ПЛОВДИВСКИ УНИВЕРСИТЕТ "ПАИСИЙ ХИЛЕНДАРСКИ", БЪЛГАРИЯ
НАУЧНИ ТРУДОВЕ, ТОМ 37, КН. 3, 2010 – МАТЕМАТИКА
PLOVDIV UNIVERSITY "PAISSII HILENDARSKI", BULGARIA
SCIENTIFIC WORKS, VOL. 37, BOOK 3, 2010 – MATHEMATICS

ENHANCING MATHEMATICS EDUCATION THROUGH INFORMATION TECHNOLOGY INTEGRATION

Ivaylo Staribratov, Asen Rahnev

Abstract. This work considers the authors experience with the use of information technology in Mathematics education. A didactic experiment was conducted featuring two different approaches applied in the teaching of Mathematics to six different classes. Information technology was employed to teach the three experimental classes, while traditional teaching methods were offered to the three controls. The impact was assessed and the experimental results were analyzed.

1. Introduction

"...since we know that the progress and prosperity of future generations will depend on what we do now to educate the next generation, today I'm announcing a renewed commitment to education in mathematics and science." — remarks by US President Barack Obama at the National Academy of Sciences Annual Meeting on April 27, 2009.

Without a government policy, it is impossible to implement such a profound change in the education system of any country. Bulgaria is no exception. This was recognized in 1999 by elaborating and introducing the National Strategy for Introduction of ICT to Bulgarian Schools [10]. The rapid development of the new technologies has necessitated multiple updates of this strategy: 2002, 2005, and 2009 [12]. All deadlines underlying this strategy and its updated versions have been met well in advance, but nevertheless, a delay in ICT integration has been reported.

This work presents the outcomes of a didactic experiment conducted to assess the efficiency of the use of information technology in Mathematics Education.

2. Overview of computer integration in education

Systematic research on the use of computers in education began in mid 70s in Great Britain, the Netherlands, the USA, France, the Federal Republic of Germany, Japan, Russia, and, naturally, in Bulgaria [8]. Investigations and experiments in this field are still being done today. Based on the results from such endeavors, three major patterns of computer integration have been identified: "programming and informatics, use of computers as an auxiliary teaching aid by teachers, and use of computers as tools in programmed education meant to replace the teacher" [9].

A government policy is required to introduce computers in education. Every country has its own approach but they all tend to be very cautious at the beginning, to research and analyze before they decide to act on a mass scale.

Although no centralized research has been done in the USA or Great Britain to date, hundreds of various projects have been launched and implemented. The governments of these countries have employed projects basically in terms of providing financial support for research and granting 50% discounts for the schools which purchase locally made computers. The number of computers in US and British schools significantly exceeds that in the other countries. As early as in the distant 1985/86, all schools in the USA and Great Britain had computer rooms. France launched its project "10,000 Computers in the High Schools" in 1981/82.

The first stage of the research was completed in 1985–1986 and led to the following conclusions: 1. The study of Programming and Informatics at school is a necessity (in the Netherlands, this was recommended to begin at the age of 11 or 12). 2. The use of computers by teachers as an auxiliary educational aid enhances many-fold the quality and efficiency of learning. 3. The use of computers as tools for programmed education designed to replace the teachers, has remained questionable, largely due to the high cost of such lessons [15].

3. E-learning content

Some of the first attempts at elaborating electronic content were made in the USA in a town called Pravo, Utah, and in the city of Denver, Colorado, and it was there that numerous lessons were developed (in Denver alone, more than 2,000 different lessons were created) [9]. The programs used in those

schools were too sophisticated. The school administrations claimed that a large part of what the programs did completely replaced the traditional lesson work. The use of computers as tools in programmed education revealed a number of new possibilities, which considerably enhanced the efficiency of the positive aspects of this type of learning. Such training programs are very expensive, because of the massive labor intensiveness behind their development. The development of 10–15 lessons costs as much as a computer system. Most countries government projects for introduction of computers in schools spend some 40% of the development budget on software [11].

The underlying idea defining the nature of E-learning content is that of the role of the teacher in computer-aided instruction. The teacher is still the director and organizer of education. The computer is just a new and, in certain aspects, more perfect teaching aid compared with the aids preceding it [2]. Even the most sophisticated machines, however, are not able to orient themselves so quickly in the possibilities, inferences and mistakes, as a human being can with his or her subjective evaluation system. This is why opportunities should be provided for the teachers to decide on where, when, and how to use computers as their assistants. "With regard to the sensor-motor experience, computer software is fully comparable with textbooks" [14].

The first computer-aided lesson in Bulgaria involved over two hundred students and was demonstrated at the National Seminar on the Issues of Computer-Aided Instruction in Sofia in June 1983, under the title "An Algorithm for Computing Square Roots" [4]. The next lesson was on "Geometric Progression" [3]. The Division of Mathematics and Informatics Education, together with the Laboratory of Mathematical Linguistics at the Unified Center of Mathematics and Mechanics at the Bulgarian Academy of Science were among the most ardent participants in this endeavor. They developed two lessons, viz. "Metric Dependences in a Rectangular Triangle" and "The Pythagorean Theorem" using computer features, such as sound, graphics, and text. During the time period 1982–1986, teams of high school teachers and students, university lecturers and students, as well as research scientists, developed lessons in a range of subjects taught in Bulgaria schools.

With time, experience was acquired in the use of computers in Mathematics education and in the methodology for E-learning content design and development.

In 2006, the Ministry of Education and Science announced a competition in design and development of E-learning content in most subjects taught at the upper high schools in Bulgaria. The authors of this paper took part in this competition and were awarded the design and development of E-learning

content in Mathematics for the compulsory courses for 11th and 12th graders. The proposals complied with the MoES standards and were made publically available via the National Education Portal. There is a forthcoming follow-up project for launching a system designed to upgrade and supplement this curricular content due to the "Panta rei" syndrome (i.e. everything flows, everything changes). Needless to say, our achievements then cannot satisfy us now, five years later.

E-learning content also brings about changes in the role of the teacher. With the first training software, the teachers role was neglected, as teachers were involved (to a certain extent) in the development of the training program, after which they made a straightforward direct use of computers in the classroom [13]. Recently, experiments have been made with software whereby the teacher is able to intervene in the running of the program, to "instruct it", to modify some of its features. At no stage so far, however, has the fear of teacher replacement been substantiated.

Resorting to these specific methods in the classroom can excite and maintain students interest in a manner that traditional teaching methods are not up to. Thus, personalized training and creative approaches are encouraged in the acquisition of knowledge and skills, as the students take a central place in the learning process.

4. Didactic experiment on the quality and efficiency of learning trigonometric functions by using information technology

Should information technology be used in every lesson? Definitely not!

We chose a topic that was suitable to produce the required effect as a result of a lesson conducted with the use of information technology. Our goal was to conduct a didactic experiment in order to assess this effect and analyze the results.

The topic "Trigonometric Functions" is a section from the compulsory training curriculum for 10-graders and is very challenging both for students and teachers. This E-lesson is published on the National Education Portal [7] and can be used with some of the approved textbooks without replacing them. Methodology-wise, it is structured as follows: (Main Menu):

- New Knowledge — in addition to becoming acquainted with the facts, this page features four dynamic tables through which students can illustrate what they have learned. Each page allows the student to play some music while being introduced to the core concepts or while solving the problems, but this feature is limited to home settings only.

- Training Problems — two types of problems: solved or with hidden solutions. These problems are clarified by the teacher and it is recommended that students write down some of them in their notebooks.
- Self-Study Problems — featuring both solved problems and ones with hidden solutions. Depending on the computers performance, the solutions can be displayed with a delay of a couple of minutes.
- Test — performance assessment with a key role to play. The test is not lengthy, but bears a direct relevance to the taught material. It is made up of 5 problems and the score is calculated in terms of the number of problems that have been solved correctly. There is a key provided for self-assessment. This test has been designed for self-assessment and has not been used as a student assessment tool.

According to the State Educational Standards in Bulgaria, this section is meant to be taught over 8 to 10 periods of 45 minutes each. To carry out our experiment, we involved four classes from a high school of Mathematics and two from an average high school. Three of these classes constituted the experimental groups, and the other three were assigned to be the controls, each with 26 respondents. The experimental classes were taught using information technology, and the controls were taught in the traditional way. Two teachers were involved in the experiment and they taught both with and without using information technology, as necessary. Initially, we conducted a twenty-minute placement test to identify the knowledge levels of all students before the experiment. To cover the New Knowledge part, the experimental group spent 4 periods in a computer room, unlike the control, which was taught in a traditional classroom. During the following 4 periods, both groups practiced the new material and finally did a progress test.

The students in the control group made drawings on the blackboard and in their notebooks, which took a lot of time although the teachers were experienced and did their best.

In the experimental groups, however, the teachers gave a number of examples and the students experimented using the plotter integrated in the E-lesson. Due to the good skills demonstrated by the students, the examples implemented on the computers were extremely numerous. A lot of students were creative and proactive, and the students interest was immense. The problems solved by the experimental groups during the first 4 periods largely outnumbered those solved by the controls. A disadvantage was in that their notebooks remained almost intact.

5. Results from the experiment

In the assessment of the initial knowledge level, both the experimental and the control groups demonstrated similar performance, which was a sound basis to undertake the experiment.

The experiment revealed that during the next class periods meant for practice, the students from the experimental groups were able to solve twice as many problems as their peers from the control groups.

After the unit was completed, tests were administered in the traditional way and performance was compared. The average grade from the tests of the experimental groups was compared with that from the tests of the controls and was found to be higher by 0.48 on a 2(Fail)-to-6(Excellent) scale. That confirmed the expected, i.e. teaching that material with the use of information technology was not only appropriate, but also, perhaps, mandatory in order to ensure a better quality of Mathematics education.

At the end of the experiment, the students were asked to complete a questionnaire. The question "Should computers be used in Mathematics Education?" scored a 100% Yes responses by the experimental group and 93% Yes responses among the control. We cannot, but take into account that the students made a very accurate remark that not all lessons are suitable to be taught in this way.

The teachers opinion was also invited and they were enthusiastic to share that they were satisfied with the use of the electronic version of the teaching materials. They were explicit that the leading role in conducting the lesson is to be played by the teacher. S/he directs, monitors and facilitates the learning process. They also highlighted that the methodology of teaching is similar to that applied in teaching Informatics.

6. Conclusions and suggestions

The use of information technology provides an environment for: flexible personalization of the pacing of acquisition of the content knowledge; self-regulation; solving more problems in less time; development of spatial imagination in terms of 2-D and 3-D graphical images; identification and systematization of error patterns; more teachers time spent on coaching their learners; creative and innovative work by each and every student.

These advantages of training with the use of information technology, however, do not rule out certain shortcomings from a pedagogical and psychological point of view, such as confining the sensor inputs and to a certain degree the direct contact with the teacher.

Summarizing the above mentioned advantages and disadvantages, we can assert that education that integrates information technology will lead to a reduction in the time period needed for the acquisition of the subject content and will enhance the efficiency and quality of training. This is taking place at a range of educational institutions and involves various teachers, but should become regular practice in the teaching of certain lessons in Mathematics at all schools. One of the goals is to accelerate the process of its growing on a mass scale without waiting for a centralized body to coordinate the efforts to that end. A teacher should be able to make the decision of when and how to efficiently use information technology in the classroom and, hence, to accept or reject pedagogical hypotheses with a precisely evaluated certainty.

The E-lesson used in this experiment was static. There is an ever growing need for a new type of E-learning materials: dynamic, self-developing, and intelligent. Each of them is subject to further development and fine-tuning by the teacher to match the knowledge level of the students and their personal capabilities. To that end, they can use popular software environments and integrated systems, such as Planimetry, GeoNext, Mathematica, etc. [5].

7. Conclusion

Due to the use of information technology in education, some of its traditional features have undergone certain changes. The initial fears among the teachers have been overcome and a growing number of them are successfully integrating information technology in their teaching practice [16].

Given enough time and appropriate training, a lot of teachers would develop efficient E-learning materials for their school, but as a rule they are short of time and are not treated as professionals who can contribute to their school system in addition to the day-to-day classroom teaching. What is more, should the school system be willing to train certain teachers in computer integration in the teaching and learning process, the possibilities for such training are limited.

The integration of information technology into the teaching and learning process normally requires restructuring of the pedagogic practice in place. This is extremely difficult to implement by the local school systems without the availability of external guidance, consulting services and training materials, which are hard to get. The strongest support for such a change comes perhaps from the hardware and software manufacturers, as well as from textbook publishers, driven by their own goals — to sell their products.

It is often the case that innovations and changes are made, but the need for long-term training of teachers and follow-up support is neglected. Expe-

rience shows that a teacher needs two years to get accustomed to the use of information technology in their classes. Unfortunately, the school system offers short-term, mostly two-week courses [6]. The commercial developers also underestimate training and support, while focusing on profits.

A critical factor in introducing technology is the involvement of teachers in planning the projects and in the decision-making. If teachers advice is sought and they are treated as professional collaborators, there are great chances that they will really use the new technology and software.

Let us learn from the experience of others, e.g. the Stevens project in the USA suggests, "Empower teachers with training, time, and support by the school system, the community, and the corporations, and you shall receive ..." [1]. The Stevens project called for wider use of computers in Mathematics lessons and was focused on teachers. Efforts were made not only to provide teachers with knowledge and experience, but also with a better working environment, and the outcome was the publication of over 1,000 textbooks in a year. Provided that our school systems were encouraged to more actively develop e-learning content, then within a year or two we could reach a more satisfactory level. Consideration, focused on teachers needs for time, resources, and recognition is key to success.

8. Acknowledgements

This work is partially supported by the Scientific Research Fund at Plovdiv University "Paisiy Hilendarski", Contract IS-M-4/2008.

References

[1] Friedman E., Computer Integration in Teaching Mathematics — Opportunities, Obstacles, and Strategies, Journal of Mathematics Education, Issue No 3 (1993), pp. 8–17 (in Bulgarian).

[2] Ganchev I., Y. Kuchinov, Interactive Training Software: Essence, Guiding Ideas, Principles, and Stages of Development, Journal of Mathematics and Informatics Education, Issue No 2 (1987), pp. 1–8 (in Bulgarian).

[3] Ganchev I., Y. Kuchinov, Methodological Support for Mathematics Education through Computer Integration. The Use of Personal Computers

in a Mathematics Lesson, Journal of Mathematics Education, Issue No 3 (1987), pp. 3–7 (in Bulgarian).

[4] Garov K., A. Rahnev, Enhancing Mathematics Education in Secondary Schools through Computer Integration. Journal of "Mathematics Education" Issue No 5 (1984), pp. 5–10 (in Bulgarian).

[5] Gocheva S., Introduction to Mathematica, Eks-Pres (2009) (in Bulgarian).

[6] Grozdev S., E. Angelova. Word Processing as a Competence in the Qualification of Teachers of Information Technology, Science, Education and Time as Our Concern, Smolyan, Nov 30 — Dec 1 (2007), pp. 110–116 (in Bulgarian).

[7] http://www1.znam.bg/zmonres/edu/Matematika 10_ORAK /math10/sydyrj.htm

[8] Monahov V., A. Kuznetsov, D. Smekalin, Microprocessors in Schools Abroad, Journal of Mathematics Education, Issue No 1 (1985), pp. 8–14 (in Bulgarian).

[9] National policy perspectives, European Journal of Education, V. 17, No 4 (1982).

[10] National Strategy for ICT Integration in Bulgarian Schools. helpdesk.mon.bg/files/strategia_ikt.pdf (in Bulgarian).

[11] O'Shea T., Self-improving teaching systems, Birkhauser Verlag, Basel, (1979).

[12] Program for Development of Education, Science and Youth Policies in the Republic of Bulgaria (2009-2013), http://mon.bg/opencms/export/sites/mon/left_menu/documents /strategies/programa_MOMN-2009-2013.pdf (in Bulgarian).

[13] Sendov B., Issues in Computer Education — The Second Wave, Journal of Mathematics Education, Issue No 1 (1985), pp. 2–7 (in Bulgarian).

[14] Sendov B., Children in the Information Age, Journal of Mathematics Education, Issue No 3 (1985), pp. 1–5 (in Bulgarian).

[15] Sleeman D., J.S.Brown, (Eds). Intelligent Tutoring Systems, Academic Press, London, (1982).

[16] Stefanova E., N. Nikolova, E. Kovatcheva, P. Boytchev, E. Sendova. Discovery as part of the teaching process in an information technologies context, Mathematics and Mathematics Education (2009), pp. 319–328 (in Bulgarian).

Received 31 January 2010

Ivaylo Staribratov
Model High School of Mathematics "Acad. Kiril Popov"
11, Chemshir Str., Plovdiv 4001, Bulgaria
e-mail: ivostar@abv.bg

Asen Rahnev
Faculty of Mathematics and Informatics
Plovdiv University "Paisiy Hilendarski"
236, Bulgaria Blvd., Plovdiv 4003, Bulgaria
e-mail: assen@uni-plovdiv.bg

ИНТЕНЗИФИКАЦИЯ НА ОБУЧЕНИЕТО ПО МАТЕМАТИКА ЧРЕЗ ИЗПОЛЗВАНЕ НА ИНФОРМАЦИОННИ ТЕХНОЛОГИИ

Ивайло Старибратов, Асен Рахнев

Резюме. В работата се споделя опит от използване на информационни технологии в обучението по математика. Проведен е експеримент за преподаване в шест паралелки чрез два различни подхода. В експерименталните три паралелки са използвани информационни технологии, а в контролните три — традиционни методи за обучение. Оценен е ефекта и са анализирани резултатите от експеримента.