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Electronic Presentation as a Factor to Improve Learning Outcomes in Mathematics: the Case of Elite Engineering Education

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The paper describes the dependence of the quality of mathematics education on the methods applied at lectures delivered for elite engineering students. Two approaches to giving lectures, conventional and presentation-based, are compared. The academic progress performed by students within the frameworks of these two approaches is assessed. The assessment is based on the comparative analysis of the results achieved by students doing theoretical tasks in different sections of the course.

Key words: electronic presentation, mathematics education, lectures, elite engineering education.

Tomsk Polytechnic University (TPU) is one of the leading higher education institutions in Russia: it ranks fifth among national engineering universities. Since 2008, TPU has had the status of national research university, which implies that the university graduates, besides having a bulk of knowledge, have developed the abilities to analyze and summarize the information obtained, integrate the knowledge acquired through studying different sciences, conduct research, and create new products. Therefore, the most important of university's objectives is to train highly-qualified professionals, who are aware of modern trends in science and manufacturing, have an ability to reflect on their work, and are in demand on the labor market [1]. There should also be graduates with the potential to conduct scientific research.

Starting with the first years of professional activities, the educator should be focused on achieving the major objectives, even if facing challenges. One of the difficulties to be overcome when teaching first year students is different levels of student's background knowledge. Some students acquired profound knowledge at school while the others failed to obtain sufficient knowledge even in the disciplines which are majors at technical universities (mathematics and physics).

Diverse levels of student's background knowledge result in different numbers of academic hours necessary to study new material: some students comprehend new information quickly and easily, while the others lacking sufficient basic knowledge need much more time. To solve this problem, TPU has implemented the system of three pathways for studying mathematics and physics: basic, adaptive, and profound.

Compared to the basic pathway, the adaptive one implies more academic hours and is designed to fill in the gaps in school knowledge, which hinder comprehension of new material.

The profound pathway for studying mathematics is implemented as elite engineering education (EEE) [2]. One of the EEE project targets is to distinguish students eager to solve original research tasks and to create special conditions for nurturing student's research potential.

The type of pathway is determined via entry testing which is held for first year students over the first days of studies. The unified state exam (USE) results do not always reflect the level of knowledge, which is attributed to the fact that USE tasks are typical and applicants are simply trained to solve the tasks of a particular pattern. The tests for students are also developed to check the knowledge within the scope of school programme, however, they are diverse and, as a result, are more efficient in identifying the level of background knowledge. The students who get less than 50% of points then follow the adaptive pathway and the rest of the students follow the basic pathway. The students who get more than 90% can take an additional test and be selected for EEE. As a result, EEE is for students with profound background knowledge who find the educational process within the basic pathway tiresome since they need less time to understand theoretical issues and develop practical skills. Therefore, compared to the basic pathway, the EEE programme is more sophisticated.

The EEE programme is more than 10 years. In compliance with the programme, over the first four semesters, the student acquires profound knowledge in mathematics and physics. In general, the blocks within the disciplines are the same as those within the basic pathway programme, but they are taught in detail and the tasks are more complicated. Moreover, there are some topics that go beyond the scope of higher mathematics programme developed for the majority of specialties (mathematical statistics, partial differential equations, etc.).

At higher education institutions, the educational course on mathematics includes lectures and practical tasks, with lectures being particularly important component at Russian universities [3]. As a rule, lectures take 50% of discipline academic hours. The lecturer plays a major part as he/she presents the developed educational material with the emphasis on theory. It is at the lectures where students learn to conduct a logical argument, which is an essential skill for a prospective engineer.

Over the first two years of the EEE programme implementation, students were taught in compliance with a classical scheme, i.e. the lectures were given in the form of the lecturer's monologue on basic concepts, theorems and their proving. The lectures served as foundation for solving practical tasks. At the end of each semester, there was a final test to assess the knowledge obtained by students following the basic and the profound educational pathways (the results are given in Fig. 1).

As seen in the diagram, the outcomes of the basic education and the EEE programmes are similar, with better results of EEE students being attributed to successful performance in solving practical tasks. The level of theoretical knowledge was approximately the same, however, the potential of EEE students was higher and they were supposed to achieve better results. To identify the reason for such unexpected performance, we conducted a survey among EEE students. The questionnaire was developed to identify the challenges students face during the lectures. None of the students answered that they faced no challenges and the difficulties specified were as follows:

1. Difficulties in making notes due to the lecturer's fast speech (34%).

2. No visual aids for concepts presented (38%).

3. Difficulties in understanding theoretical material and following the lecturer's logics without any visual aids (69%).

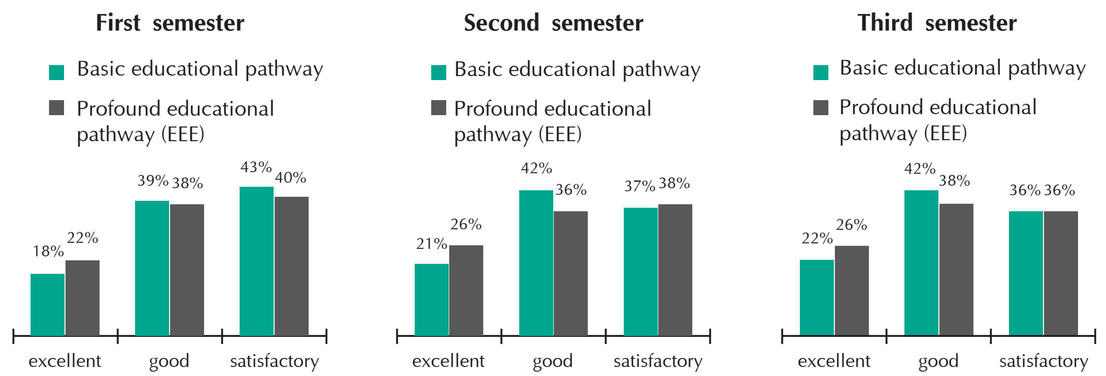
4. Difficulties in formulating clear questions to the lecturer (32%).

5. Insufficient number of examples to illustrate the theoretical material studied (67%).

6. No time to reflect on new material (64%).

Based on student's answers analysis,

Fig. 1. Learning outcomes of students following basic and profound educational pathways over the first two years of EEE programme implementation.



we identified the disadvantages of lectures given in the form of the lecturer's monologue:

1) passive perception of information provided;

2) while lecturing, the lecturer fails to adjust the pace to student's individual needs: some students have enough time to reflect on the information while the others can only make notes;

3) the lecturer does not get any feedback from students and cannot monitor the educational process;

4) educational forms and methods at school and university are different: at school, the emphasis is put on practical skills and students often have poor knowledge of theory, which causes challenges for first year students.

The disadvantages identified, it is necessary to eliminate them and improve educational process to obtain the expected learning outcomes.

The lecture can be enhanced via introduction of active learning forms and methods [4]. The lecture should not be a monologue but a conversation with students. The lecturer should address students with questions, involve them in discussion. When answering a question, the student reflects on the information obtained and changes his role of passive listener for the active participant of education process. This allows making shift from transmitting information to developing cognitive skills and elaborating scientific methods of information processing.

At the end of the lecture, it is also important to ask a number of questions on the studied material so that the students can identify the key points.

Another tool to improve the lecture efficiency is to make historical references when giving a definition or explaining a theorem. This is due to the fact that students lose concentration when processing a bulk of theoretical information, while historical facts and practical examples allow deviating from the main topic for a while and then concentrating on the studied material again.

Technology advances and modern devices (computers, projectors, etc.) the classrooms are equipped with can also improve the lecture performance.

In our opinion, one of the effective tools is electronic presentation [5]. Over three years we were experimenting with different types of presentations on different mathematical topics. The aim was to determine what kind of material should be put on slides and identify the best way to present the material. Having analyzed the experience obtained [6], we made a conclusion that the adequate information to be put on slides is definitions, theorems, and figures. As for theorem proof and examples, they are to be given on the board. The reasons for this way of material presentation are as follows:

1) The definition and theorems are given on slides using quantifiers and contractions, therefore, the information is conveyed concisely and can be easily comprehended. Moreover, this concise information is perceived as a figure visualizing the knowledge obtained.

2) Electronic presentation allows avoiding lecturing heavily with a fast pace: the lecturer has enough time to comment the definitions and theorem given on the slides since he/she need no time for writing.

3) There are opportunities to emphasize key ideas and new terms via changing font and colour.

4) When there is a bulk of information to be processed, the student inevitably loses concentration and stops following the lecturer's logics. Electronic presentation conveys information concisely, and this creates an illusion that there is less information to be comprehended, which results in more efficient cognition.

5) The lecturer has more time for giving examples and discussing new topic with the audience. The dialogue between the lecturer and student clarifies how well the material is comprehended, which information should be revised or added, and what attention should be paid to when doing practical tasks.

6) Electronic presentations are available and students can look through them in advance, think of the questions to be asked, which significantly improves student's cognitive skills.

Results

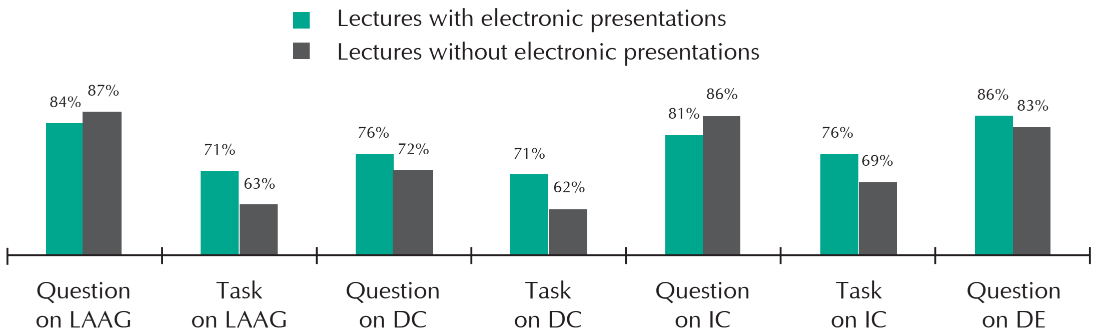
The experiment was conducted over two years and involved two groups comprising 48 and 43 students, respectively. For these groups, the lectures on mathematics were given with and without electronic presentations. In the first semester, the first group had lectures on Linear Algebra and Analytical Geometry (LAAG) supported with slides and lectures on Differential Calculus (DC) given without presentations. In the second semester, the same group had lectures on Integral Calculus (IC) presented with the supportive slides and the course on Differential Equations (DE) given without. The second group had lectures on Differential Calculus (DC) and Differential Equations (DE) supported with slides and lectures on Linear Algebra and Integral Calculus (IC) without presentations. The aim was to identify the best way to comprehend the theory, therefore, the final exam comprised the tasks of two types. The fist type was developed to check the knowledge of theory: the students had to give a definition or formulate and prove the theorem previously explained by the lecturer. The other type was theoretical task developed to determine the level of theoretical knowledge: the students had to prove the statement based on the theoretical knowledge obtained. The exam results are given in Fig. 2.

As seen in the diagram, the numbers of students giving answers for theoretical questions slightly differ in two groups. However, the number of students coping with tasks is higher in the group which attended lectures supported with electronic presentations. This proves the idea that electronic presentations used as visual aids for lectures lead to more efficient cognition: the students can not only give answers to the question on theory (since they learned some definitions and theorems), but are able to reflect on the information obtained and can use it appropriately, which proves a high level of theoretical knowledge.

The experiment results indicate that electronic presentations are very contributive to improve lecture performance. Over the past five years, we supplied all the lectures on mathematics with visual aids (electronic presentations) and assessed the efficiency of lecture performance via developed theoretical tasks. Fig. 3 presents the results of these innovations.

These data prove the idea that electronic presentation significantly improves student's knowledge of theory.

Fig. 2. Lectures with and without electronic presentations and final exam results



Conclusion.

All TPU classrooms are equipped with multimedia devices, which allows supplying lectures with visual aids, i.e. electronic presentations, which improves the education provided.

Based on the experience obtained, we can say that electronic presentation used to provide visual aids for lectures allow students:

1) to better understand the information due to its being conveyed concisely;

2) to spend more time on reflecting of the information since there is no need to make notes on definitions and theorems;

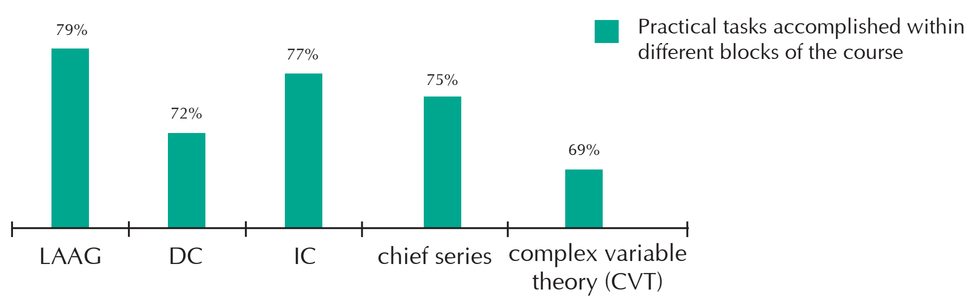
3) to prepare for lectures in advance since all presentations are available;

4) to perform efficiently at practical classes as electronic presentation facilitates information processing, which is important for solving practical tasks.

Electronic presentations used in educational process improve lecture performance. As the lecturer need not write down definitions and theorems, he/she can focus on explaining new material, giving comments and examples. Since the presentations are available and students can look through them in advance, they can participate in discussion, which makes student's work at lecture more effective and ensures profound comprehension.

Therefore, electronic presentation is a tool to visualize education content. It improves interaction between lecturer and students and lead to more efficient acquisition of theoretical knowledge.

Fig. 3. Practical tasks accomplished within different blocks of the course



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Unification of Engineering Education Programmes

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The article deals with the unification of engineering academic programmes. It provides a professional functional map and generalized analysis of the competencies included in FSES in engineering. The author suggests a unified engineering education model developed in terms of the structure of basic competencies and including competency-based modules.

Key words: unification, engineering education, functional map, competency, credit-modular structure, education programme.

The concept of improving the Russian higher education system, involving the transition to FSES (Federal State Education Standards) HE (Higher Education), multitiered-level education and integrating the competency-based approach were defined in the strategic objective itself: **"the development of fundamentally-oriented, practice-oriented and innovative higher education".** This also includes the industrial-innovative strategy, i.e. uniting the development strategies of education and science with the development strategies of different economic sectors.

The three above-mentioned strategic aspects could be defined as:

- **fundamentally-oriented** – unifying the programmes within the framework of sciences and developing the basic education modules (units) for fundamental student training in terms of the best Russian education traditions;
- **practice-oriented** – developing industry-functional models of professional activities as formalized requirements in organizing the educational process with in-depth practical dominance instrument;
- **innovative** – competency-based model for future specialist based on the principle of productive competency to shape professional skills and further professional experience.

Professional engineering education is technically – oriented, based on the fundamental principles of natural sciences, theory of human activities and interpersonal relations, knowledge of project management methods and active communicative skills. This predetermines the unification factors of basic engineering education system, its cognition and fundamental orientation.

Universality of numerous engineering activity functions promote the application of the integrative approach in the education process for training engineering Bachelors. The aim in this case is to **develop a unified teaching-learning model, determining the standard engineering education requirements, regardless of this or that programme and to recommend a body of relevant activities (actions) in developing integrated academic programmes.**

Instructional research in shaping the conceptual framework for unified engineering education programmes has been conducted in Cherepovets State University. The experimental base involved four Bachelor programme tracks: 08.03.01. Civil engineering [1],13.03.02 Power and electrical engineering [2], 15.03.01 Mechanical engineering [3] 22.03.02 Metallurgical engineering [4].

The following tasks were solved: development of universally functional map; classification of competencies and