrical Engineering (FEE) of University of Žilina revealed similar results (pre-test Mean(FEE) = 29%, post-test(FEE) = 36%) [3, 4]. It was 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 [4]. The better results of students' conceptual understanding in mechanics can be achieved using more activating methods in introductory physics education [5].

At the beginning of the academic year 2016-2017, the Force Concept Inventory (FCI) was administered to students at Electrical Engineering Faculty to find out their prior knowledge level of physics. The FCI is a scientifically validated instrument that aims to measure students’ conceptual understanding of Newtonian physics. The pre-test was carried out at the beginning of the semester during the first week and it was attended by 190 students. Post-test was carried out at the end of semester (the 13th week, after the semester course ‘Introduction to Physics’) and it was attended by 170 students.

The students were randomly assigned to two groups – the experimental (98/75) and the control group (92/95). Only those students who participated actively in the lecture took part in the experimental group. The lectures for the experimental group were conducted in an interactive way aimed at clarity - using real-life videos related to the topic. All videos were analyzed with the help of the program Tracker (using VAS method). In the control group, lectures were conducted in a traditional way. Students from both groups attended compulsory computational physics seminars. The subject ‘Introduction to Physics’ consists of 2 - 1 - 0 (lectures - exercises - labs) lessons per week, presence study.

![Fig. 1 Pre-test of Experimental and Control groups.](image-url)
Table 1. Pre-test - F-Test Two-Sample for Variances and t-Test: Two-Sample Assuming Equal Variances.

<table>
<thead>
<tr>
<th></th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>28.94557823</td>
<td>29.92753623</td>
</tr>
<tr>
<td>Variance</td>
<td>176.310868</td>
<td>143.5844349</td>
</tr>
<tr>
<td>Observations</td>
<td>98</td>
<td>92</td>
</tr>
<tr>
<td>df</td>
<td>97</td>
<td>91</td>
</tr>
<tr>
<td>F</td>
<td>1.227924657</td>
<td></td>
</tr>
<tr>
<td>P(F&lt;=f) one-tail</td>
<td>0.161561961</td>
<td></td>
</tr>
<tr>
<td>F Critical one-tail</td>
<td>1.408158018</td>
<td></td>
</tr>
<tr>
<td>Pooled Variance</td>
<td>160.4698818</td>
<td></td>
</tr>
<tr>
<td>Hypothesized Mean Difference</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>df</td>
<td>188</td>
<td></td>
</tr>
<tr>
<td>t Stat</td>
<td>-0.533981607</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>0.296992544</td>
<td></td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>1.652999113</td>
<td></td>
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<tr>
<td>P(T&lt;=t) two-tail</td>
<td>0.593985087</td>
<td></td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>1.972662692</td>
<td></td>
</tr>
</tbody>
</table>

These results (Fig. 1, Tab. 1) indicate that there is no statistical difference in the mean pre-test FCI score of the experimental and control group at the beginning of term.

The FCI is a scientifically validated instrument that aims to measure students’ conceptual understanding of Newtonian physics [1].

Fig. 2. Post-test of Experimental and Control groups.
Table 2. Post-test - F-Test Two-Sample for Variances and t-Test: Two-Sample Assuming Unequal Variances.

<table>
<thead>
<tr>
<th></th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
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<td>35.47368421</td>
</tr>
<tr>
<td>Variance</td>
<td>313.2652653</td>
<td>193.83352</td>
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<tr>
<td>Observations</td>
<td>75</td>
<td>95</td>
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<tr>
<td>df</td>
<td>74</td>
<td>94</td>
</tr>
<tr>
<td>F</td>
<td>1.616156304</td>
<td></td>
</tr>
<tr>
<td>( P(F\leq f) ) one-tail</td>
<td>0.014016431</td>
<td></td>
</tr>
<tr>
<td>F Critical one-tail</td>
<td>1.431981884</td>
<td></td>
</tr>
<tr>
<td>Hypothesized Mean Difference</td>
<td>0</td>
<td></td>
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<tr>
<td>df</td>
<td>138</td>
<td></td>
</tr>
<tr>
<td>t Stat</td>
<td>4.364207215</td>
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<tr>
<td>( P(T\leq t) ) one-tail</td>
<td>1.24133E-05</td>
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<tr>
<td>t Critical one-tail</td>
<td>1.655970382</td>
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<tr>
<td>( P(T\leq t) ) two-tail</td>
<td>2.48266E-05</td>
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<tr>
<td>t Critical two-tail</td>
<td>1.977303642</td>
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</table>

These results (Fig. 2, Tab. 2) indicate that there is statistical difference in the mean post-test FCI score of the experimental and control group at the end of term.

Gain of courses calculated

\[
g = \frac{\text{postscore\%} - \text{prescore\%}}{100 - \text{prescore\%}}
\]  

was \( g_{\text{exp}} = 0.22 \) for experimental group and \( g_{\text{cont}} = 0.08 \) for control group.

3 RESULTS AND DISCUSSION

The results of pre-test (Fig. 1) reveal that only 4-5 \% of students (in experimental-control group) reached the level of 60\% or higher from FCI score and in post-test 19 \% in experimental group (Fig. 2). As the authors claim [1] 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 [1].

The low growth of successful students can be caused by the fact that only one third of the total number of students attended lectures. In experimental group final number of students attended lectures decreases to 60\% in comparison with beginning of term.

After first semester we decided to find out what our freshmen thought about the video analysis using during Introductory Physics course when they passed their examination from this subject successfully. So we gave those 179 students a questionnaire consisting of several questions. For the purpose of this article, the results of some questions are depicted via graphs below:
74.9% of students used interactive methods during Introductory Physics lessons, they answered the following three questions:

Did the video analysis encourage you to further studies of Physics?
- totally disagree: 2 (1.5%)
- disagree: 6 (4.5%)
- neither agree nor disagree: 32 (23.9%)
- agree: 76 (56.7%)
- totally agree: 18 (13.4%)

Did the video analysis help you to better understand the physical laws?
- totally disagree: 3 (2.2%)
- disagree: 3 (2.2%)
- neither agree nor disagree: 10 (7.5%)
- agree: 76 (56.7%)
- totally agree: 42 (31.4%)

Did the video analysis improve your attitude towards studying Physics?
- totally disagree: 3 (2.2%)
- disagree: 5 (3.7%)
- neither agree nor disagree: 26 (19.4%)
- agree: 73 (54.5%)
- totally agree: 27 (20.2%)

The graphs above show that freshmen consider video analysis using during Introductory course of physics useful even after the first semester and their first exam period. Thanks to the video analysis they increased not only their knowledge level of physics but also enhance their noncognitive skills such as attitude and motivation in a positive way [6].

After finishing the course of Physics I (summer term of academic year 2016/17), students who actively attended this course could express their opinion on the course – their comments can be read below:

- I liked video analysis in the program Tracker (5x), using videos to explain the topics, the total number of videos on lectures, which help me to understand some physical facts, interesting statistics,
I liked visual illustrations of physical phenomena, examples and real life videos (16x), crash tests, brake track analysis, thanks to them it was easier to understand what was going on,

I was absolutely satisfied with a lecturer's attitude, not many of them devote some much time to the individuals as he does (our lecturer),

I liked the way of teaching, the explanation of the subject, the teacher's positive attitude (2x), the methodology of teaching through videos and practical examples on the lectures, which helped to visualise the assignments better,

I appreciate the possibility to discuss the syllabus topics and also the possibility to work independently on the lesson, the teacher’s willingness to explain certain things several times, individual approach,

I really appreciate the explanation of the demanding tasks via videos (2x),

I appreciate the choice of additional teaching aids, audio-visual demonstrations, interactive form,

I liked the practical application of the theory while solving various practical tasks (6x), clear explanation (2x) and the simplicity of explanation, the teacher’s control whether students solve the task assignment,

I highly appreciate the empathic and individual approach of the teacher (2x), the lessons were well organized,

I appreciate learning by integrating theory with practice,

I enjoyed that the teacher tried to push everyone to put down notes and calculate the assignments individually, it was obvious that he really cares if his students prepare for the lecture or not, even though it was a lecture and not a seminar

4 CONCLUSIONS

Watching real physics concept videos and their subsequent video analysis had a positive impact on the growth of knowledge and improving of conception of Newtonian mechanics at the end of the semester as was declared in previous studies by other authors [7 - 10].

Student t-test confirmed statistical significant difference in knowledge and conception of Newtonian mechanics at the end of the semester in comparison with the prior knowledge level for both the experimental and the control group. However, our results also confirmed that there is statistical difference in the mean of post-test FCI score of the experimental group in comparison with the control group at the end of semester.

As was declared in previous studies [11, 12, 13], motivation and attitude to study are important self-regulatory skills for successfullness of students. Interactive lectures help to positively influence students and start motivating them to achieve better results.

ACKNOWLEDGEMENTS

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