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Assessment of the Readiness of Future Mathematics Teachers to Use Digital Educational Resources in the Study of Geometry in Kazakh Universities

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Abstract

The purpose of the study is to assess the readiness of future mathematics teachers to use digital educational resources and analyze their efficiency in the study of geometry in Kazakh universities. The relevance of the study is due to the lack of serious scientific research and reliable data on the effectiveness of using digital educational resources as part of studying mathematical disciplines. An experimental study of the readiness of students majoring in mathematics to use digital educational resources in the study of geometry is carried out based on the Auezov South Kazakhstan University at the Mathematics Department of the Faculty of Natural and Pedagogical Sciences. As part of the experimental work, in the 2020-2021 academic year, an experimental group of 49 students and a control group of 51 students, a total of 100 people, were formed from first-year students in the 6B01510 Mathematics educational program. The main objective of the experimental study was to determine the efficiency of students' learning with and without the adoption of digital educational resources in the educational process.

The survey method is employed to assess students' psychological readiness to use digital educational resources and the level of the development of their motives to do so. The methods of educational testing and methodological experiment are used to establish the effectiveness of digital educational resources in the university study of geometry.

Since the readiness of future mathematics teachers to use and implement digital educational resources in the learning process is found to be high at the first stage of the study, it is deemed necessary to conduct a methodological experiment on the implementation of digital educational resources in the learning process.

As part of the five-semester-long methodological experiment, students in the experimental group were taught with the use of digital educational resources, while the control group students

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studied using the traditional geometry teaching system. The final results based on student testing and the application of statistical methods demonstrated the effectiveness of the use of digital educational resources in the university study of geometry, which leads to higher test scores.

Proceeding from the results of the study, the authors conclude on the feasibility of using digital educational resources in the learning process in the study of mathematical disciplines.

Keywords: geometry, digitalization, digital competence, teacher training, information and computer technology.

1. Introduction

The active introduction of digital technology in all spheres of human life contributes to the popularity and importance of digital educational resources (DERs) as one of the most promising and trending e-learning paradigms.

Although the introduction of computer and information and communications technologies (ICT) in general education and higher education institutions in Kazakhstan is highly widespread (Filinova et al., 2015), the introduction of digital technology in the educational process poses several issues for Kazakh education. First, there is the question of whether future teachers possess sufficient skills, knowledge, and motivation to integrate DERs into the educational process. Second, under question is the efficiency of the use of DERs in teacher training. To comprehensively and competently implement digital technologies in the educational process and the training of future teachers who would be able to use and create interesting, proper, and original digital resources, it is necessary to have theoretically and experimentally confirmed results of DERs effectiveness in the educational sphere.

The above has prompted us to investigate the readiness of future teachers to use DERs in the learning process, as well as the effectiveness of using DERs in the study of geometry in Kazakh universities since the use of DERs promotes better visualization of information provided during the study of geometry by both student teachers and their future students and, as a result, ensures better understanding and assimilation of the studied educational material.

Due to the increased interest in the use of DERs in the classroom (Filinova et al., 2015; Ustatdzhalilova, 2013), the issue of training future teachers in Kazakhstan becomes particularly relevant, and various measures are being taken at the state level to improve the quality of education. Thus, the program for the development of education in Kazakhstan stipulates among the key directions for the modernization of the education system: ensuring equal access for all participants in the educational process to the best educational resources and technologies; integration of ICT into the educational process; creating conditions for the introduction of automation of the educational process (Decree of the government..., 2017; State program..., 2020).

At present, however, training in the use of DERs in Kazakhstan is provided for teachers only in advanced training courses. For this reason, the inclusion of new disciplines related to the preparation and creation of DERs in the curriculum will allow students to acquire skills in the application and implementation of new digital technologies.

Nevertheless, many leading universities in the country, through the efforts of individual scientists and research institutes, are working on the formation of an innovative educational environment for a modern university. The latter represents a set of content, forms, methods, and means of learning, which are based on the transfer of the achievements of modern science and technology in the educational process of the university and are aimed at the formation of innovative personalities of future teachers, capable of making creative decisions in professional activities (Alisov, Podymova, 2011), through the introduction of new digital learning technologies and resources into the traditional system of teacher training (Velitchenko, 2021).

In connection with the above, the purpose of the study is to assess (determine) the readiness of future mathematics teachers to use DERs and to analyze their effectiveness in the study of geometry in Kazakh universities.

Research objectives:

- to consider the essence of DERs and the prerequisites for their use in the educational process based on a review of scientific literature;
- to conduct an empirical study into students' psychological readiness to use DERs and determine their motivation to use DERs;
- to experimentally investigate the impact of introducing DERs into the educational process of higher education institutions on the level of students' knowledge of mathematics.

The novelty of the study lies in the experimental justification of the use of DERs in teaching geometry to future teachers of mathematics.

Conceptual background and research questions

According to I.N. Golitsyna (2014), DERs are a modern variety of information resources used in education. As demonstrated by D.S. Shapiev (2019), DERs are electronically presented teaching and learning materials that accommodate both elementary objects (text, picture, animation, model) and complex forms (document, slide, presentation, test, course). A.G. Rakhymbergenova et al. (2016) point out that DERs combine a wide range of teaching software, electronic textbooks, electronic tests, computer models, simulators, didactic games, and stimulators of different purposes, levels of complexity, a form of technical performance, and types of interface. As defined by A.I. Pasyeva and A.Kh. Shaikhlislamov (2020), DERs are electronically presented teaching and learning materials containing elementary objects (text, pictures, animation, and models) and complex forms (documents, slides, presentations, tests, and courses).

Relying on the theoretical analysis of the concept of DERs, the following definition is the most suitable: DERs are subject-specific information resources for educational purposes – a type of learning tool that exists in an electronic format (Kalimullina, Trotsenko, 2018).

Important for today's pedagogical reality in terms of developing modern pedagogical skills is the ability of future teachers to design digital narratives (Vaindorf-Sysoeva, Subocheva, 2020). D.S. Shapiev (2019) projects the known principles of didactics and didactic conditions for the effectiveness of traditional teaching tools on the requirements for the content and presentation of educational material in DERs, namely the principle of scientificity, the principle of clarity, and the consistency of presentation and delivery of educational material. A.I. Pasyeva and A.Kh. Shaikhlislamov (2020) consider that to create high-quality DERs, one must consider the principles of manufacturability, flexibility, modularity, accessibility, and individuality.

I.F. Yarullin et al. (2015) note that the pedagogical design of DERs combines information culture and multilevel imaginative pedagogical thinking of the developer, the means of implementation of pedagogical creativity in the form of DERs structure, their content, control test tasks, and pedagogical comments and is based on a multi-criteria analysis of compliance with educational standards.

Particularly comprehensive and interesting results on the implementation of DERs in teaching mathematical disciplines are presented by S. Abramovich (2013), A. Sahin and T. Adiguzel (2014), P. Drijvers et al. (2010), and K.E. Leong and N.N. Alexander (2014), and specifically in the geometry course – by D.N. Shekhovtseva (2010), N.K. Madiyarov (2018), and Kh.A. Ustatdzhalilova (2013).

However, the findings of G.O. Haugsbakk (2013) show that investments in high technology in education do not always yield great results, one of the main reasons for this being insufficient training of teachers. Studies (Gouseti, 2013; Selwyn, 2016) demonstrate that a major barrier to the successful integration of digital tools in schools has been the lack of skills and motivation among teachers to use digital resources in the classroom.

The importance of incorporating DERs into the traditional system of mathematics training for future teachers stems from the fact that today's students represent the network generation (N-Geners), and as such require a change in teaching and assessment strategies (Mamina, Tolstikova, 2019). According to M.S. Bezbogova and M.V. Iontseva (2016), the network generation grew up owing to the presence of the Internet and digital technology throughout their lives, making them the first generation to be quite digitally literate. This unique life experience has brought about differences in learning, thinking, and working. In addition, the online generation communicates differently than their predecessors because they tend to use digital resources to communicate (Viberg et al., 2020). The network generation as learners is different from the previous one, for their learning requires a transformation of the educational sphere with the introduction of digital technology in the learning process. The use of the latter is familiar to them, which contributes not only to a better understanding of educational material but also increases learning motivation (Viberg et al., 2020). Consequently, for high-quality and effective education of the future mathematics teacher, it is critical to put into practice innovative digital resources and technologies.

One of the main issues of effective implementation of DERs in the educational process is the preparation and readiness of the teacher to use them. The readiness of teachers to effectively utilize digital technologies in education, as well as their digital competence, become central and are recognized as a key element in the formation of useful practical pedagogical knowledge and skills

(Mena et al., 2017). While universities are increasing expenditures on equipment and software to create infrastructure for the integration of digital technology (Velitchenko, 2021), of equal importance is the motivation of teachers to use digital technology in the educational process (Craven et al., 2014).

2. Materials and methods

The empirical research methods chosen for the experimental study were the following:

a) a survey to determine students' readiness to use DERs and their motivation to use DERs in their future pedagogical practice at school;

b) student testing to determine the level of knowledge in geometry carried out in the first (initial) and the third (control) stages of the study;

c) a methodological experiment consisting in the introduction of DERs in the educational process of the experimental group (EG) carried out in the second (formative) stage of the study.

The preparation and organization of the experimental study involved the formulation of the research hypothesis. The main objective of the experimental study was to determine the effectiveness of student learning with and without the introduction of DERs in the educational process.

The research hypothesis relies on the assumption that the use of DERs in the study of geometry will lead to an increase in the level of geometric training of students.

The experimental study of the readiness of mathematics students to use DERs in the study of geometry was carried out based on the Auezov South Kazakhstan University at the Mathematics Department of the Faculty of Natural and Pedagogical Sciences.

For the experimental work, in the academic year 2020-2021, we allocated an EG consisting of 49 students (two academic groups), and a control group (CG) of 51 students (two academic groups) of the first year, a total of 100 people, studying in the educational program 6B01510 Mathematics.

The characteristics of the study sample are presented in Table 1.

Table 1. Characteristics of the study sample

Group	Number of students, persons		Age, years
	Male	female	
EG	28	21	18-19
CG	29	22	18-19

Four teachers took part in testing students, one for each academic group.

The experimental study was conducted in three stages.

At the first (initial) stage of the experimental study, the students participating in the study were divided into EG and CG, according to the list of student academic groups. Subsequently, students were surveyed to assess their readiness to use DERs. The survey contained 10 questions about the role of DERs in the geometry learning process. The survey was administered on the Google Forms platform (URL: https://forms.gle/Ei1X685XDNGjw9VU8) in September 2020. The link to the survey was distributed in a targeted way through the corporate e-mail of the university, social networks among student associations, and WhatsApp and Telegram messengers.

Moreover, at the first stage, testing of students' knowledge was conducted based on the results of residual geometry knowledge tests in EG and CG to obtain data on the homogeneity of the groups in terms of the initial level of knowledge in geometry.

Before each stage of the testing, the students were familiarized with the rules of conduct during the execution of tasks and the testing algorithm. Test tasks were printed and distributed at the beginning of the testing. For teachers who were involved in the testing, an instruction was drawn up with a clear algorithm for conducting it.

The testing procedure required a clear sequence of actions. For this purpose, schedules for the testing groups of students were drawn up, indicating the location, time, and duration of testing.

The duration of the entire test was 2 hours 10 minutes. The time was determined considering the number of tasks, their complexity, the form of presentation, the method of execution, etc.

Examples of test tasks:

- on the topic "Examples of vector spaces and bases":

1. How many (total) a) vectors, b) ordered sets of k linearly independent vectors, and c) k-dimensional subspaces are in an n-dimensional vector space over a finite field of q elements?

2. Specify the basis and find the dimension of the space:

a) polynomials of degree ≤ n in m variables;

b) homogeneous polynomials of degree d in m variables;

c) homogeneous symmetric polynomials of degree 10 in 4 variables;

d) symmetric polynomials of degree ≤ 3 in 4 variables.

- on the topic "Euclidean geometry":

Find a) volume and b) surface area of a section of a 4-dimensional cube $0 \leq x_i \leq 1$ with hyperplane $x_1 + 2x_2 + 3x_3 + 4x_4 = 1$.

At the second (formative) stage of the study, together with the department faculty, different types of DERs were developed for classes in the EG on geometry and the newly introduced subject "Digital Educational Resources in Geometry". Thus, in the EG, all practical and laboratory classes were conducted in a computer lab using various DERs, including such software packages as GeoGebra, Cabri Geometry, the Geometer's Sketchpad, Mathematica, GRAN 2D, as well as presentations, 3D modeling tools, virtualization, animation, electronic textbooks, computer tests, etc. Experimental training with the use of DERs was conducted over two and a half years (the first five semesters). Additionally, a questionnaire survey was conducted in the EG to determine the development of students' motives for using DERs in geometry lessons in their future pedagogical practice at school after a partial familiarization with them during the formative stage of the study (at the end of the second semester).

The CG was trained in the traditional system, without the use of DERs.

At the third (control) stage of the study, special testing of students' knowledge (in EG and CG) and a follow-up questionnaire to determine the development of motives for the application of DERs in geometry classes at school (in EG) were carried out.

The rationale behind the special testing of students in the EG and CG was the assumption that the results of current examinations could be subjective, influenced by the personal preferences of the examiners. The testing included problems compiled by department teachers to assess the ability to solve geometric problems of certain types. The maximum score for each test was 100. The tests were generated by the level of difficulty to avoid ceiling effects where a large percentage of respondents get scores near the upper limit of the test and to ensure that the distribution of test takers by scores falls close to a normal distribution.

Examples of test tasks:

- on the topic "Affine and orthogonal transformations":

Describe the composition of four reflections of a plane about successive (CC) sides of a square.

- on the topic "Convex polyhedral cones and polyhedra":

Show that the inclusion-minimum face σ is $\sigma \cap (-\sigma)$.

- on the topic "Topologies, distances, and convexity":

Prove the equivalence of the following properties of a topological space X (if they hold, the space is called a compact space):

a) from any open cover X, one can choose a finite subcover;

b) any set of closed subsets in X, each finite subset of which has a non-empty intersection, itself has a non-empty intersection.

The groups were compared by the average scores received by the students: x_e – mean score of the EG, x_e – mean score of the CG.

The following statistical hypotheses were formulated:

H0: there are no statistically significant differences between the groups under study in terms of the level of test performance ($x_e = x_c$).

H1: there are statistically significant differences between the groups under study in terms of the level of test performance ($x_e \neq x_c$).

The closeness of the distribution of the students' scores to a normal distribution and the independence of the samples allowed us to use Student's t-test as the statistical criterion.

$$t = \frac{x_e - x_c}{S_{x_e - x_c}}, \quad (1)$$

where:

$$S_{x_e - x_c} = \sqrt{\frac{(n_e - 1) \cdot S_e^2 + (n_c - 1) \cdot S_c^2}{n_e + n_c - 2} \cdot \left(\frac{1}{n_c} + \frac{1}{n_c}\right)}, \quad (2)$$

where n_e and n_c are the sizes of the EG and CG samples and S_e^2 and S_c^2 are distribution variance.

To avoid testing for homogeneity of variance, samples of equal size were taken ($n_e = n_c = n$). In this case, we can check $S_{xe\text{-}xc}$:

$$S_{x_e - x_c} = \sqrt{\frac{S_c^2 + S_c^2}{n}} \quad (3)$$

Checking: at the significance level of $\alpha = 0.05$ with the number of degrees of freedom $v=n_e+n_c-2$. The number of degrees of freedom v with n = 61 is 59, in all of these cases, if a=0.05, t_{crit}= 2.001.

3. Results

The results of the initial stage of the study are presented in Table 2 and Figure 1.

The results of the student survey to determine psychological readiness to use DERs are presented in Table 2.

Table 2. Readiness to use DERs among students

Question	Number of responses (people)		
	yes	no	difficult to answer
1. Do you believe the active implementation of digitalization is the right trend?	72	11	17
2. Do you believe it is possible to get a quality education from home?	57	22	21
3. Do you think DERs will help improve the geometric training of schoolchildren?	56	26	18
4. Do you find it difficult to work with DERs?	62	18	20
5. Do you find that the use of DERs can completely replace the teacher?	54	40	16
6. How do you feel about using DERs in geometry classes?	69	27	14
7. Are you familiar with the different types of DERs?	46	39	15
8. Do you think that problems might arise when using DERs in geometry classes?	57	26	17
9. Do you consider it necessary for a future mathematics teacher to be able to use DERs in the classroom?	66	19	15
10. Will the use of DERs help improve the training of future teachers?	77	11	12
Mean, %	**61.6**	**23.9**	**16.5**

The results of the survey (Table 2) suggest that 18 % of respondents believe that they have no difficulty with DERs, and 72 % believe that the active implementation of digitalization in people's lives is the right trend. Thus, 77 % believe that the use of DERs will help increase the effectiveness of geometry training for future teachers and is of undeniable benefit.

However, 26 % of respondents feel that communication with digital resources in geometry or mathematics classes cannot fully replace the teacher, they are more interested in the process of communicating with other students, pupils, or teachers.

Consequently, the results of the survey prompted the conclusion that the use of DERs in the geometric training of students of mathematical specialties is advisable.

The results of the testing of students' knowledge based on residual knowledge tests in geometry prove the level of knowledge of students in the CG and EG to be the same (Figure 1), which demonstrates the homogeneity of the groups by the level of geometric knowledge.

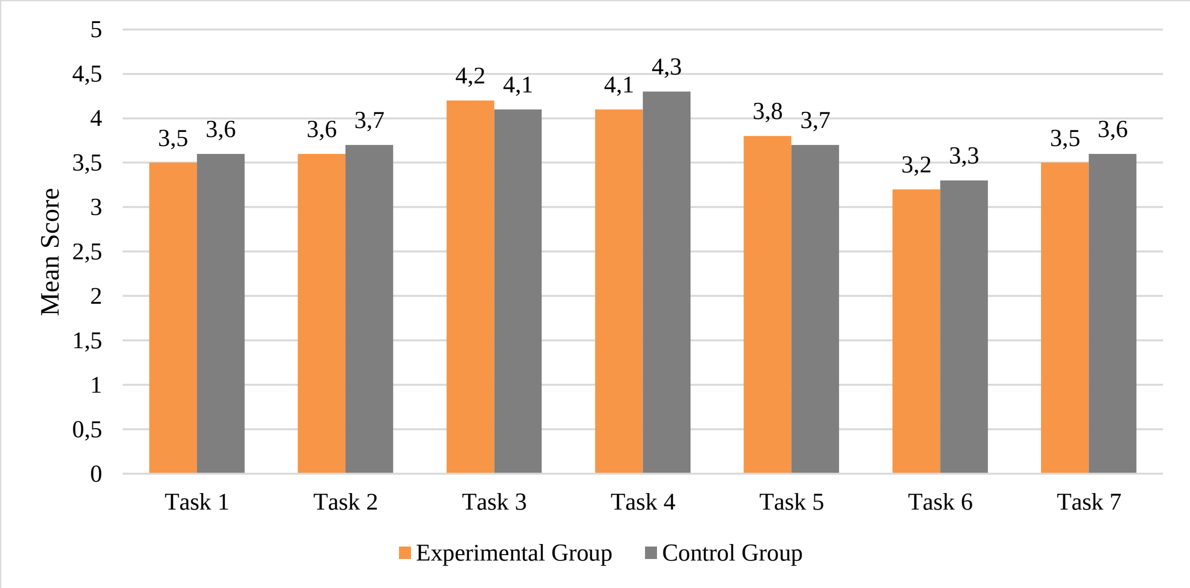

Fig. 1. Comparative characteristics of the results of residual knowledge tests in geometry in the EG and CG

The results of the control stage of the study are presented in Tables 3 and 4 and Figure 2.

A comparative analysis of the results of the student survey in the EG on the formation of motives for the use of DERs at the initial and control stages of the study is presented in Table 3.

Table 3. Assessment of the development of motives for the implementation of DERs in geometry classes

Question	Number of responses			
	2020-2021		2021-2022	
	yes	no	yes	no
Did you enjoy your geometry classes using DERs?	41	8	46	3
Have you gained the motivation to use DERs?	40	9	47	2
Does using DERs help:				
increase the clarity of the discipline?	41	8	46	3
instill independent work skills?	42	7	43	6
visualize geometric objects more clearly?	40	9	46	3
Would you like to create your own DERs in the future?	41	8	45	4

According to the survey results (Table 3), positive motivation for conducting classes with DERs is quite high: upon completion of geometry classes with the introduction of DERs, 93.9 % believe that the visualization of the subject matter is very high, and 95.9 % have a persistent intrinsic motivation to use DERs.

The key results of knowledge testing in the EG and CG focused on students' ability to solve certain types of problems are shown in Table 4 and Figure 2.

Table 4. Key test results

No.	Study	n-sample size	x_e – mean	x_c - mean	S_{ae} variance	S_{ac} variance	S_{ae-ac} standard deviation	t_{emp}	t_{crit}
1	Ability to solve geometry problems and their application	100	83.7	68.2	212	402	3.22	5.73	2.001
2	Ability to establish connections between analytic expressions and geometric images	100	82.4	63.5	285	456	3.54	5.33	2.001
3	Ability to read drawings	100	78.5	70.8	298	399	3.43	2.24	2.001
4	Development of spatial thinking	100	79.5	65.4	318	420	3.53	3.98	2.001
5	Ability to use geometric concepts	100	69.2	62.8	356	433	3.65	1.75	2.001

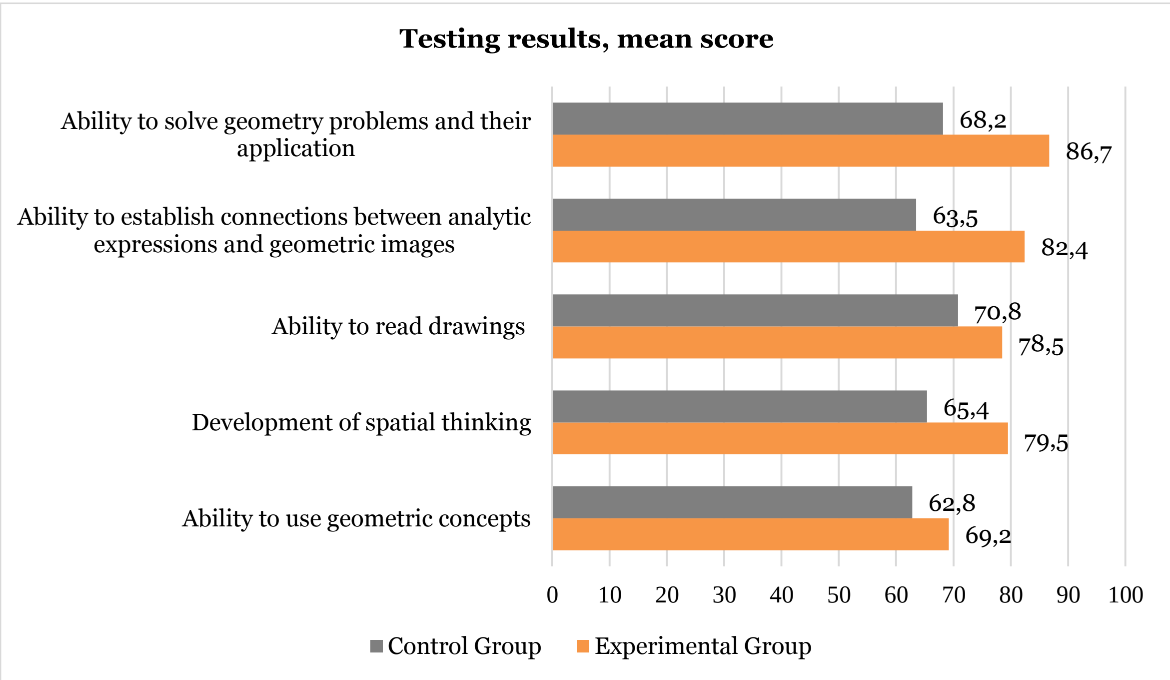

Fig. 2. Results of tests assessing students' ability to solve geometric problems of certain types

The test results indicate that the most significant difference is found in the students' ability to solve geometry problems and their application and in the development of spatial thinking. A comparison of the results shows that $t_{emp} > t_{crit}$ in four cases out of five. Therefore, the null hypothesis should be rejected, as the surplus of the mean scores in the EG over the mean scores in the CG is statistically significant. Statistically insignificant surplus is observed only in the ability to use geometric concepts.

4. Discussion

The results of students' psychological readiness to use DERs (Table 1) at the initial stage of the study suggest that the use of DERs in the geometric training of students of mathematical specialties is expedient. This is consistent with previous findings (Abramovich, 2013; Yarullin et al., 2015), according to which the introduction of new teaching tools inevitably leads to changes in the methods and forms of learning. Moreover, researchers also suggest (Madiyarov, 2018; Ustatdzhalilova, 2013) that with the emergence and introduction of ICT tools in the process of teaching geometry, the traditional forms of learning are combined with computer-oriented ones (based on the systematic, consistent, and logical use of ICT in the educational process).

Based on the results showing the development of motivation to use DERs in geometry classes among students in the EG (Table 2), which were investigated in dynamics, we can assume that when DERs are used in classes, students develop a strong interest in creating their own DERs, easily use information from the Internet, and are active in their classes. Most importantly, students in the experiment gained a pronounced desire to become professionals in the design and implementation of DERs in geometry classrooms, and they make every effort to do so.

Students in the EG also report that the use of various digital resources, such as GeoGebra, Cabri Geometry, the Geometer's Sketchpad, Mathematica, and GRAN 2D, which took over all the computational work, made them feel more confident in doing the work and helped them focus on solving more important problems. This falls in line with the conclusions of P. Drijvers, C. Kieran, and M.-A. Mariotti (2010) that when carrying out complex calculations of an intermediate nature, which take a lot of time to solve, it is advisable to use computer mathematical systems (CMS). The availability of a great variety of mathematical packages allows the teacher to choose a resource that is convenient, accessible, and understandable to them, considering the above advantages and disadvantages of the software (Ustatdzhalilova, 2013). Analysis of educational practices in US universities shows that the most popular CMS used in mathematics courses in the US are: Mathematica, MATLAB, Maple, GAUSS, Scilab, Mathcad, Maxima, and Sage (Shekhovtseva, 2010).

Thus, during the two-and-a-half-year study, students in the EG demonstrated a high motivation to use DERs in geometry classes.

The results of the final testing of students' abilities to solve geometric problems of certain types (Table 3) demonstrate that students in the EG taught with the use of DERs perform better than students in the CG on four types of problems out of five. This leads us to conclude that the use of DERs in the study of geometry in higher education is effective and that there is a need to further improve the training of students using DERs in the study of not only geometry but also other mathematical disciplines.

As noted by the EG students themselves after completing the experiment, the DERs succeeded in equipping them with visual skills, helped them develop spatial thinking, and facilitated their understanding of difficult geometric concepts.

The effectiveness of DERs in the study of subjects in the mathematical cycle is also confirmed in a study by A. Sahin and T. Adiguzel (2014).

The main limitation of the study is the fact that it was conducted at one university with a relatively small sample size, which restricts the generalizability of the findings to other contexts. Moreover, the study did not take into account potential challenges and barriers to the implementation of DERs in the educational process, which should be considered in future research to ensure successful integration of DERs into the educational process.

5. Conclusion

The experimental findings indicate the effectiveness of using DERs in the study of geometry in universities, resulting in higher performance on test assignments. Thus, the effectiveness of DERs is confirmed, which testifies to the feasibility of using DERs in the educational process in the study of mathematical disciplines.

The prospect for future research could be to investigate the implementation of DERs in other mathematics disciplines in the training of future mathematics teachers.

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