Analysis of the e-learning technologies used for teaching mathematics at Tomsk Polytechnic University

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Abstract. This article analyzes the implementation of e-learning technologies in the study of mathematics at Tomsk Polytechnic University. It describes research findings of the suitability of the e-learning technology for first year students of an engineering university. The research involved 248 students and 38 teachers of Tomsk Polytechnic University. The authors surveyed first-year students to check whether they are ready to learn in the electronic environment. In addition, the students and teachers were surveyed on the possibility of teaching a course in mathematics in the electronic environment and on the preferred mode of learning: web-based instruction, blended learning, or full e-learning. The research identified the main difficulties when working with e-learning courses as well as the optimal form of e-learning for the study of mathematics.

Introduction

The XX century can be called the beginning of a new era, the era of technological advancement, which accelerated with the advent of computer technologies. One of the reasons for it is that the Internet triggered a dramatic change in the technologies of information exchange. Information search takes just a few minutes these days, and people can learn more in a shorter time. Consequently, we have an opportunity to resolve ongoing issues faster. At the same time, we are facing new challenges in various spheres of our activity, which require efficient solutions. Therefore, the problem of acquiring new knowledge over a short period of time and in an accessible environment is more relevant than ever. This, in its turn, requires new methods and forms of learning that would not only help train students within a limited time but also teach them how to solve ongoing problems [1,2]. In our opinion, one of such methods is electronic education [3-6]. New advanced computer technologies and means of communication enable its mass introduction in the educational process.

When educators realized the traditional form of teaching is still important in the modern world and technological advancement allows making it more effective, it led to the implementation of e-learning in higher education. The advent of computers and their usage in the educational process led to the emergence of new methods and forms of teaching with the aim of accelerating the learning process and improving its quality.

Methodology

Now that new forms of study are gaining momentum, e-learning becomes one of the top priorities in higher education. Many countries have a long-term and successful experience of applying it in the educational process [7-9]. Some scientists focus on the questions related to creating models of e-learning courses [10]. For example, the United States of America have been using e-learning in education for over a decade [11,12]. More and more people support this type of learning in Russia as well.

We are going to rely on the definition of electronic learning provided by Wikipedia: E-learning (stands for electronic learning) is a system of learning by means of information and electronic technologies.

Although Russian educators started introducing electronic learning in the educational process a relatively short time ago, higher educational institutions are actively using e-learning when teaching students who choose such forms of learning as extramural, intra-extramural, and externship.

Among the models of e-learning, which are different forms of integration of traditional learning and e-learning, the following models are most commonly used today:

1. *Web-based instruction;*
2. *Blended learning;*
3. *Full e-learning.*

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We must clearly understand that we cannot introduce any changes without checking whether the audience and the teachers are ready for new forms of education [13,14]. We should not introduce new technologies if the students are not willing to perceive and absorb information within this new technology. The audience needs some coaching before they study in an electronic environment [15]. New technologies are only useful if teachers see how these technologies can improve the quality of the learning process.

In order to make it possible for a teacher at Tomsk Polytechnic University (TPU) to choose the form of e-learning consistent with the capabilities of students, we surveyed 248 intra- and extramural students starting their first year at TPU. The aim of the questionnaire was to find out whether first-year students are ready to learn in an electronic environment.

We divided first-year students into three categories:

I. Full-time intramural students commencing their first higher education.
II. Extramural or distance students commencing their first higher education.
III. Students undertaking additional education or employees receiving advanced training.

The aim of the survey was to find out whether teaching of the course of mathematics in the electronic environment is possible and to choose the preferable type of learning. The results of this survey are given in table 1:

Table 1. The results of the survey

Student categories / Mode of study	I	II	III
Traditional learning	30%	10%	0%
Web-based instruction	50%	30%	10%
Blended e-learning	15%	40%	40%
Full e-learning	5%	20%	50%

The survey findings show that extramural and distance students (the latter are now called e-learners) mostly choose blended e-learning. This is because most of the students are over 25 years old with a history of learning at vocational schools and several years of work experience. These people know what they want to study and have chosen their major. Their aim is to raise their level of theoretical knowledge. Moreover, they can study on their own and plan their time. However, they still cannot absorb theoretical knowledge absolutely independently: student-teacher communication is important to them for better understanding. For this category, we can and even should use blended e-learning.

The survey results also show that most students pursuing additional education are willing to learn in an electronic environment, and online courses will be the form of preference for them. As a rule, these students have already been through all the stages of conventional higher education, understand the need in knowledge perfectly well and are able to rely on the knowledge acquired when working independently. With such students, it is enough to provide a direction vector in their studies, and they will successfully go all the way to achieve the necessary results.

The greatest challenge is still the introduction of e-learning for intramural students.

In order to check if first-year students are ready for learning in an electronic environment, we conducted an experiment, in which first-year engineering students of TPU were to explore the topic of "Curves of the second order" in the course of Linear Algebra and Analytic Geometry using three technologies:

1. conventional lectures and practicums;
2. web-based instruction (a student listens to a lecture, takes a test and then undergoes some practical training with a teacher);
3. blended e-learning (students explore the theoretical material on their own, take a test and undergo practical training with a teacher).

After studying the topic, the students were to perform two tasks: 1) to reduce a five-term curve equation to a standard form and construct a curve; 2) to construct a conic curve given by the general equation.

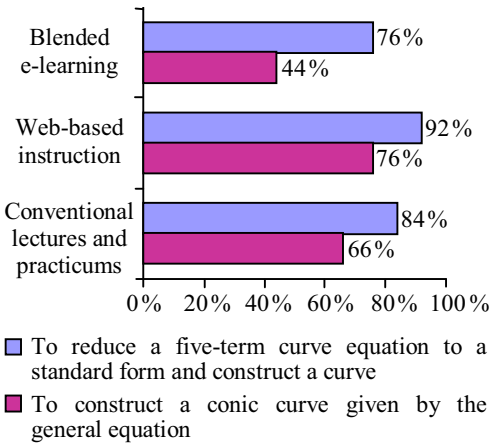

Fig. 1. A chart of task success in different forms of learning.

The chart shows that web-based instruction provides the highest efficiency. The technologies of blended learning proved to be ineffective for first-year students.

The purpose of a later survey of students was to identify the reasons for the success of conventional learning and web-based instruction. Students were to answer the following questions:

1. Your education:
   a. Secondary;
   b. Secondary vocational.
2. Your level of computer skills:
   a. User (able to operate a PC, but unable to solve hardware or software problems);
   b. Confident user (able to operate a PC and solve most of the software problems);
   c. Advanced user (able to eliminate problems arising during operation of the computer and software).
3. Owning a computer or tablet:
   a. I have a computer;

   b. I have a tablet;
   c. I use a computer in a library or my friend's (or relative's) computer.
4. Internet access:
   a. Wired Internet;
   b. Mobile (tablet);
   c. Mobile (smartphone);
   d. Access from a library or my friend's (or relative's) place.
5. Your main difficulties studying Mathematics at university:
   a. No difficulties;
   b. Wide range of tasks;
   c. No visual illustrations (many abstract concepts that cannot be visualized);
   d. Gaps in knowledge;
   e. Not enough analyzed examples;
   f. Doing homework by a fixed time;
   g. There is no clear understanding of the application of mathematics in professional and daily activities.
6. Difficulties encountered when working with the electronic course:
   a. No problem;
   b. Problems with the Internet or computer;
   c. No visual illustrations;
   d. Gaps in knowledge;
   e. Not all kinds of tasks are analyzed;
   f. The analysis of tasks was not detailed enough;
   g. There were some questions and no answers in the proposed material.

The survey shows that students are ready to learn in an electronic environment from the technical viewpoint: 94% of students have a computer or a tablet with the Internet access and 87% of students describe themselves as confident or advanced users. There are no technical problems among the difficulties outlined by the students when working with an e-course. The difficulties marked by the students belong to the substantive part: only certain types of tasks are analyzed; when studying the material; there are some questions and no answers in the proposed material (which in our opinion is more often connected with gaps in knowledge); insufficiently detailed solution of problems (Figure 2, Figure 3).

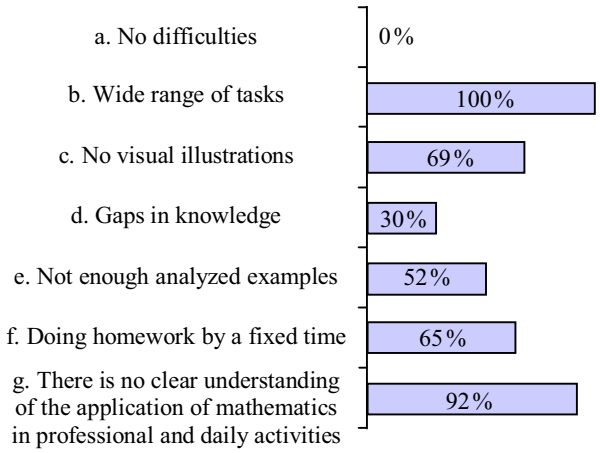

Fig. 2. Main difficulties of studying mathematics at university.

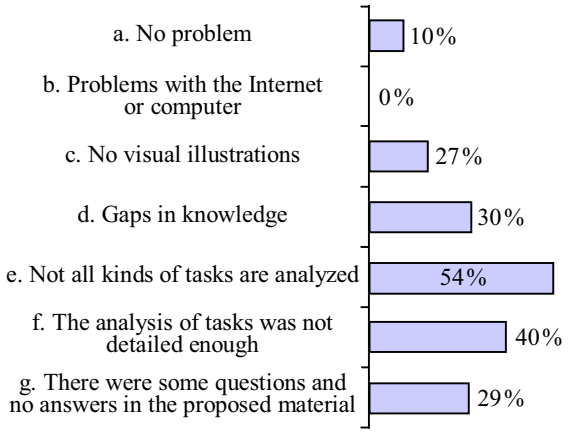

Fig. 3. Difficulties encountered when working with the electronic course.

Results and discussion

In addition to questioning of the students, we also interviewed 38 teachers. The purpose of this survey was to identify the challenges that mathematics teachers face when working with first-year intramural students. Almost all the teachers, when working with this category of students outlined the following major difficulties:

1. Most students occasionally get distracted from the learning process, referring to a phone or tablet. The current generation of students were growing up with a telephone in their hands. This is an integral part of their life. Consequently, they have a habit of referring to their phone or tablet in order to check their email, read a tweet or a message in social networks. Their motto is "I am always online".
2. Gaps in knowledge.
3. Low percentage of homework done.
4. No independent working in class and at home.
5. Poor creative thinking. Most students are unable to think outside the box.
6. There is no clear understanding of the application of mathematics in professional and daily activities.

The results of the students' answers to questions five (see Figure 2) and six (see Figure 3) as well as the results of the teachers' survey make it possible to draw the following conclusions.

1. First-year intramural students have just finished school, and the last two years of their learning life focused on passing a unified state exam. The exam includes a certain set of problems, and the learning process at school is reduced to drilling pupils on similar problems. There are specified criteria to evaluate the performance in solving these problems, so the solution must fit a certain template. If the answer does not fit, it is not counted, although it might as well be correct. Thus, schoolteachers focus more on the formal sides of recording the answer.

Unlike school, though, university adopts a different approach to teaching students. There are no patterns here. One of the key objectives of a university professor is to teach a student to think, reflect, and reason, to see the general in the specific and the other way round as well as to find solutions to ongoing issues. A university course of mathematics implies a high level of abstract thinking. At school, teachers analyze a problem and then give pupils a similar problem to solve, whereas at university, you study the theoretical background of a subject and then, using the knowledge acquired, you solve a category of problems, and each of them may look differently. A high level of abstraction is a cornerstone of learning mathematics for students.

2. Currently, many people perceive education as educational service and, therefore, a student perceives themselves as a consumer of this service rather than a creator of intellectual products. Students stick to the position "I have come to learn and you must teach me".

3. Modern students cannot listen and, more importantly, hear. Here is a simple example: we schedule a consultation and announce the time and date for it. In our experience, of 20 people, 5-10 will definitely ask again, although a teacher draws their attention to this information right from the start.

4. Students cannot remember it or make their own conclusions.

5. The general problem of students is the lack of ability or desire to do their homework systematically, although competences are formed as a direct result of their independent work. Students' inability to work on their own, acquire information in the learning process or data mine.

6. Lack of knowledge on the subject necessary for its further study. Teachers have to return constantly to the school course in order to remind some facts to the students or to teach them some things anew. We cannot foresee all the questions that may come from students as they study mathematics, because not all students know what they are supposed to know at this stage of learning.

7. Students do not consider mathematics a significant profession-related discipline in higher professional education. Unlike other general subjects, it is more detached from reality, from life, from problems of professional activity; it is more abstract. The connection of the concepts under study and professional subjects is difficult to trace.

8. Lack of comments from the teacher when studying the theoretical material, lack of face-to-face contact with the lecturer (blended learning).

Conclusions

We have drawn the following conclusions from our findings:

1. Electronic learning cannot replace face-to-face communication between a teacher and a student, i.e. lectures. A competently arranged lecture is not a monologue but a dialog of a teacher and a student, with the student not only acquiring new knowledge but also learning how to think logically and adopting experience from the teacher.

2. The performance of students who studied a topic in a blended learning model is inferior to that of students who relied on the conventional educational system and web-based instruction. The result is easy to explain: face-to-face communication between students and teachers leaves fewer unanswered questions and, consequently, fewer gaps in knowledge. Web-based instruction allows a teacher to effectively monitor the digestion of the material given. At the same time, the use of web-based instruction also increased the workload of the teacher.

3. Newcomers to university cannot organize their educational process on their own, because they are not yet accustomed to having a free hand. Not being able to arrange the learning process, they just stop trying.

4. The intramural students who set blended e-learning as their top priority mostly have some learning experience (vocational schools). They already have acquired some time management and data mining skills. However, there are not so many students of this category at the university; hence using blended e-learning during the first years of study is ineffective.

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