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Dynamic Mathematics Software as a Necessary Component of Modern-Math-Teacher Preparation in Ukraine

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Abstract

The article discusses the relevance of the study of dynamic Mathematics software by future math teachers in Ukraine. The focus is on the requirement, not only to know about specialized dynamic software, but also to be able to organize an effective learning process with its usage. The arguments for the organization of special courses in the study of dynamic Mathematics software are based on the need to demonstrate the skills of usage of modern Mathematics software. The authors describe their own experience of teaching the course at A. S. Makarenko Sumy State Pedagogical University (Ukraine), which is included in the curricula as variable course of math-teacher preparation, in particular, the successive changes of the content of the course, due to constant and rapid development of Information Technology, during all periods of learning.

Keywords: dynamic mathematics software, math-teacher preparation, special course, pedagogy.

1. Introduction

Higher education, in the system of general education aims to solve the problems related to individuals' future working career. Such preparation is determined by many factors, among which there is the set of future competences of the graduate, which is consistent with the requirements of both the employer and the profession itself.

In the framework of higher education, the determining factor is not so much knowledge of the subject being taught, as the possession of a set of pedagogical approaches and techniques that allow to develop knowledge and skills in the entities of study. The ability to use information technologies (software components), that support the study of school subject, is allocated among such methods. Numerous results of pedagogical studies prove the influence of the level of information technological development, not only on the level of the development of science, but also on the technology of teaching of courses (Bykov, 2012; Spivakovskyi, 2003; Spirin, 2013; Tryus, 2012; L'vov, 2008).

This influence occurs in a variety of methods. Among the methods is the creation and continuous improvement of specialized software, which can demonstrate the basic ideas of the course, investigate the properties of typical objects, and hypothesized techniques of solving of problems. Such software include Dynamic Mathematics Software (DMS) as the base of "learning" and "teaching", which is invented to support school Mathematics.

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Monitoring the usage of DMS shows that various popular types of software and their country of use include; MathKit (1C Company: Educational software), *Live Mathematics, Live Geometry* (Institute of new technologies) (Russia), *GRAN, DG* (Dynamic geometry software *DG*) (Ukraine), *GeoGebra* (GeoGebra Wiki) (Austria), *Cabri* (CABRILOG. Innovative Maths Tolls) (France), *The Geometer's Sketchpad* (The Geometer's Sketchpad. Resource Center) (USA), and *GeoNext* (GeoNext) (Germany).

In effect, it is not enough for the math teachers to be aware of the existence of such dynamic software. Rather, they need to be able to establish its usage in an effective learning process. This ability can be obtained with the practical experience in solving problems, as well as in the process of organizing special training for that purpose. This is possible with the introduction of special courses for the study of specialized software in the curricula (the variable part) in the framework of the math-teacher preparation.

The authors have already mentioned the need and the arguments in favor of the actuality and the relevance of special courses of Computer Mathematics for specialists-mathematicians (Semenihina, 2013). To be precise, special courses should be provided for the study of software as a modern support of scientific research. In addition, there should be the demonstration of aptitudes for Mathematics software usage, the acquaintance with the specificities of the work of the various Mathematics software, and the simplification of modeling for mathematical objects.

Although these arguments specify the certainty of the study of Mathematics software for mathematicians, that is not enough for the future math teachers. The modern-math-teachers' preparation must include both the study of the methods of teaching Mathematics and the study of technologies for the usage of specialized software, among which the DMS is significant. This implies an emphasis on two points – the ability to apply DMS to solve the problem, and the ability to use DMS for the organization of the educational situation. Such vision is agreed with modern competence approach and it is a natural consequence of the development and the impact of modern information technologies, as well as the trends of the improvement of traditional methods of teaching Mathematics. Consequently, it is relevant in the math-teacher preparation (Semenihina and Chashechnikova, 2013).

2. Method

During 2010-2014, the authors investigated the impact of the special course on the psychological readiness of future math teachers as to use DMS at the lessons of Algebra, Geometry, Solid Geometry or Mathematical Analysis (Semenikhina and Drushlyak, 2015). The base of the research was A. S. Makarenko Sumy State Pedagogical University in Ukraine.

Because this personal objectives can be formed within the teaching of the special courses, it was natural to involve statistical methods to give the opportunity to talk about the dynamics of change based empirical on data (about the initial and the final state of the object).

As a result, the authors fixed the internal state of the psychological readiness of the student to use DMS with the help of research questions at the beginning and end of the study of the special course. The research questions were: "Are you mentally ready to use the DMS in the study of: (a) Algebra; (b) Planimetry; (c) Solid Geometry; and /or (g) Mathematical Analysis? What DMS are you ready to use during these lessons? Why did you choose that type(s)?"

3. Results

Readiness to Use DMS in Teaching

We applied the McNemar's test (Grabar and Krasnyanskaya, 1977), because the scale of results in the questions has two items ("Yes" or "No"). Thus, this nonparametric was used to compare the distributions of objects in two sets according to the two categories; "ready – not ready". For the McNemar's test the following conditions are required: (1) random sample; (2) dependent sample; (3) pairs (x_i, y_i) which are mutually independent (the members of the sample have no effect on each other); and (4) the scale has only two categories.

The research was conducted from 2010 to 2014. Each year the authors have accumulated the results of the sample with volumes – 37, 35, 38, 37, and 31 respectively. The total number of respondents amounted to 178 people. The authors selected results from them at random.

The hypothesis H_o: the special course does not impact on the psychological readiness of students to use DMS in professional activities. Then the hypothesis H_a: the special course impacts on the psychological readiness of the future math teachers to use DMS. The test of the assumption was carried out according the McNemar's test on taken results in 40 pieces from 178 questionnaires at random (see Table 1).

Table 1. The survey of the psychological readiness to use DMS.

The Second Surve			
The First Surve	$y_i=0$	$y_i=1$	
$x_i=0$	a=7	b=16	a+b=23
$x_i=1$	c=6	d=11	c+d=17
	a+c=13	b+d=27	N=40

Since $n=b+c=22>20$, the statistics of the test was calculated according the formula $T_{exper}=(b–c)^2/(b+c)=4,54$. The assumption of the fairness of the null hypothesis was approximated like the χ^2 distribution with one degree of freedom ($\upsilon=1$). For significance level $\alpha=0.05$, the critical value of the test was $T_{critic}=3.84$. The obtained value $T_{exper}= 4.54 > T_{critic}= 3.84$, therefore, the hypothesis H_0 was rejected and alternative hypothesis, indicating that the impact of the special course on the readiness to use DMS in future professional activity is significant and cannot be explained by random variation, was accepted.

Because the problem was to study the psychological readiness to use DMS at the lessons of Algebra, Planimetry, Solid Geometry and Analysis, as well as the readiness to use different DMS {*Gran (Gran1, Gran2d, Gran3d), GeoGebra, Cabri, MathKit, DG, GS*}, the authors were able to fix the results of the readiness to use DMS in teaching of different subjects (Algebra, Planimetry, Solid Geometry, Analysis) (see Table 2).

Table 2. The Survey of the Readiness to Use DMS in Teaching of Different Subjects.

Do You feel readiness to use DMS at the lessons of:	Quantitative indices					Indices of the McNemar's test (α=0.05)			
	a	*b*	*c*	*d*	*N*	*n=в+c*	*T_2*	H_0	H_a
Algebra	6	17	7	10	40	24	4.17	0	1
Planimetry	2	21	9	8	40	30	4.80	0	1
Analysis	5	18	7	10	40	25	4.84	0	1
Solid Geometry	4	17	15	4	40	32	0.13	1	0

For all items, except the last, the authors had the rejection of the null hypothesis, H_0 and the acceptance of the alternative hypothesis. At the significance level α=0.05, the studying of the special course had a positive impact on the psychological readiness of future math teachers to use DMS at the lessons of Algebra, Planimetry, and Analysis.

However, experimental results did not support the positive impact on the readiness to use DMS at the lessons of Solid Geometry. The increase in the number of students who feel the readiness to use DMS at the Mathematics lessons is presented in Figure 1.

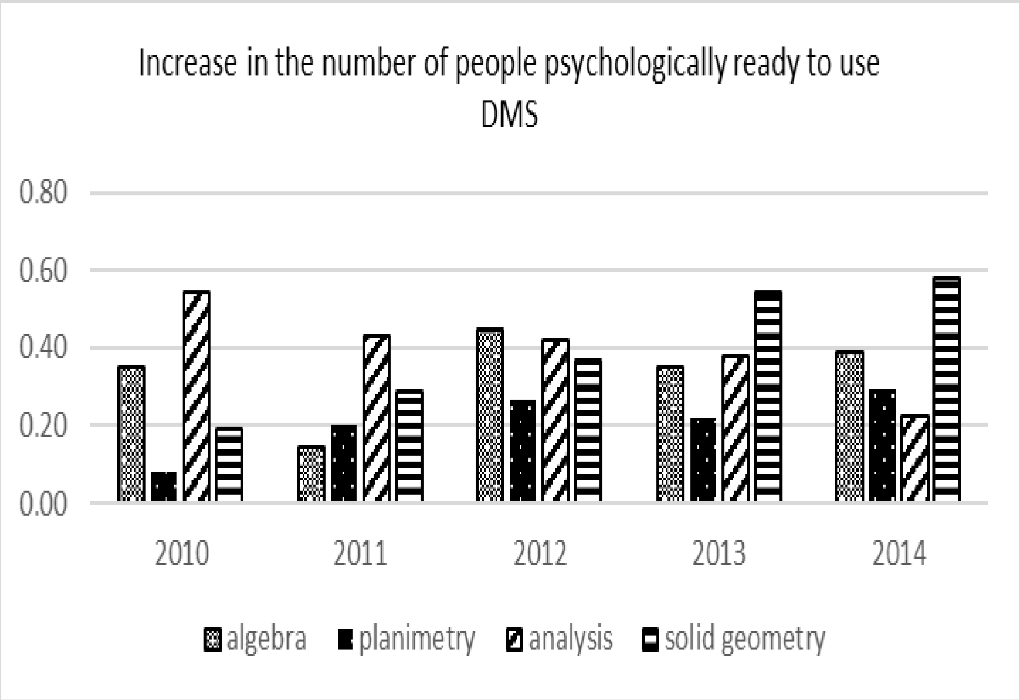

Figure 1. Increase in the Number of People Psychologically Ready to Use DMS.

Impact of the Special Course on the Formation of Skills

This research also sought to answer the question: "Does the special course contribute the formation of skills to choose DMS rationally to solve a mathematical problem?" (Semenikhina and Drushlyak, 2015). These skills were formed during study of the special course, so statistical assessment of the learning results could be based on non-parametric sign test for dependent samples (Semenikhina and Drushlyak, 2015).

During the special course, there were two examinations in the middle and at the end of the semester. Five tasks were offered at these exams. Each well-reasoned choice of DMS was estimated at one point. At the end of the semester, comparative tables were composed; where the dynamics of results were fixed during 2010 to 2014. The number of sample of 178 people were selected. Thirty (30) results were taken at random (Table 3).

Table 3. The results of two exams in the middle and at the end of the semester.

Number of Student	The first mark	The second mark	Number of Student	The first mark	The second mark	Number of Student	The first mark	The second mark
1	2	3	11	2	4	21	3	4
2	1	4	12	4	4	22	2	3
3	4	5	13	3	3	23	2	2
4	1	3	14	3	3	24	3	2
5	1	2	15	3	3	25	3	3
6	4	5	16	1	2	26	3	3
7	3	4	17	2	3	27	3	3
8	3	2	18	2	2	28	4	5
9	3	4	19	4	3	29	2	3
10	3	2	20	3	3	30	3	4

These points determined the number of respondents whose total score decreased ("–"), didn't change ("0") and increased ("+") (Table 4).

Table 4. The dynamics of the results of two exams

The dynamics of the results	«–»	«0»	«+»	n=«–»+«+»
The number of respondents	4	10	16	20

In accordance with the purposes of the experiment the hypothesis, H_0: the study of the special course does not contribute the formation of skills to choose DMS rationally in solving a mathematical problem. Then alternative hypothesis, H_a: the study of the special course contributes the formation of such skills.

These hypotheses determine one-sided sign test for testing dependent samples. According to the decision rule (Grabar and Krasnyanskaya, 1977) the value of $T_{exp}=16$ (the number of characters "+" in the sample), $n=20$ (the number of respondents who had changes in the results), the interval of the hypothesis H_0 is (1C Company: Educational software; Semenihina and Chashechnikova, 2013) at the significance level of 0.05.

T_{exp} was not included in the acceptance interval of the hypothesis H_0, so the hypothesis H_0 was rejected and the hypothesis H_a was accepted. Thus, the study of the special course contributes the formation of skills to choose DMS rationally. The value of T_{exp} went beyond the segment to the right, so a conclusion about positive dynamics in the number of students who have formed a critical view on the use of some DMS was made.

4. Discussion

The development of the information society influences education in several dimensions. This impact is observed not only in active equipment settings of educational institutions with computers, but also in the understanding of the need to rethink conventional approaches to teaching. This particularly applies to Mathematics, the classical course of which, not only is systematically and fundamentally built but is quite flexible in terms of introduction of modern information support. Such support is in simplification and acceleration calculations, visualization of mathematical objects, and their dynamic change. This cannot be said, for example, about Philosophy, which is an established discipline, whose study has not significantly changed with the involvement of information technologies.

Now the authors can say that there are countless varieties of Mathematics software {computer algebra systems (CAS) like *Maple, Mathematica, Maxima, Sage*, etc.; dynamic Mathematics software like *GeoGebra, The Geometer's Sketchpad, Cabri*, etc.}. These software allow rapid solving of problems in various fields of Mathematics, from simple constructions to complex analytical calculations and modeling of processes. A variety of such software is an additional tool for specialists in various fields of Mathematics, in particular, for those who teach Mathematics. In other words, such software is necessary object of study for mathematicians.

Ukrainian math teachers at secondary schools and universities feel the impact of information technologies and understand the potential that Mathematics software carries. Therefore, they use such software to support the educational process, as evidenced by publications in relevant Ukrainian periodicals – "Information Technologies in Education", "Information Technologies and Learning Tools", "Computer in School and Family".

Currently, the widespread use of Mathematics software in the educational process at secondary schools and universities is well acknowledged in Ukraine. At the beginning of the 21st century, courses for the study of Mathematics software were introduced in the curricula of math-teacher preparation, and dissertation research for the last 10-15 years and had often focused on the integration of such software in the learning process.

However, the analysis of the Ukrainian practice of usage of Mathematics software in math-teacher preparation, conducted on the basis of existing curricula, materials of scientific-methodical conferences of various levels, and interviews with graduates of different universities, assures that either Mathematics software is never used, or some components of different Mathematics software were used, or only one Mathematics software is used in studying Mathematics. This impoverishes substantive specialist preparation and does not contribute to the formation of a culture of the use of such software in the teacher's professional activities. Few, if any, research works could be identified regarding to the use of different Mathematics software in the teaching of some fields of Mathematics. In the authors' opinion, there are also few research works that present approaches to the systematic use of Mathematics software in teaching school Mathematics within one year (5th class, 6th class, etc.).

A detailed study of the research works of the authors, which were focused on the involvement of such software in the teaching of Mathematics, showed that there are no research devoted to learning the usage of Mathematics software (CAS, DMS) in teaching. There are research works which rather focused on solving problems in some Mathematics software (*Maple, MathCad, Maxima, Sage, GRAN*, etc). Also the authors identified too few research works that demonstrate the systematic implementation of software in the math-teacher preparation.

On the other hand, the study of research focused on the attraction of Mathematics software in the process of teaching Mathematics, confirms the relevance of the problem of the usage of such software. Researchers such as the following can be mentioned: E. Vinnychenko, J. Goroshko, M. Zhaldak (Zhaldak et all., 2008), O. Zelenyak, S. Rakov (Rakov, 2005), Yu. Tryus, S. Semerikov (Tryus, 2012) (Ukraine); V. Dubrovsky (Dubrovskij and Poznjakov, 2008), Yu. Zhuravlev (Zhuravlev, 2005), V. Dyakonov, L. Martirosyan (Martirosjan, 2010), M. Ragulina (Russia); I. Khrapovitsky (Hrapovickij, 2016) (Belarus); M. Hohenwarter (Hohenwarter et all., 2008) (Austria); D. Scher (Scher, 2000), S. Althoen, J. Brandell (Althoen and Brandell, 2009) (USA); G. Dimakos, N. Zaranis (Dimakos and Zaranis, 2010) (Greece). They comment how to use various Mathematics software, and they point to the need to introduce the respective author's methods of teaching Mathematics, which are based on Mathematics software and computer-oriented systems of teaching Mathematics, computer-oriented methods of teaching of some topics and sections of secondary school and university Mathematics courses, technologies of electronic, mobile and blended Mathematics teaching, etc.

Thus, the authors can note that there is a contradiction between the need to use Mathematics software and the absence of sufficient methodological support, or even developed courses devoted to the attraction of such software in the mathematical training of the young people. This suggests that the need for the formation of skills of future math teachers to use such software in their professional activities is urgent.

On the other hand, there is currently a unique situation in which the computer revolution has brought intellectual work in the priorities of human activity. People with mental actions – to understand the task clearly; to be able to solve it without additional guidance; to be ready for active but responsible involvement of innovations; and to find the time to study constantly and to teach others – have become more valued (Druker, 2012). These factors cannot be implemented without the mastering of specialized software. According to the forecasts of the world's leading experts, new jobs will require intelligent actions that rely on information technologies. The requirements for qualification and versatility of employees will increase constantly and steadily. It requires focusing on professionally oriented software and the ability to use them in solving professional and life goals.

The generalization of the results of Ukrainian research works recommend that teachers formerly focused on the process of getting an answer during teaching Mathematics (it was important to develop skills to transform and simplify expressions, calculate its value, etc.). However, too little time was devoted to study of the answer. After the advent of computer technologies and Mathematics software, the process of finding the answer becomes less important, because the computer finds it. The empirical search of laws, the interpretation of results, and a critical look at its application have become more important. The authors believe that this should be the basis for the reformation of the math preparation in Ukraine. Despite the fact that high-quality Mathematics education is formed under influence of good teachers, teacher preparation should be focused on the need to teach the use of Mathematics software consciously and rationally in daily life and future career.

Economists talk about the reduction of the role of industrial and agricultural workers in the countries of Western Europe, the USA and Japan, and the rapid rise of a new class of intelligent employees, who already comprise more than half of the employed population in developed countries (The concept of development of the Russian mathematical education. Retrieved on

5th January, 2016; Wolfram, 2016). As the Minister of Education and Science of Ukraine S. Kvit noted*: "Today more than 95% of Ukraine's economy is 'in the past'. This is the third and the fourth technological structures – ferrous metallurgy, petrochemistry, etc. The modern, the fifth and the sixth levels of technological structure, which, in particular, include information, bio- and nanotechnologies, accounts for less than 5% of the economy. In the world there is a struggle for intelligence"* (Kvit, 2016).

Therefore, the authors can say that the transition of society to a new stage of its development gives education a task to reform the Mathematics teaching, which is in line with the goals of the computer revolution. In other words, a new system should organize math preparation of students for life in the modern world in a novel way; not so much to accumulate Mathematics knowledge. But then again, students should be able to operate this knowledge with the production of new knowledge, using mathematical methods based on the potential of information technologies. By coincidence, the rare application of Mathematics software, which we can see in Ukraine, is not enough. The urgent need is a harmonious combination of Mathematics knowledge and Mathematics software even at school. The leading role of this combination is imposed on teachers and the quality of math preparation of young people and the development of society as a whole, depends on the teacher preparation for professional work (Semenikhina and Drushlyak, 2015).

The authors believe that, the level of the development of Mathematics software should be taken into account together with a focus on the fundamentalism of math preparation. This is because of the need to involve specialized software by teachers. We believe that specialized Mathematics software will be perceived as the object of study and learning tools.

This is confirmed by the experience of the introduction of the course "Computer Applications in the Study of Mathematics" at A. S. Makarenko Sumy State Pedagogical University (Ukraine) (Semenihina and Drushlyak, 2011). The course involves 50 hours of class work. The main purpose of the course is the study of Mathematics software to support the learning of school Mathematics, clarifying the usage of software in teaching school Mathematics, and the study of modern methods of usage of software in the study of school Mathematics.

Concerning the formed knowledge and skills of students, future math teachers should present knowledge and skills in the following content areas:

1. the awareness of Mathematics software and the ability to classify them;
2. the proficiency of the typical problems of the school Mathematics and ability to solve them with the tools of dynamic Mathematics software which include:

a. the construction of graphical models of plane and solid figures;
b. the determination of quantitative characteristics of mathematical objects (length, angle, area, volume);
c. the solving and the studying of construction problems;
d. the calculation of triangles;
e. plotting graphs and functions research;
f. graphical solution of equations, inequalities and their systems;
g. the study of the properties of derivatives of functions;
h. the calculation of definite integrals; and
i. basic statistical data processing, the determination of numerical characteristics of the statistical probability distributions.

5. Conclusion

This course has already been studied for 7 years. It has been revised several times, in terms of content and learning structure. Initially, it focused only on the study of computer elaboration of Ukrainian researchers but later, the issues of computer testing and project technologies were included in the course. This included recent enhancement related tools of dynamic Mathematics software, deeper investigation of the possibilities of software *MathKit* and *GeoGebra* for automatic answer checking and the creating of interactive applets.

Statistical analysis of the effectiveness of such special course suggests the feasibility of its study and usage. Experimental data (178 respondents) confirmed the positive dynamics on the readiness to use DMS (the McNemar's test at the significance level of 0.05), and on the formation of a critical choice of the usage of some tools of different DMS (the sign test at the significance level of 0.05).

The authors suggest that, such a course cannot become classical because of a constant and sufficiently rapid development of Information Technology. Nevertheless, they consider it as unavoidable in the curriculum of the specialization of Mathematics as a pedagogical direction. To study such a course, future math teachers need the skills to: (i) use Mathematics software in order to support the professional pedagogical activity; (ii) demonstrate the abilities of DMS; and (iii) also provide the need to develop a culture of software usage in their professional activity as math teachers.

Conflict of Interest Statement

The authors declare that they do not have any conflict of interest.

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