Implementing EU Interactive Teaching Methods at Al-Farabi Kazakh National University

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Abstract. This article presents the effectiveness of multimedia tools and communication technologies usage in teaching electricity and magnetism course at al-Farabi Kazakh National University, Kazakhstan. The implementations are based on prepared multimedia packages within EU projects of Didactics of Physics Division at Nicolaus Copernicus University in Toruń in earlier collaboration with University of Udine, Italy and Charles University, Prague. The implemented packages at KazNU are simple didactical objects (“Physics and Toys”) and “hands-on” experiment in electromagnetism. All implementations were positively evaluated by students, as they lead to an increased didactical efficiency and improve students’ motivation to in self-learning.

1. Introduction

Educational issue of the XXI century on forming clever, talented, smart and intelligent individuals is in the focus of the World. Therefore, the role of teacher is changing with penetration of IT to the process of education, and her/his knowledge must embrace not only the strict didactical methodology, but also transversal abilities, called in its total the Pedagogical Contents Knowledge [1]. One of the most important conditions of innovative education is the use of non-traditional educational technologies, i.e., optimizing and increasing the effectiveness of information technology in the learning process of the younger generation. At the same time, the application of new technology during the lesson will help to keep up with the global news, especially in the development of advanced physics [2].

In generally the basic concept of education consists of creation of a such system, which will provide each person the possibility of receiving and acquiring knowledge, possibility of development, improvement and self-development throughout all their life [3].

As research university, Al-Farabi Kazakh National University is leading institution of the higher education system in the Republic of Kazakhstan, which has justified its rights to realize academic activity in all specialties and at all levels. The University has an enormous educational, scientific, innovative and production potential which is aimed to the high qualified specialists training, further integration into global educational space, development of fundamental and applied research, their implementation into production.

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It is known that students of various ages have problems in understanding some basic concepts of electricity and magnetism; they hardly conceptualize phenomena like magnetic fields, electromagnetic induction, bi-directional flow of charge carriers, and so on. These facts have been verified repeatedly by conceptual tests like CSEM (Conceptual Survey on Electricity and Magnetism, Maloney et. al., 2001), BEMA (Brief Electricity and Magnetism Assessment), DIRECT (Determining and Interpreting Resistive Electric Circuit Concepts Test) and others, see [6] for a comprehensive study. Such comparisons have not been performed yet in Kazakhstan.

Al Farabi KazNU has established close ties with leading universities in the world, including the Nicolaus Copernicus University, Poland. Therefore, we decided to introduce changes in teaching physics at the university level not adopting a single model, but exploring several “packages” developed in frameworks of EU collaboration. The Didactics of Physics Division, from Nicolaus Copernicus University (NCU) allowed us to bridge the experience from several countries (Italy, Poland, Czech Republic etc.) into KazNU. This paper reports the first year of our mutual experience.

The two general principles adopted at DPD NCU consist of the result oriented, step-by-step work with the student, developing his/her knowledge (“hyper-constructionism”) [4] and with the use of interactive, simple experiments, possibly based on every-day-use objects (“neo-realism”), see [5]. This is because the observation of a real-world is always the first in any of the discoveries (not only in the constructive one). Simple experimental objects are proved to be highly efficient in many different national realities [6, 7]. In a real case scenario, it means that we must start not only by re-building laboratories, but also from re-integration of didactics with pedagogy, that, again, proved to be indispensable in different realities, also in a broader, EU context [8]. Keeping the above mentioned in mind, and depending on the priority of obtaining knowledge by students, the guidance and a correct orientation of the teacher must be strengthened. An increase of teachers’ professional preparation, their personal development, general culture and also interpersonal relations will be necessary for an increased number of students.

2. Interactive Teaching Methods and EU-based educational packages

The new teaching technology that we applied is a collective, self-complementary, participatory learning process. In figure 1 we show the general view of interactive teaching approaches. The key change as compared to the traditional teaching, that are still in use also at KazNU (figure 2) is the key-role of students’ own activity at all stages, from planning to the self-evaluation.

![Figure 1. The general outline of the interactive technological method.](image)

The main purpose of educators is to update the content of knowledge using new technologies as mentioned above by implementing it in 4 stages:
Learning;
Application in practice;
Creative development;
The result.

In this regard, we analyze the MOSEM webpage, which is used as a new technology [9].

2.1. EU-based educational packages

Traditional teaching methods at KazNU are based on plenary lectures, tutorials in smaller groups and laboratories. Moreover, more sophisticated experiments with digital electronics have only been introduced recently at KazNU. Along with new technologies old devices are also used. Currently, there are given additional video lectures for virtual laboratory works and their interpretation.

New descriptions of experiments are needed, presently used instructions are detailed, many students were questioned, and they noticed this information allowed to understand deeply the practical importance of phenomena. Therefore, a reform of whole teaching Physics system is needed, which includes new equipment, contents and teaching methods. We have already introduced two educational modules from NCU at KazNU, that differ in the approach (more intellectual or more emotive), differ in the subjects (but we concentrated on electromagnetism) and also differ in methods (simple objects vs. hands-on experiments and internet-based problems with interactive solutions).

Figure 2(a). Course of Electromagnetism at KazNU traditional laboratories: equipment for studies of V-A characteristics of semiconductors.

\[ V(x) = \mu_x \rho \int \frac{x}{X^2 + \left[\sqrt{x^2 + L^2} - \sqrt{x^2 + L^2} - X \right]^2} \]

(1)

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Figure 2(a). Course of Electromagnetism at KazNU traditional laboratories: equipment for studies of V-A characteristics of semiconductors.

\[ B = \frac{\mu}{\rho \mu L} \]

(2)

Figure 2(b). Traditional laboratory instructions for the studies of solenoid.
For the first stage of collaboration we adopted some simple solutions, developed by Didactics of Physics Division NCU in the period 2006-2018 (and earlier by GK at Trento University, Italy).

1) “Physics and Toys” is a collection of real objects and simple experiments developed by one of the authors (GK) at NCU and earlier at Pomeranian Academy, Słupsk, Poland [10] starting from 1997.

2) Experiments in Electromagnetism, developed for didactical laboratories and science divulgation activities within three EU-based projects [11].

All two resources are based at NCU, but their preparation went in different ways. The used material was developed in some twenty years of international collaboration (and foreign teaching experience). We mentioned the most important partners in that process here, i.e. University of Trento [12], University of Udine in Italy [13] and University of Antwerp [14].

1) Interactive, simple experiments “Physics and Toys” is now also in the form of multimedia resources, were initially developed by prof. Vittorio Zanetti at Trento University, Italy and then (in 1998) “were imported” to Poland [16]. The success of first two interactive exhibitions, in Warsaw and Słupsk was enormous, more than 10,000 visitors in two weeks. In the following years, this type of exhibition was repeated (more objects were added) in numerous occasions, including three National Congresses of Polish Physical Society. This, in turn, triggered the interest at the national level: first permanent exhibition was founded by prof. Stelmach in Szczecin, next (with participation of GK) in Gdańsk (2009) and Warsaw (2011). The latter, Science Center hosted 1 million of visitors in the first year of activity. This illustrates the deep need of the Polish educational system (after transformations) in new forms, new contents and new institutions in Physics education.

The main advantage of “Physics & Toys” resource that we found at KazNU is that it triggered the interest of students in observing objects around them. Obviously, this concept was already noticed (and even “translated” to text books), e.g. [6,7], but bringing some small equipment and/or their virtual mirrors [11] (jumping balls, inverting tippe-tops, plasma balls) into the lesson induces students into comments: “I have seen it in a shop” or “My brother has such a pendulum”. What is important, however, is not to show the object, but to use it at the right time in the lesson (a kind of “focusing” [6]): “Did you understand the conservation of energy? So, please, explain me why this balls is jumping up to the ceiling?”

Figure 3(a). The main page of Didactics of Physics Division at NCU Torun “dydaktyka.fizyka.umk.pl” including the two resources used in the present implementations at KazNU, from upper left to the right: laboratory of electromagnetism, and “Physics and Toys”.

Figure 3(b). Simple didactical objects (“toys”) that are directed to explain the phenomena of electricity and magnetism in the following NCU link dydaktyka.fizyka.umk.pl/zabawki1.
We underline the description of a “chaotic” movement in the magnetic field by developing it in next, specific projects on electromagnetism, see figure 3(a,b).

Further, the advantage of the “P&T” collection at NCU is that they are grouped into categories and inserted into scenarios. “What colour is the pink lamp?” [15] illustrates not only atomic and molecular spectra and the diffraction grating, but also teaches on human visual perception and on Bohr’s atomic model. Thanks to EU Science & Society Project S&S 027227, descriptions are available in several languages. We developed its Kazakh and Russian versions, (figure 3a). As illustrated in figure 3b, there are 24 “toys” in the subject of electromagnetism. In each case, there are always several similar objects illustrating a given problem, like the electrostatic interaction between two glass balls from Christmas tree. These descriptions, photos and videos are ideal to be used as a demonstrative experiment. Students consult these page as a supplementary introductive material.

Second package, which was used at KazNU was the collection of simple, “hands-on” experiments in electromagnetism, similarly to P&T forming subject groups, which are magnetostatics, Lorenz force, electromagnetic induction and so on. Differently from typical experiments at schools or at universities, the presently tested E-M experiments are quick to be performed: a set of four ready-to-use boxes was produced by NCU. Again, the advantage of these simple experiments is that they can be constructed directly by students, with the use of every-day objects, like anti-theft labels mounted in clothes, which are sold in supermarkets, magnetic fridge stickers, pieces of wires, and neodymium magnets, and so on, see details in [12].

![Figure 4. Interaction of point-like electric charges: A real experiment with a simplified video description (dydaktyka.fizyka.umk.pl/zabawki1/files/elmag/choinka-pl.html).](image)

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![Figures 5(a). “Chaotic” movement in the magnetostatic field, developed for EM experiments dydaktyka.fizyka.umk.pl/mosem site; translated into Kazakh here.](image)

**Figures 5(a).** “Chaotic” movement in the magnetostatic field, developed for EM experiments dydaktyka.fizyka.umk.pl/mosem site; translated into Kazakh here.

![Figures 5(b). The experimental kit for electromagnetism from NCU: one of four equipment boxes [11]](image)

**Figures 5(b).** The experimental kit for electromagnetism from NCU: one of four equipment boxes [11]
3. Research

The question of research was whether introducing new teaching technology with simple experiments and interactive, narrative approach would be accepted by student at KazNU, who are accustomed to rather traditional laboratories and lectures. How will it work in electromagnetism? Which of the proposed multimedia will gain the best interest of students: “physical toys” translated into Kazakh or some videos on electromagnetism in English (or even Polish)? How does the additional teaching material affect the educational process?

The aim was to show the effectiveness of using additional, multimedia technology for the laboratory work at university level. Can we, outside the university hours, add some optional material for students, partially in Kazakh and partially in English? Will they use it? Will their performance improve?

The research was conducted for the students of the specialty "Physics education" consisting of two groups, first with traditional teaching and second with multimedia technology added, each of 11 students (aged 18-19). There are 2 boys, 9 girls in first group and 4 boys, 7 girls in second group. The test was done in summer term 2018/2019; all students followed their first year of university studies.

The first group used the device shown in Figure 8, and descriptions of the laboratory work in the book shown in Figure 2b.

The second group (the experimental group) was tested with new technologies: where we applied the additional multimedia, for example NCU internet sites and videos on electromagnetism with the same laboratory equipments as the first group. This additional activity was done mainly by students in their “free” time, i.e. as the home preparation to the experiment and the consolidation after the laboratories (and before the final test). Teachers gave only short information when the multimedia material could be found and later served as consultants on questions that students had not understood during their self-work.

Figure 6a. General view of the test done before conducting the research.
Figure 6b. General view of the test done after using the EU teaching technology.

The pre-test results of the two groups are given in figures 7 a.b. First group’s students got 6 as minimum value, and 12 as maximum value, so the average was 8.9, which was 59%, second group’s students got 6 as minimum value, and 14 as maximum value, so the average was 9.1, i.e. 61 %. The two groups, therefore, were not statistically different before testing with the innovative material.

| Details       | Statistics |
|---------------|------------|
| Score         | Percent    |
| Min. Score:   | 6.0        | 40.0      |
| Max. Score:   | 12.0       | 80.0      |
| Average:      | 8.9        | 59.4      |

Figure 7(a). The result of the pre-test of the first group.

Figure 7(b). The result of the pre-test of the second group.

Then, the two groups followed different teaching scenarios. The control group used traditional KazNU labs: for example, №3 laboratory work to search the solenoid’s magnetic field is shown here, fig. 8. The purpose of the work is to conduct research of the finite length of spreading solenoid’s magnetic field through the electromagnetic induction phenomena.

Figure 8. №3 laboratory work, first group: experiment on the magnetic field inside a solenoid, see fig. 2b for the instruction. As seen, student copy “by hand” a lot of material and the laboratory equipment is rather simple: little inter-disciplinary aspects are present.
The second group used traditional equipments (laboratory instrument and description from the book) as the first group and additionally applied the No. 6.6-experiment on “interaction between magnet and coil” as extra technology (http://dydaktyka.fizyka.umk.pl/MOSEM/html-kz/6.6.html) at DPD NCU Toruń website (Teaching Minds-On Experiments on Electromagnetism in Secondary Schools), figure 9 a,b. (Also, 6.1, 6.2- experiments are recommended to be used [12]). The same experiment that is shown in fig. 8, in fig.9 is simplified – no supplier is needed to show the same effect. The experiment from fig. 9 can be repeated by teachers in every school.

Figures 9 (a, b). Applications (experiments) on electro-magnetism from NCU web pages, EU Projects [11, 13, 14]: simple electromagnetic motors.

After finishing the laboratory work №3 conducted by two groups, they tested their acquired knowledge in ZipGrade program (Zip Grade is an application for quick and convenient testing of students’ quizzes, which can be downloaded in 5 versions, and works on Android and iOS platforms).

The questionnaire was constructed to get second group’s opinions (those who used the interactive technology). The survey was conducted anonymously using Google form. All 11 students took part in the survey.

1. How much need new technologies for the course of electricity and magnetism?

2. What assistance did (MOSEM) movies give during teaching process?

In the figure 10 a, nine students mostly used new technology in all parts of physics, other three students’ opinions are divided into 3 answers as education using only books, neutral, quite good to use. As you see in the figure 10 b, 82% of students, i.e., 9 of 11 students gave affirmative answers about NCU material on EM. Only two students chose neutral answer. No one have chosen negative answer.
3. What is your opinion about virtual laboratory work?

- I consider that lab works must be done only by equipments: 27.3%
- I hold to make with virtual laboratory work, if equipments do not work: 27.3%
- It is possible, it will be right to make with equipments a...: 27.3%
- It is good to do virtually, it will encourage the usage of new technology: 27.3%

5. Does lab work with usage of new technology save the time?

- A) no: 45.9%
- B) it relates to individual skills of students: 45.9%
- C) yes, it does. It helps to spend the time useful: 1.1%
- D) of course, according to the time: 4.6%

**Figure 10 c.** The third analysis of the questionnaire: is the use of the virtual material decisively better than the traditional experiment?

**Figure 10 d.** The fifth analysis of the questionnaire: does the new technology save time?

Further, we asked “free-lance”, one sentence opinions of the students from the experimental group on the use of new technologies. The student’s opinion about usage of new educational technology is shown in the figure 10 e. What results common from these sentences is that new technologies make teaching/learning: individual, interesting, simpler and faster. “Self-esteem can be achieved” is the most important statements: it means that we move in the directions which are indicated (but very generally) in Kazakh National requirements for the education.

**Figure 10 e.** The fourth analysis of the questionnaire.

4. Results

The testing results of two groups after performing the lab are shown in the figures 11-12. First group’s students got 9 as a minimum value, and 13 as a maximum value, so the average is 10.9, which is 73%. The second group’s students got 11 as a minimum value, and 14 as maximum value, so the average is 12.4, which is 82%. 

| In your opinion, the usage of new educational technology: |
|---------------------------------------------------------|
| Marking each student in class                           |
| Saving time                                             |
| The assessment time takes short time.                   |
| We should not stand in one place in education.          |
| Facilitates teacher's work                              |
| The lesson is unique                                    |
| Ensures the workshop is interesting                     |
| Lesson is interesting, it is not boring                 |
| The lesson is memorable                                 |
| Accelerates the expense                                 |
| Self-esteem can be achieved                             |
If we compare the data given in figures 7a, 7b and 11a, 11b, we can see that prior to undertaking the laboratory research, the average point of the first group was 59%. Then, when we tested the students on the laboratory research they had done previously, their average point increased up to 72%. Second group’s students were tested the same way. Prior to the research, their average point was 61%. Then, after having questioned them on their laboratory research, their average result rose up to 82%, thus showing good acquiring of the necessary knowledge. Even if the first group obtained quite satisfactory results, the second group after testing was decisively better.

In figures 12a,b we compare the individual results of students of both groups. Students of the first (i.e. control) groups improved modestly, on average by some 15-20%. If we have a look at Figure 12 b, we see that the knowledge of the 3rd and the 10th student on the subject had increased twice and almost all students reached the level 12 (!) We are particularly pleased by this latter result, as it corresponds to EU (and USA) educational indications “no student left behind”. Before training with the innovative methods
(blue columns in fig. 12b) differences between individual students were up to a factor of two (compare student No. 3 and No. 11); after test both of them were equally excellent.

These results demonstrate that the technological impact is useful especially to the students with low initial scores; the NCU educational materials are written with an easy language and are rich in photos and videos. Furthermore, if we compare Figures 7a, 7b and 11a, 11b again, we witness higher results of the whole group that was taught using new technologies.

Already stated, an extensive survey was conducted to find out the students’ opinions. The analysis of their answers proves again that the NCU web site is made of simple (for students) experiments; the analysis shows that this way of explaining electricity and magnetism is useful also at the university level. Our next step will be to include the interactive problems in physics [16], as a tool for not only qualitative but also mathematical understanding of experiments done.

5. Conclusions
Nowadays the current National Policy on Education of Kazakhstan gives great emphasis on new education technology as an integral part of national development strategy. It is expected that the student using this technology will be able to solve any problem on each topic. In the laboratory work, the student can practice the theory that he/she has learned during the lecture. Requirements for the student in each laboratory work are to know the theory of work, make further work, draw schema, calculate the report and make conclusions. The pre-test done in the present research showed that they perform modestly well in these tasks, with the traditional ways of teaching.

The main goal of the present use of multimedia was to consolidate the theoretical knowledge in practical terms. The results show that books and traditional laboratory instructions certainly serve as a basis of the education, but additional technologies improve, consolidate and make more “democratic” the educations. Our study was limited to the electromagnetism, but the overall level of appreciation, as seen from questionnaires, was very high. We are aware that these are still preliminary conclusions.

The interactive methods of learning often used by students in the field of active education to improve the lessons quality, to increase students’ commitment about learning. The application of innovative technologies in the learning process does not only reveal the attention of students, it also ensures that we do not stand aside from world news on industries. Application of modern demonstrative experiments like an additional tools in laboratory works help the students to explore further and to understand the work more efficiently. Information and methodological materials are intended to improve education with the help of communication means. Short video clips on simple experiments E-M packages from NCU were highly estimated by students. This triggers next work on translating the multimedia and fabricating simple experiments.

Our tests showed that the application of interactive teaching methods and simple experiments led to a substantial increase of the students’ educational level quality. The choice of electromagnetism as a starting branch proved to be very fruitful, as various educational resources developed within EU projects are available online at NCU. Obviously, these are only preliminary results and we continue.

Organization of education on the basis of new technologies should especially emphasize that it is important for students to be active in their ability to act independently, to develop themselves as a person, to develop self-education and to take into account their personality. The present implementation manage to obtain this goal, going far beyond the mere knowledge of electro-magnetism. In the future, we will continue to apply these technologies in teaching different fields of Physics, first at the university level and then at secondary-school level.

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