On the Results of a Study of the Willingness and the Readiness to Use Dynamic Mathematics Software by Future Math Teachers

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Abstract. The article presents the results of pedagogical research on the willingness and the psychological readiness to use dynamic mathematics software by future math teachers. We used nonparametric method for dependent samples – the McNemar's test. The hypothesis, that the study of Special course on the use of dynamic mathematics software for future teachers has a positive impact on the willingness and the psychological readiness to use such software in their own professional activities, is confirmed at the significance level of 0.05. Additionally, the results of the experiment on the willingness and the readiness to support the teaching of some subjects (algebra, planimetry, solid geometry and analysis) with dynamic mathematics software and the willingness and the readiness to use some dynamic mathematics software (*Gran (Gran1, Gran2d, Gran3d), GeoGebra, Cabri, MathKit, DG, GS)* by Ukrainian math teachers is given.

Keywords. The study of mathematics, computer applications in the study of mathematics, special course, dynamic mathematics software, the McNemar's test.

Key Terms. InformationCommunicationTechnology, TeachingProcess, TeachingMethodology.

1 Introduction

Ukrainian education has always tried to involve leading technologies and tools that have spread in the world and improve the level of education of ordinary Ukrainians. That is why since the end of the last century information technology has started to be actively implemented in the learning process (also in mathematics). Specialized software appeared and the main purpose of them was computational and visual support of solving of math problems. Later the software, that allows to model processes and to observe the changes in constructions, appeared. But the use of such

software was limited in schools because of a number of reasons, among which the insufficient technical equipment of schools, the lack of targeted preparation of teachers to use specialized software, the lack of software with a clear (Ukrainian, Russian) interface, a small number of teacher's guides, etc.

Now there is a great amount of software which can be used in teaching mathematics. We previously conducted an analisis of the current tendencies of mathematics software use in education in [1]. But the workload of school teachers does not let them to monitor the appearance of such software, to learn the tools and to use them at their lessons. The main part of Ukrainian math teachers are 40 and more years old. This means that they were not acquainted with mathematics software during their preparation, and they used information technologies on the level of Internet users and *Word, Excel, PowerPoint*. They do not use software consciously, because they believe that chalk-and-Board style is better at studing mathematics.

These and other reasons have led us not only to enter the Special course of the study of mathematics software in the curricula of preparation of modern teachers, but to study the impact of this course on the willingness and the readiness to use mathematics software in the professional activity of math teachers.

2 Research of the Willingness and the Psychological Readiness of Future Math Teachers to Use Dynamic Mathematics Software

During 2010-2014, we have investigated the problem of the willingness and the psychological readiness to use mathematics software by future math teachers [2].

We allocate dynamic mathematics software (DMS), that can model and modify mathematical objects interactively. We consider *Gran, DG* (Ukraine), *GeoGebra* (*GG*, Austria), *MathKit*, *Live Mathematics (LM)* (Russia), *Cabri* (France), *The geometer's Sketchpad* (*GS*, USA), etc. We allocate these software for the following reasons: 1) software *Gran* and *DG* are recommended by the Ministry of Education and Science of Ukraine; 2) software *MathKit* and *Live Mathematics* are actively used by Russian teachers, as evidenced by a great number of methodological works of math teachers; 3) software *Cabri*, *The geometer's Sketchpad* and *GeoGebra* are the most popular in the world, as evidenced by the numerous translations of monographs and multi-lingual interfaces of these software.The work with them intuitive and identical – basic objects are built, then they can be dynamically changed and user can observe certain quality properties and quantitative characteristics. The study of features of these software and recommendations for their use are generalized by us in [3-10].

The base of the reaserch was Sumy Makarenko State Pedagogical University. Preparation of math teachers is in accordance with the curricula. The introduction of these software was during the study of methodology of mathematics and during the study of a special course "Computer Applications in the Study of Mathematics" (further Special course). The program of the Special course was described in [11-13] and was improved during the years 2008-2014. The experience of the involvement of

dynamic mathematics software in support of teaching mathematics in the school was during teaching practice (see Table 1).

Table 1. The extract from the curriculum of the speciality "Mathematics*"

Course	Feachers		Note
Methodology of mathematics	Semester	6;7;8	The course contains the module "Computer support for learning mathematics" – 7-th semester, 12 hours.
	Credits	2,5;2;2	
	Class hours	46;46;44	
Teaching practice	Semester	8	At the beginning of the third quarter, within 2 months, on the basis of city schools
	Credits	6	It is supposed to teach 10 math lessons at 5-9 classes
Special course	Semester	8	It is supposed to study different dynamic mathematics software during solving algebra, geometry, analysis problems
	Credits	3,5	
	Class hours	50	

At the beginning of the teaching practice students learn how to solve mathematical problem with the use of dynamic mathematics software (DMS) at the lessons of Special courses. During the teaching practice they have the opportunity to see (or not to see) and analyze lessons of those teachers who use DMS in their own professional activity.

We believe that during this period the basis for the motivation of the learning and further use of DMS in professional activities is formed. Therefore, the Special course, which is studied immediately after the teaching practice, becomes the factor of impact on the student, which gives the opportunity to talk about the willingness and the readiness to use DMS in the future professional activity.

Because these personal characteristics can be formed within the teaching of the Special course, it was natural to involve such statistical methods, that give the opportunity to talk about the dynamics of change based on data about the initial and final state of the object. So we fixed the internal state of the willingness and the psychological readiness of the student to use DMS with the help of questionnaires at the beginning and at the end of the study of the Special course (see Table 2).

Table 2. The questionnaire

№	Questionnaire	Answers
1.	Do You need to use DMS at the lessons of algebra (planimetry, solid geometry, mathematical analysis)? Why?	Yes Yes, not at all No

№	Questionnaire	Answers
2.	Do You want to use DMS at the lessons of: a) algebra; b) planimetry; c) solid geometry; g) mathematical analysis? Why?	 Yes/No Yes/No Yes/No Yes/No
3.	Do You feel readiness to use DMS at the lessons of: a) algebra; b) planimetry; c) solid geometry; g) mathematical analysis? Why?	 Yes/No Yes/No Yes/No Yes/No
4.	Specify a priority of DMS that You like.	*Gran* *DG* *GG*
	Specify a priority of DMS, which is better to use at math lessons on Your opinion.	*MathKit* *GS* *Cabri*

It was applied the McNemar's test [14], because the scale of results in questions 1-3 has two items ("Yes" or "No"). This method is nonparametric and used to compare distributions of objects in two sets according to some property on the scale with two categories (e.g., "like - dislike ", "ready - not ready," "willing - unwilling" and others).

For a McNemar's test the following conditions are required: 1) random sample; 2) dependent sample; 3) pairs (x_i, y_i) are mutually independent (the members of the sample have no effect on each other); 4) the scale has only two categories.

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

2.1 The Use of Dynamic Mathematics Software in the Study of Mathematics in Secondary Schools

The beginning of our research was associated with the study of the status of the use of DMS in the study of mathematics in secondary schools. Through conversations with teachers, graduates, teachers-methodists of our region it was found that the "poor" use of DMS in the learning process is not only due to the limited number of computers in schools, but due to lack of the willingness of teachers to involve such software to the solution of mathematical problems. Although they did not deny the feasibility of this approach, but noted, among other things, about the inability to use DMS (68%), the need for additional time to study them (87%), the small number of methodological literature on the use of DMS (90%) and the lack of collections of tasks, which can be solved by using DMS (36%).

2.2 The research of the Willingness of Future Math Teachers to Use Dynamic Mathematics Software in Their Professional Activities

Searching for ways to solve the problem, we have suggested that a focused study of the Special course will have a positive impact on the willingness of future math teachers to use DMS in their profession.

The test of the assumption was carried out according the McNemar's test on taken results in the amount of 30 pieces from 178 at random.

Hypothesis H_0: the Special course does not impact on the willingness of students to use DMS in the future math teacher's profession. Hypothesis H_a: the Special course has a positive impact on the willingness of future math teachers to use DMS.

We had two series of observations: $X=\{x_1, x_2, ..., x_N\}$ and $Y=\{y_1, y_2, ..., y_N\}$, where (x_i, y_i) are the results of measuring of the willingness to use DMS in the future professional activity of the same object (the willingness of the student before and after the Special course). In our notation, x_i or y_i takes the value 0 if the object of study does not wish to use DMS at any of the classes (algebra, planimetry, analysis, solid geometry) and 1 otherwise. The results of the dual survey recorded in the Table 3.

Table 3. The survey on the willingness to use DMS

	The second surve		
The first surve	$y_i=0$	$y_i=1$	
$x_i=0$	a=6	b=10	a+b=16
$x_i=1$	c=2	d=12	c+d=14
	a+c=8	b+d=22	N=30

In the conditions of the experiment parameter a determined the number of students who both times said "No"; the parameter b was the number of students who the first time said "No" and the second time said "Yes"; the parameter c was the number of students who the first time said "Yes" and the second time said "No"; the parameter d was the number of students who both times said "Yes".

To apply the McNemar's test we will find $T_{exper}= min(b,c)$, if $n = b + c < 21$. For our data $T_{exper}= 2$, since $n = 10 + 2 = 12 < 20$. Statistics of the criterion for significance level $\alpha = 0,05$ is $p = 0,019$. According to the rule of decision [14] we have $0,019 < 0.025$. We have to reject hypothesis H_0 and accept the alternative one, and since $b > c$, then we consider that the impact of the study of the Special course on the willingness to use DMS is not only statistically correct, but also positive.

2.3 The research of the Readiness of Future Math Teachers to Use Dynamic Mathematics Software in Their Professional Activities

In parallel with the research of the willingness to use DMS we explore the personal readiness of future math teachers to use DMS in their professional activities (question 3 of the questionnaire).

The hypothesis H_0: the Special course does not impact on the psychological readiness of students to use DMS in their professional activities.

Then the hypothesis H_a: the Special course impacts on the psychological readiness of 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 4).

Table 4. The survey of psychological readiness to use DMS

The first surve	The second 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 criterion is calculated according the formula $T_{exper}= (b - c)^2 / (b + c) = 4,54$. The assumption of the fairness of the null hypothesis is approximated like the χ^2 distribution with one degree of freedom ($v=1$). For significance level $\alpha=0,05$ the critical value of the test is $T_{critic}=3,84$. The obtained value of $T_{exper}=4,54 > T_{critic}=3,84$, therefore, the hypothesis H_0 is rejected and the 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, is accepted.

2.4 The research of the Willingness of Future Math Teachers to Use Different Dynamic Mathematics Software in Their Professional Activities in Teaching of Some Subjects

Because the questionnaire was on the research of the willingness to use DMS at the lessons of algebra, planimetry, solid geometry and analysis, and on the research of the use of different DMS (*Gran (Gran1, Gran2d, Gran3d), GeoGebra, Cabri, MathKit, DG, GS*), we were able to fix and process results about the willingness to use DMS in teaching of some subjects – algebra, planimetry, solid geometry, analysis (see Table 5) and about the willingness to use different DMS – *Gran, DG, GeoGebra, MathKit, GS, Cabri* (see Table 6).

For each position of the table 5 we have the rejection of the null hypothesis H_0 and the acceptance of alternative hypothesis, i.e., at the significance level $\alpha=0,05$ we can say about the positive impact of the studing of the Special course on the willingness of future math teachers to use DMS at the lessons of algebra, planimetry, analysis and solid geometry.

Table 5. The survey of the willingness to use DMS in teaching of different subjects

Question. Do You wish to use DMS at the lessons of:	Quantitative indices					Indices of the McNemar's test (α=0,05)				
	a	**b**	**c**	**d**	**N**	**b+c**	T_{ek}	**P**	H_o	H_a
algebra	6	11	2	11	30	13	2	0,011	0	1
planimetry	2	15	5	8	30	20	5	0,021	0	1
analysis	5	12	3	10	30	15	3	0,018	0	1
solid geometry	6	14	4	6	30	18	4	0,015	0	1

Table 6. The survey of the willingness to use some DMS

Question. Do You wish to use:	Quantitative indices					Indices of the McNemar's test (α=0,05)				
	a	**b**	**c**	**d**	**N**	**b+c**	T_{ek}	**P**	H_o	H_a
Gran	8	11	2	9	30	13	2	0,011	0	1
DG	5	12	3	10	30	15	3	0,018	0	1
GG	2	12	2	14	30	14	2	0,006	0	1
MathKit	6	14	4	6	30	18	4	0,015	0	1
GS	12	10	6	2	30	16	6	0,227	1	0
Cabri	20	6	3	1	30	9	3	0,254	1	0

For indeces of the table 6 we have the acceptance of hypothesis H_0 for the last two rows. This means that at the significance level 0.05, future math teachers wish to use software *Gran, DG, GG, MathKit*, but we have no reason to say about the willingness to use *GS* and *Cabri*. We can explain this because of "poor" interface of *GS* and the absence of Ukrainian (or Russian) interface of *Cabri*.

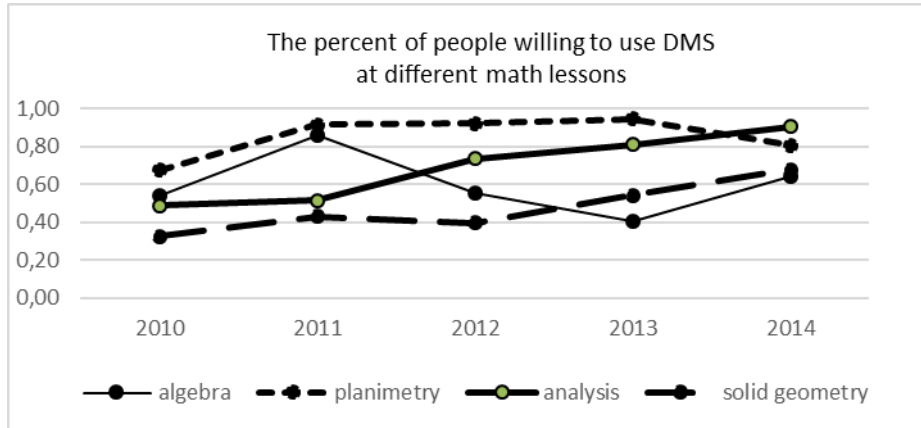Visualization of the obtained results during the experiment years is given in Fig. 1-2.

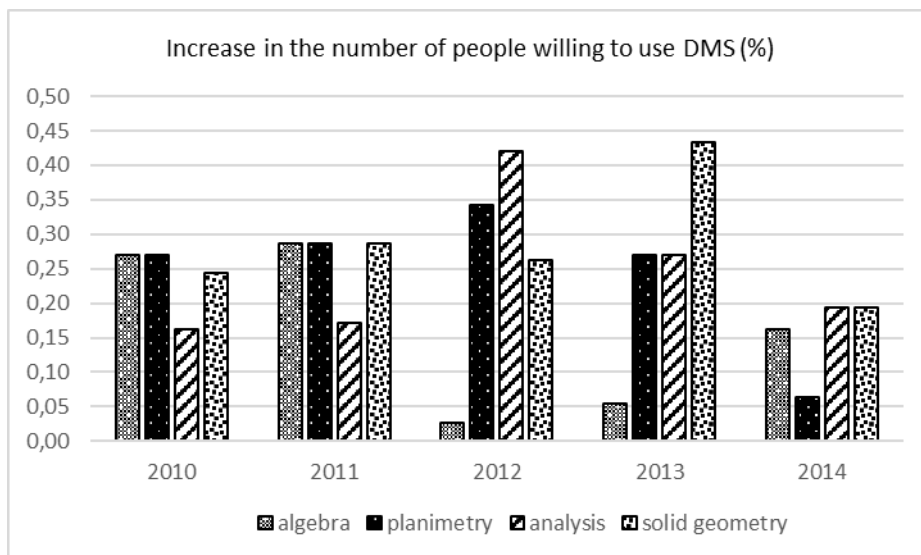**Fig. 1.** The percent of people willing to use DMS at different math lessons

Fig. 2. Increase in the number of people willing to use DMS (%)

Also we give some information about the "attractiveness" of software according to the survey of future and working math teachers, which was conducted at scientific-methodical seminars (on the basis of physics and mathematics faculty) (see Table 7, Fig. 3-10).

Table 7. The attractiveness of software (%)

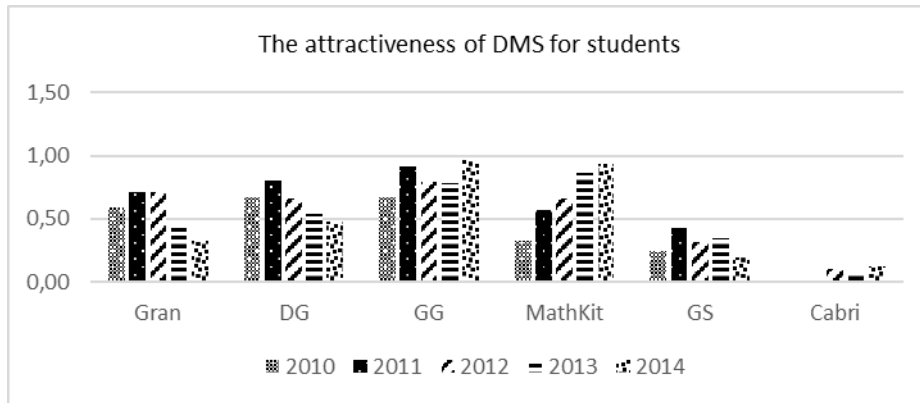|	Gran		DG		GG	
Year	T	S	T	S	T	S
2010	0,93	0,59	0,74	0,68	0,28	0,68
2011	0,75	0,71	0,51	0,80	0,32	0,91
2012	0,86	0,71	0,83	0,66	0,45	0,79
2013	0,68	0,43	0,54	0,54	0,68	0,78
2014	0,40	0,32	0,13	0,48	0,66	0,97
	MathKit		GS		Cabri	
Year	T	S	T	S	T	S
2010	0,11	0,32	0,00	0,24	0,00	0,00
2011	0,11	0,57	0,02	0,43	0,00	0,00
2012	0,17	0,66	0,08	0,32	0,00	0,11
2013	0,19	0,86	0,03	0,35	0,05	0,08
2014	0,13	0,94	0,00	0,19	0,07	0,13
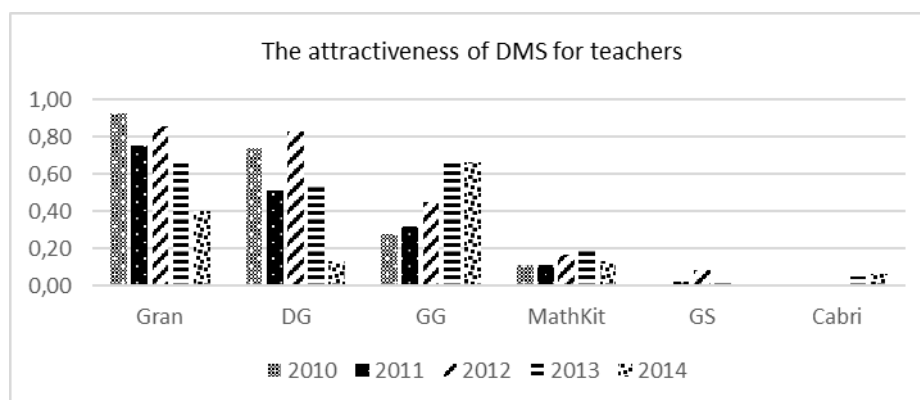
Fig. 3. The attractiveness of DMS for teachers

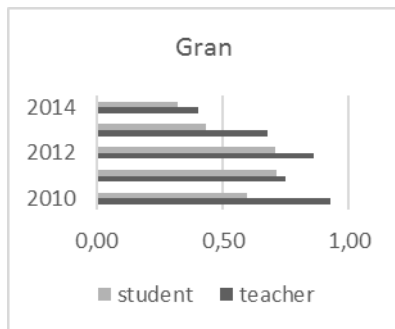**Fig. 4.** The attractiveness of DMS for students

Fig. 5. The attractiveness of *GRAN*

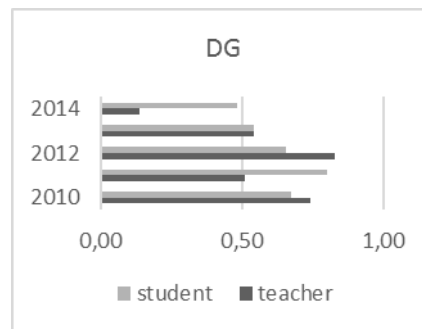**Fig. 6.** The attractiveness of *DG*
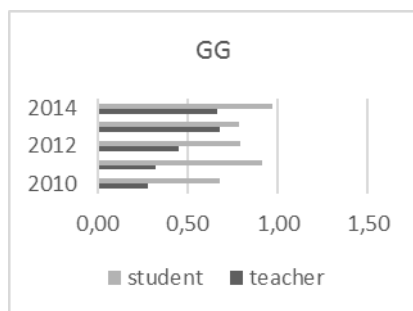

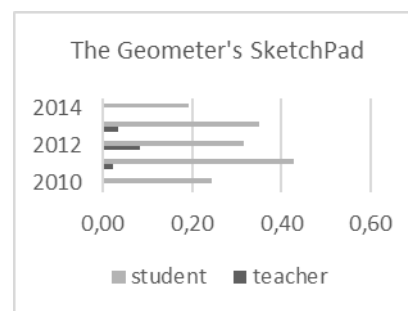**Fig.7.** The attractiveness of *GG*

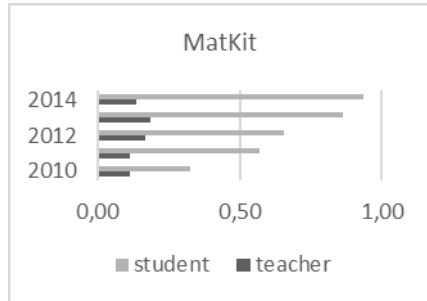**Fig.8.** The attractiveness of *GS*
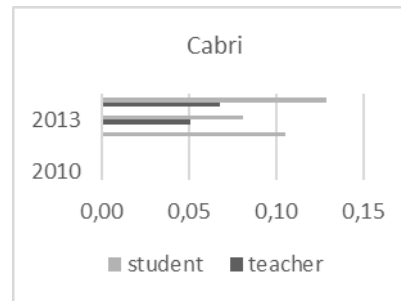
Fig. 9. The attractiveness of *MathKit*   **Fig. 10.** The attractiveness of *Cabri*

2.5 The research of the Readiness of Future Math Teachers to Use Different Dynamic Mathematics Software in Their Professional Activities in Teaching of Some Subjects

Because the questionnaire was on the research of 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*), then we could fix the results of the readiness to use DMS in teaching of different subjects (algebra, planimetry, solid geometry, analysis) (see Table 8).

Table 8. The survey of the readiness to use DMS in teaching of different subjects

Do You feel the readiness to use DMS at the lessons of:	Quantitative indices					Indices of the McNemar's test ($\alpha=0,05$)			
	a	**b**	**c**	**d**	**N**	**n=в+c**	**T_2**	**H₀**	**Hₐ**
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, we have the rejection of the null hypothesis H_0 and the acceptance of the alternative hypothesis, i.e., at the significance level *α=0,05*, we can say about the positive impact of studing of the Special course on the psychological readiness of future math teachers to use DMS at the lessons of algebra, planimetry, analysis. However, experimental results do not give grounds to say about the positive impact on the readiness to use DMS at the lessons of solid geometry. Increase in the number of students who feel the readiness to use DMS at the math lessons is presented in Fig. 11.
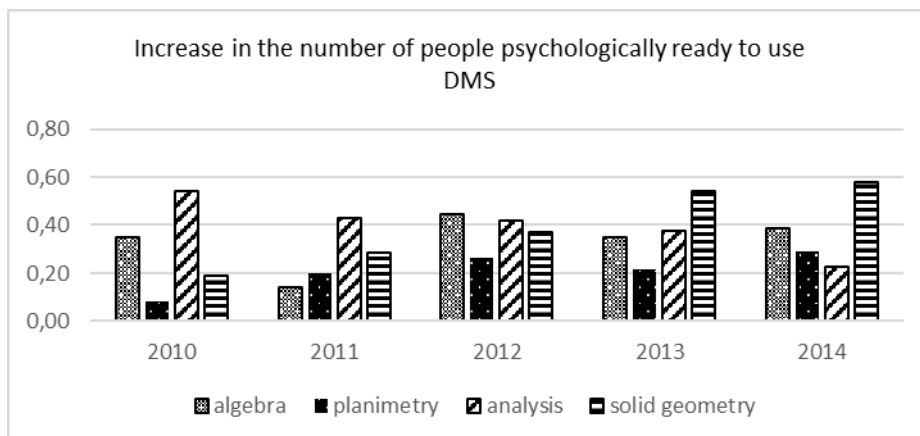
Fig. 11. Increase in the number of people psychologically ready to use DMS

3 Conclusion

Thus, this research allows to state the following.

1. Future math teachers understand the need to use DMS and welcome the studing of the Special course, since the research of the willingness and the readiness to use DMS demonstrates a positive dynamics. The assumption about the positive impact of the studing of the Special course on the psychological state of students is confirmed at the significance level of 0.05 according to the McNemar's test. In other words, after the studying of the Special course "Computer Applications in Teaching Mathematics" the number of students, who have the willingness and feel the readiness to use DMS in future professional activity, increases.

2. Most students focused on using DMS at the lessons of algebra, planimetry and analysis. We explain this because of not only a sufficient number of DMS and good tools in such software, but enough number of teacher's guide for their application and free access to DMS with Ukrainian or Russian interface.

The percentage of students, who are willing to use DMS at the lessons of solid geometry, is too small. We explain this not only because of small number of software and "poor" tools in such software, but of lack of Russian or Ukrainian interface in them. Also there is the lack of methodical material of solving solid geometry problems with the use of specialized software.

3. Teachers, who work at the school, have the willingness and the inner readiness to use DMS, but face with the limited access to computer classes. The involvement of DMS, as they say, is possible only during extracurricular activities.

4. *GRAN* and *GeoGebra* are the most popular in Ukraine. In recent years there has been a decline in the use of the first and great attachment to the second. We explain that because of free access and frequent updating of *GeoGebra*, the steady growth of

its tools (in particular, the version *GeoGebra 5.0* with 3d-tools was tested in 2013, and is distributed now).

5. Russian software *MathKit* finds his supporters (the latest version is license, but the early versions can be found in Internet). It is attractive because of "rich" tools and automated control, which is not provided in other DMS.

6. Students and teachers prefer *Gran* and *DG*. We explain that because of the free distribution, the Ukrainian interface, a sufficient number of researches in periodicals, the recommendations of the Ministry of Education and Science of Ukraine (also at the lessons of computer science).

Note that students prefer *GS*, *MathKit* and *Cabri* more then teachers. We explain that becourse of the lack of Ukrainian interface, the license and the unwillingness of teachers to work with unfamiliar DMS.

7. According to the research we note the increasing demand for *GeoGebra* (it was pointed out by the future and working math teachers). We believe that it is necessary to pay attention just at it, because *GG* is continuously updated, freely distributed, has interface on 30 languages, that confirms its popularity.

8. Future research should be conducted towards the creation of methodical support of school math courses based on *GG*. During the preparation of future math teachers we need to focus not only on traditional for the Ukrainian school software *Gran, DG*, but also on the other DMS, which are widely distributed in Internet and used by teachers.

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