The Use of Digital Technologies for Flipped Learning Implementation

Oksana Klochko[1[0000-0002-6505-9455]], Vasyl Fedorets[2[0000-0001-9936-3458]], Svitlana Tkachenko[3[0000-0003-0530-5973]], Olena Maliar[4[0000-0001-5924-4120]]

[1,3] Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Vinnytsia, Ukraine
{klochkoob, tsvitjane}@gmail.com

[2,4] Communal Higher Education Institute "Vinnytsia Academy of Continuous Education", Vinnytsia, Ukraine
{bruney333@yahoo.com, malayryk@gmail.com}

Abstract. The article presents the study of the use of digital technologies for flipped learning implementation. In this context, the use of the virtual learning environment has been analyzed. The assessment of the efficiency of flipped learning implementation based on this environment and the process of defining the ways of improving the components of the scientific-methodological system of flipped learning was carried out using the technologies of machine learning. The innovative and personalized nature of flipped learning implemented with the use of the virtual learning environment is a methodological condition for increasing the students' interest in learning, activating their study process, revealing their cognitive and personal potentials as well as developing digital competences, independence and individuality etc. The authors emphasize that the use of flipped learning based on digital technologies requires thorough development of the virtual learning environment, a detailed selection of the study content and its adaptation to the concrete groups of students. By stating this we mean the search for more effective and systemic ways of achieving learning objectives: the methods of problem-based learning, flipped learning; the selection of digital tools for presenting lecture materials, development of supplementary tasks; correction of the theoretical materials and the tasks on the basis of the study results and achievements of the students; motivating students to work with the study materials on their own etc. Machine learning was used to group the students by clustering the results of their educational achievements. Based on these data, the personalized learning vector, characteristic of a specific group of students, was determined.

Keywords: digital technologies, flipped learning, virtual learning environment, machine learning, cluster analysis, innovative pedagogy.

1 Introduction

Nowadays, we cannot imagine the field of education without the use of digital technologies in the education process. With the appearance of virtual learning environments, we may observe a rapid accumulation of educational data. In conditions of active free use of digital educational environments, the assessment of the data of virtual learning environments with the use of machine learning methods is becoming more and more significant.

In modern conditions, a society requires educational services that follow the principles of student-centric education thus making the student a central figure of the teaching process. In this context, innovative teaching methods include: shifting the role of a teacher to that of a facilitator, application of interactive, project work and research methods, particularly, the methods of problem-based learning, flipped learning, the clicker technology. In the course of implementation of these principles, the most popular mixed learning model, namely, the flipped classroom model, requires particular attention.

The innovative and personalized nature of flipped learning may be provided with the help of virtual learning environment (VLE), which is a methodological condition for raising the students' interest in learning, activating their study process, revealing their cognitive and personal potentials as well as developing digital competences, independence and individuality etc. VLE contains study materials (lectures, tasks, tests, reference materials etc.) and is a useful tool while introducing the flipped learning method in the process of studying a course.

A. Littlejohn explains the ideas of intellectual and personal students' potentials actualization based on the use of digital technologies. This includes the development of individual learning plans by the students, knowledge artefacts and contemplations on the achievements [1]. Such learning model is focused on how students plan, study, learn, create and reflect/assess, its components include: consuming knowledge, creating new knowledge, connecting with people, contributing new knowledge resources [1].

M. Shyshkina, U. Kohut, M. Popel have conducted a comparative analysis of the cloud learning components, which provide access to mathematical software [2]. O. Glazunova, M. Shyshkina presented the conceptual-methodological foundations for the development of a university cloud learning and research medium [3]. On the basis of the presented methodology, the model and the experimental study, the ways of resources and services integration, of increasing the learning efficiency and of providing access to the necessary educational tools are revealed [3].

The systemic nature of students' individual work in the cloud learning medium was studied by O. Kolgatin, L. Kolgatina, N. Ponomareva, and E. Shmeltser, who emphasize the low cognitive interest of the students as one of the problems that may be solved by personalization of tasks and exercises developed; proper time management; facilitation of students' cooperation; actualization of creative aspects of the tasks etc. [4].

Digital technologies of open distance education were studied by V. Kukharenko, T. Oleinik, they define the problems of open distance learning and of mixed learning as well as suggest ways of overcoming them [5].

In the modern conditions of educational services transformation and rapid educational data accumulation, the integrated use of digital technologies, namely, the VLE and machine learning in combination with teaching techniques of flipped learning are becoming more and more appealing and relevant. But so far this field has not been sufficiently studied by the researchers.

Thus, such scientists as V. Naidu, B. Singh, K. Farei, N. Suqri claim that machine learning may be the revolutionary approach to finding out the needs of the student according to his/her skills in the course of implementation of the student-centric approach based on the flipped classroom model. They also suggest ways of increasing the effectiveness of flipped teaching by decreasing the number of manual tasks of the teachers [6].

In this respect, there is an important study of flipped learning with the application of machine learning methods (Neural Networks, Naïve Bayes, Random Forest, kNN, and Logistic regression) conducted by J. Nouri, M. Saqr, U. Fors. The authors forecasted the activities of students in the flipped classroom by providing and receiving feedback. Flipped learning is presented as a pedagogical condition of effective learning interaction of students, by managing the educational process, which includes forecasting its results, and is also viewed as a systemic opportunity for using digital technologies [7].

An empirical comparison of clustering machine learning methods with the aim of statistical analysis of the data received in the course of a survey on the presence of an Internet-addiction formed as a result of improper Internet use, which was conducted among the students majoring in computer studies, is carried out by O. Klochko and V. Fedorets [8].

The application of machine learning techniques for processing VLE data will allow the educators to conduct the analysis of the students' learning achievements and determine the ways of increasing the efficiency of flipped learning application on the basis the received results.

Unsolved aspects of the problem. Despite the experience and the result of this issue's study by the Ukrainian and foreign researchers and taking into consideration the novelty of using machine learning for VLE data processing in the course of flipped learning application, the issue of developing the techniques for study content selection and its adaptation to concrete groups of pupils has not been fully solved by the researchers. The problems that occur in the course of looking for effective machine learning methods for solving the set tasks in order to improve the study results also remain relevant. The issues outlined above need to be studied further.

The purpose of the research is to describe the aims, content and ways of broadening the flipped learning possibilities with the application of the virtual learning environment and machine learning.

2 Methods of the Research

The study on the introduction of the flipped learning method with the application of VLE was conducted on the example of studying the subject of Geometry, topic "Geometrical Transformations" in the 9th form.

Flipped learning is a form of learning, which allows change the traditional educational process in an innovative and personally-oriented way. Accordingly, the learning process is formed on the basis of the following system-organizing components: the students' homework is to watch the videos with the study materials of the next lesson; the students cover the theoretical material on their own, and the study time in class is spent on doing practical tasks [9-13] as well as for discussion and actual application of the theoretical knowledge and defining the optimal ways of its application to the real needs. Thus, flipped learning corresponds to the competence paradigm, which is based on the idea of practical application of knowledge.

A flipped lesson is a nourishing medium, which directly provides the formation of general and special competences. This includes the creation of conditions for gaining [9-13]: experience and practice reflection, development of skills of stating the problem and problematization; ability to set goals and defining the ways to achieve them; actualization of the activity-based and practically oriented nature of learning, i.e. involving the students in the implementation of the socially and vitally significant activity – researching, designing, modelling etc. In this respect, the significant points are: orientation of the study process towards development of the student's independence and responsibility for the results of his/her work, organization of effective discursive interaction between the participants of the educational process and of fruitful group work; an obligatory inclusion of developing and creative tasks into the content of a lesson [14]; actualization of critical thinking [4] as well as of personal and intellectual-value potential of a personality.

In order to implement flipped learning an educational website "Geometrical Transformations" (VLE) [15] was developed; it contains a system of various methodological developments that a teacher may use to work with students while studying the topic "Geometrical Transformations": a topical plan, multi-media presentations, lesson drafts, tests etc.

The flipped learning technique presupposes a combined form of traditional and e-learning, using the VLE tools. Figure 1 presents a structural model of the scientific-methodological system of teaching students the topic "Geometrical Transformations" based on flipped learning with the use of machine learning techniques. According to the personality oriented approach, a student, as the subject of an educational process, occupies the central place in this model. A teacher is another subject of an educational process. The following blocks were singled out as the other interrelated elements of the scientific-methodological system: target, content, methodological, organizational-activity, diagnostic-comparative (with the use of machine learning tools). This model is designed on the basis of the systemic approach, it is an open dynamic system and it interacts with the educational space.

In order to solve the set tasks, the following research methods were used: analysis of the works of the scientists in the field of application of the flipped learning method with the use of digital technologies; synthesis – in order to generalize and conceptualize the Ukrainian and foreign experience, as well as to particularize the conceptual framework, improving the experience of drafting and developing of an educational website of a teacher, formulating the received results; observation, testing students in general secondary educational institutions (GSEI); observation and conducting surveys among master students, school teachers and university professors; statistical methods and machine learning methods, particularly, cluster analysis, in order to process the results of the research; modeling; drafting an educational website of a teacher.

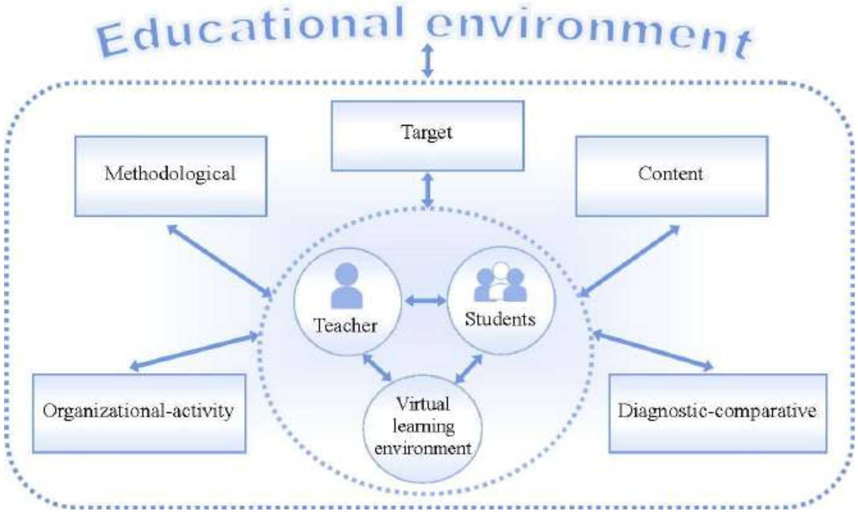

Fig. 1. A structural model of the scientific-methodological system of teaching students the topic “Geometrical Transformations” using the flipped learning method based on VLE with the use of machine learning.

While defining the organizational-pedagogical conditions, needed for successful student training on the topic “Geometrical Transformations” using flipped learning with the application of VLE, we took into consideration: the technical possibilities of a GSEI; the presence of a necessary licensed software; the use of flipped learning in order to form the necessary competences in students; the presence of the necessary methodological materials for giving lessons; forming positive motivation among the students towards studying the topic “Geometrical Transformations” using flipped learning; the use of current digital educational tools and techniques (e.g. the educational websites).

The first stage of the research was ascertaining (April 2019). The purpose of this stage was to study the state of the researched problem and define ways of solving it, carrying out the diagnostics of the initial level of knowledge in Geometry among the students (particularly, in the context of the topic “Geometrical Transformations”). The research was conducted on the basis of the 9th forms of general secondary educational institutions (GSEI) of the Vinnytsia oblast. The number of students involved in the research was 41. Pupils of two classes took part in the experiment, the number of students – 20 and 21 in each class, which we selected as a control and experimental groups respectively.

At the ascertaining stage of the research, the questionnaire method was applied, which allowed us to clarify the organizational conditions of studying the topic “Geometrical Transformations” using flipped learning with the application of VLE in GSEI.

The second stage of the study was exploring (May 2019). At this stage, flipped learning using VLE was applied for studying the topic "Geometrical Transformations".

This stage included searching for, analyzing and testing the VLE tools and flipped learning techniques with the application of machine learning methods. The students passed the tests several times in order for us to determine the ways of adapting the study content to certain groups of students according to the results of their study achievements. To assess the efficiency of introduction of particular components, a methodology for assessing the study achievements of pupils on the given topic was developed.

The purpose of the forming stage of the research (May 2019) was the assessment of the efficiency of the developed teaching methodology on the topic "Geometrical Transformations" using flipped learning with the application of VLE.

In order to carry out the forming stage of the research, the control and experimental groups of students were taught within the GSEI in accordance with the defined organizational-pedagogical conditions. The control group was taught using the traditional methods and methodology and the experimental group – using flipped learning with the application of VLE.

To compare the results and achievements of the students of the control and experimental groups, we used a Wilcoxon-Mann-Whitney test [16, p. 87]. The theoretical (T) and empirical (W_α) value of this criterion are calculated by the formula (1-2):

$$T=S-n_1(n_1+1)/2 \tag{1}$$

where $S=\sum_{i=1}^{n_1} R(x_i)$ – is the rank sum $R(x_i)$ i-th characteristic x_i; n_1 – sample size (control group).

$$W_\alpha = \frac{n_1 \cdot n_2}{2} + x_\alpha \cdot \sqrt{\frac{n_1 \cdot n_2 \cdot (n_1 + n_2 + 1)}{12}}, \tag{2}$$

where n_1 is the size of the control group, n_2 – the size of the experimental group, $n=n_1+n_2$; x_α – normal distribution quantile (for the significance level $\alpha=0.05$ $x_\alpha=1.64$).

To detect typical students' mistakes in order to adapt the components of the scientific-methodological system of teaching students using the flipped learning method based on VLE, we applied such clustering machine learning methods as Canopy, EM (Expectation Maximization) and Farthest First on the basis of the Weka platform [17, 18, 19, 20]. A more detailed description of the EM (Expectation Maximization) and Farthest First algorithms are presented in the work of O. Klochko and V. Fedorets [8, 18, 19].

The main idea of the Canopy algorithm lies in the possibility to decrease the number of distance calculations necessary for clustering by first dividing the data into subsets that overlap according to the greedy algorithm and then only measuring the distances between data point pairs that belong to the subset.

The clustering process using this algorithm can be divided into two stages. At the first stage, we use the shortest distance in order to create a certain number of overlapping subsets, the so-called "canopy". Canopy is simply a subset of elements (i.e. data points or elements), which according to some level of similarity are located within some threshold distance from the central point. It should be mentioned that some element may be under more than one canopy and that each element must be under at least one canopy [17].

At the second stage, we apply any traditional clustering algorithm using an exact distance criterion, but with a restriction that we do not calculate the distance between the two points that never appear in one "canopy", considering the distance between them to be infinite [17].

Within the framework of this research, we used the following general parameters for each of the algorithms: the size of the test sample – 215; the number of clusters – 4, determined with the help of validity indices for testing Dunn, DB, SD, CDbw and S_Dbw [21; 22; 23] (Table 1). The test was on Geometry, on the topic "Geometrical Transformations". They consisted of 10 tasks, for the first 8 tasks you could receive 8 marks (one mark per task) and for the other 2 – maximum 4 marks (2 marks for each task).

Table 1. Number of clusters (calculated with the help of quality indices).

Index	Algorithms		
	Expectation Maximization	Canopy	Farthest First
Dunn	4	6	7
DB	4	5	5
SD	4	4	4
CDbw	4	4	4
S_Dbw	4	5	6

3 Results and Discussion

Having conducted the analysis of the organizational conditions that may be applied in the course of studying the topic "Geometrical Transformations" using flipped learning with the application of VLE, having analyzed the results of the survey conducted among school teachers of the Vinnytsia oblast (15 people), master students majoring in Secondary Education (Computer Studies) and Secondary Education (Mathematics) (7 people), professors of Mykhaylo Kotsiubynskyi Vinnytsia State Pedagogical University (6 people), we have determined the main organizational-pedagogical conditions (see Fig. 2). As can be seen from Figure 2 the following organizational-pedagogical conditions received the highest number of points from the afore stated respondents who took part in the survey: forming positive motivation among the students towards studying the topic "Geometrical Transformations" using flipped learning – 271 points; the use of flipped learning in order to form the necessary competences in students – 261 points; the use of current digital educational tools and techniques (e.g. the educational websites) – 256 points. The fewer number of points was received by the following organizational-pedagogical conditions (see Fig. 2): the technical possibilities of a GSEI – 169 points; the presence of a necessary licensed software – 137 points; the presence of the necessary methodological materials for giving lessons – 179 points.

Such a result is determined by the fact that if compared with the first three conditions, other organizational-pedagogical conditions, the ones that received a smaller number of points, are not defining, however, they are also important for the respondents. The absence of those organizational-pedagogical conditions that received the highest number of points, makes the integrated use of flipped learning and modern digital tools of educational technologies ineffective. For instance, if students lack the motivation to study the topic "Geometrical Transformations", it is impossible to achieve high results using flipped learning. As for the need to have licensed software, we may state that nowadays software market offers free software, which can be used in the educational process without a license, namely, Google cloud technologies.

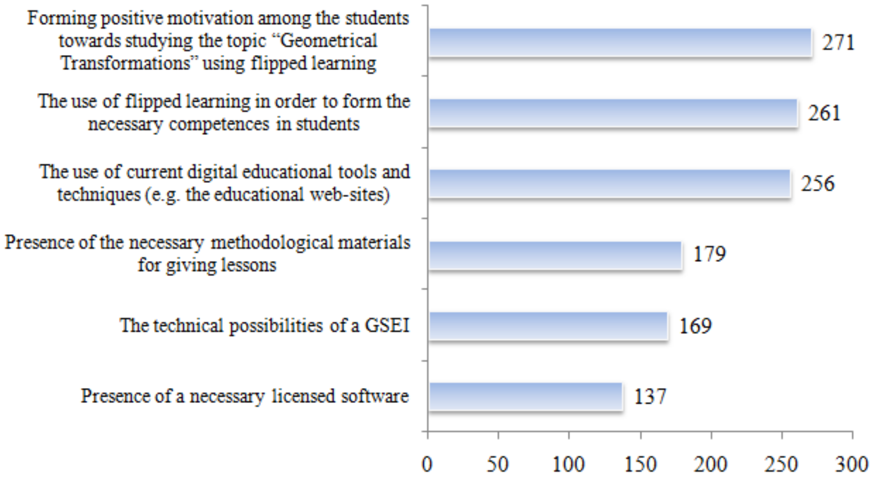

Fig. 2. Results of the respondents' assessment of the organizational-pedagogical conditions necessary for effective teaching of the topic "Geometrical Transformations" using flipped learning with the application of VLE.

Let us look at the components of the "Geometrical Transformations" website [14], which was used in the course of the study (see Fig. 3): 1) a topical plan highlights the sequence of subtopics, which need to be mastered in the course of studying the stated topic; 2) the "Theoretical Reference Guide" section contains a multi-media presentation on the topic as well as some useful links; 3) the "Lesson Drafts" section contains materials for every subtopic: motivation of the students' study activity, preparatory tasks for forming the conceptual framework and typical cognitive schemes, tasks for consolidation of the knowledge received, tasks for laboratory work, tasks ensuring the formation of key competences and cross-topic references, test tasks, project tasks;

4) the “Problem Books” contain problem books, training videos and games, which could be used while studying the given topic.

The results of the ascertaining stage of the research have shown that the average level of preparation of students in Geometry at the start of studying the topic “Geometrical Transformations” in the control and experimental groups was relatively homogeneous and was 6.8 and 6.5 points respectively.

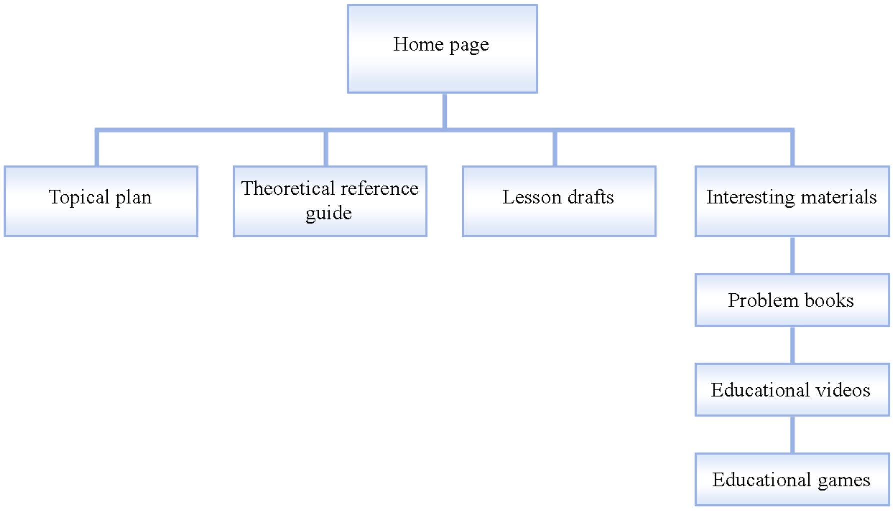

Fig. 3. Structure scheme of the “Geometrical Transformations” website (home page, topical plan, theoretical reference guide, lesson drafts, interesting materials, problem books, educational videos, educational games).

The analysis of the research results showed that after studying the topic “Geometrical Transformations” using flipped learning with the application of VLE, the experimental group demonstrated positive dynamics, but the changes were insignificant (Table 2, Fig. 4). The average point was (Table 2, Fig. 4): in the control group – 6.6, the average level of educational achievements is “sufficient”; in the experimental group – 8.2, the average level of students’ educational achievements is “medium”.

Table 2. Levels of educational achievements of students on the topic “Geometrical Transformations” at the forming stage of the research.

Level of educational achievements of students	Forming stage			
	Experimental group		Control group	
	Number of students	%	Number of students	%
Low, Sufficient	5	23.81	12	60.00
Medium	11	52.38	5	25.00
High	5	23.81	3	15.00
Total:	21	100.00	20	100.00
Average point	-	8.20	-	6.60

Let us prove the statistical validity of the received results. The number of students: control group – $n_1 = 20$; experimental group – $n_2 = 21$.

Using the bilateral Wilcoxon-Mann-Whitney test [16, p. 87], let us check the hypothesis H_0: $P(X \geq Y) = 0.5$, which presupposes that the marks of the students of the control (X) group are with identical probability P = 0.5 statistically higher (or equal) to the points of the experimental (Y) groups, i.e. the marks of the students of one group are on average (statistically) higher (or equal) to the marks of the students of the other group. If this hypothesis does not prove to be true, then we accept the alternative hypothesis: H_1: $P(X < Y) \neq 0.5$.

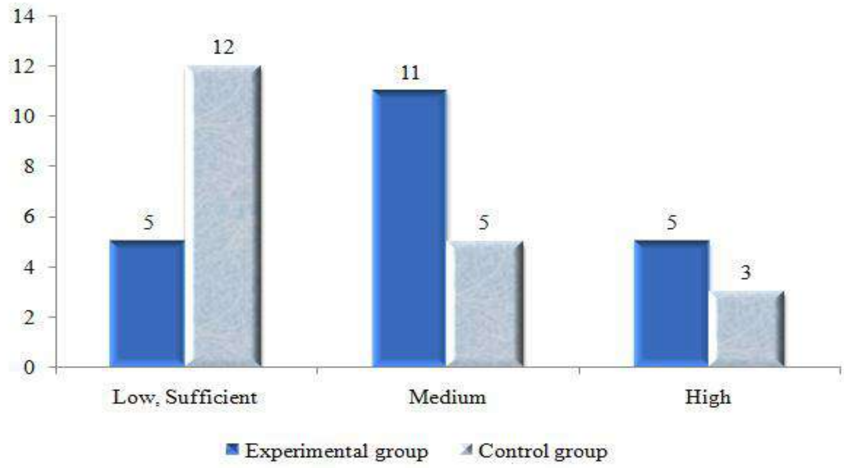

Fig. 4. Levels of educational achievements of students on the topic "Geometrical Transformations" at the forming stage of the research.

On the basis of the received data, we calculate the value of the T criterion by the formula (1):

$$T = 424.5 - 20 \cdot 21/2 = 214.5,$$

$$S = \sum_{i=1}^{21} R(x_i) = 24.5\,.$$

The empirical value of the W_α is calculated using formula (2):

$$W_\alpha = \frac{20 \cdot 21}{2} + 1.64 \cdot \sqrt{\frac{20 \cdot 21 \cdot (20 + 21 + 1)}{12}} = 272.9$$

Thus, $T=214.5 < W_\alpha=272.9$, and according to the decision making rule when using the bilateral criterion, the null hypothesis H_0 deviates at the level $\alpha=0.05$ and an alternative hypothesis H_1 is accepted. We make a conclusion that the level of educational achievements of students in the experimental group is statistically higher than the level of educational achievements of the control group.

In this research, we use clustering methods of machine learning in order to adapt the components of the scientific-methodological system of studying the topic “Geometrical Transformations” using the flipped learning method based on VLE. Namely, determining the main typical mistakes in studying the stated topic that were made in the test taken at the end of studying the topic (students took tests several times). Received the following results:

1. The EM (Expectation Maximization) algorithm (Fig. 5, Table 3). There are 25 objects in the first cluster, 66 in the second, 47 in the third and 77 in the fourth. Objects of the first cluster are the students, whose overall mark for the test approximates 3; objects of the second cluster are the students, whose overall mark for the test approximates 10, objects of the third cluster are the students, whose overall mark for the test approximates 6 and objects of the fourth cluster are the students, whose overall mark for the test approximates 7.

Objects of each of the clusters are united by the fact that most of them have made a mistake in tasks 9 and 10.

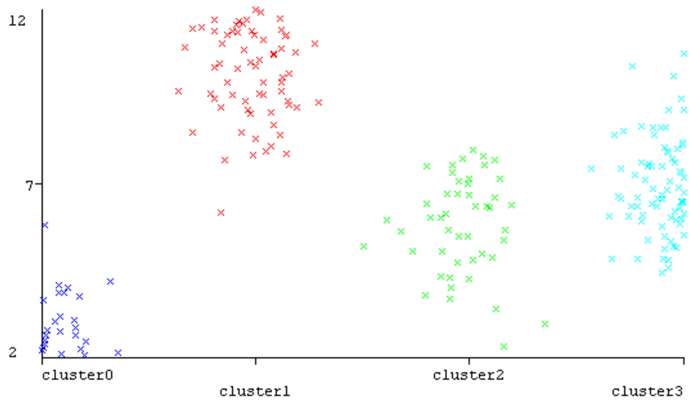

Fig. 5. Visual presentation of the test data after clustering following the EM algorithm.

Table 3. Cluster distribution of the objects, EM algorithm.

Clusters	Clustered Instances
0	25 (12%)
1	66 (31%)
2	47 (22%)
3	77 (36%)

2. The Canopy algorithm (Fig. 6, Table 3). There are 106 objects in the first cluster, 30 in the second, 25 in the third and 54 in the fourth. Objects of the first cluster are the students, whose overall mark for the test approximates 11; objects of the second cluster are the students, whose overall mark for the test approximates 8, objects of the third cluster are the students, whose overall mark for the test approximates 3 and objects of the fourth cluster are the students, whose overall mark for the test approximates 6.

Objects of each of the clusters are united by the fact that most of them made a mistake in task 10.

3. The Farthest First Algorithm (Fig. 7, Table 5). There are 52 objects in the first cluster, 7 in the second, 138 in the third and 18 in the fourth.

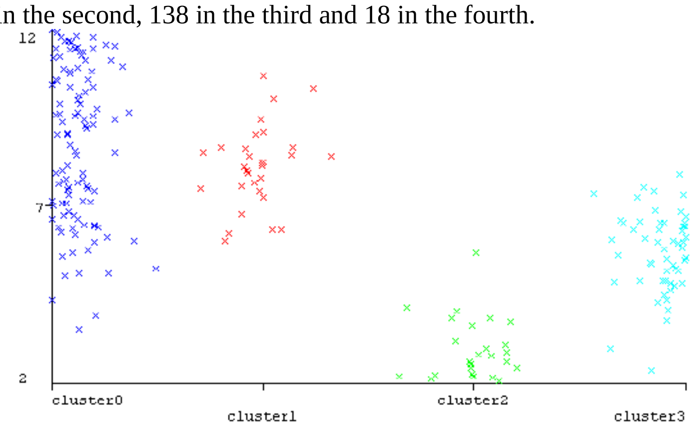

Fig. 6. Visual presentation of the test data after clustering following the Canopy algorithm.

Table 4. Cluster distribution of the objects, Canopy algorithm.

Clusters	Clustered Instances
0	106 (49%)
1	30 (14%)
2	25 (12%)
3	54 (25%)

Objects of the first cluster are the students, whose overall mark for the test approximates 5; objects of the second cluster are the students, whose overall mark for the test approximates 2, objects of the third cluster are the students, whose overall mark for the test approximates 9 and objects of the fourth cluster are the students, whose overall mark for the test approximates 3.

Objects of each of the clusters are united by the fact that most of them made a mistake in tasks 9 and 10.

As a result of using all three clustering algorithms, we may make an overall conclusion that most mistakes were made in tasks 9 and 10 (this refers to both groups):

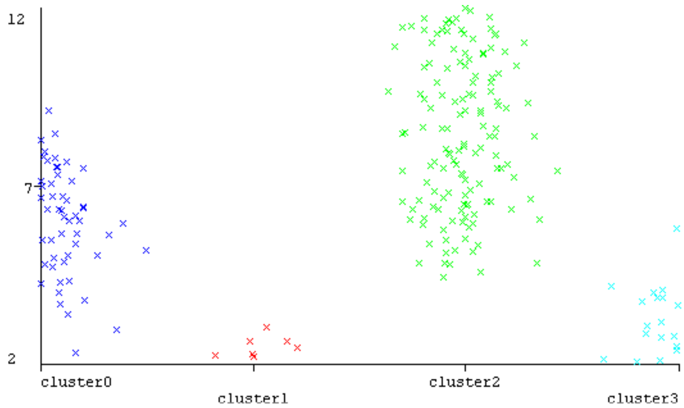

Fig. 7. Visual presentation of the test data after clustering following the Farthest First algorithm

Table 5. Cluster distribution of the objects, Farthest First algorithm.

Clusters	Clustered Instances
0	52 (24%)
1	7 (3%)
2	138 (64%)
3	18 (8%)

Task 9: Find the coordinates of the image of point B (7;-6) under a translation by the vector $\vec{b}$(-10; -1). Possible answers: 1) (-3; -7); 2) (-3; 7); 3) (17; -5); 4) (17; 5).

Task 10: One rhombus was received from another one by means of rotation. The diagonals of the first rhombus are 12 cm and 16 cm. Find the side of the second rhombus. Possible answers: 1) 14 cm; 2) 5 cm; 3) 10 cm; 4) 20 cm.

Having analyzed the received results, we may conclude that the main reason for these mistakes is the students' incorrect application of the key notions of the topic "Geometrical Transformations" to the geometrical problems of a more general type (this most concerns Task 10).

4 Conclusion

1. On the basis of methodological reflection on the results of the research and analysis of the works of the scientists, we may conclude that using digital technologies for conducting flipped learning is advisable and that the efficiency of the teaching activity increases in conditions of integrated use of the stated learning techniques. Such organization of the educational process is viewed as one of the forms of innovative education as an effective way of implementing the personality-oriented and competence approaches. The advantages of the integrated use of digital technologies and flipped learning include: actualization of the activity-based nature of learning, which includes active participation of students in the process – researching, designing, modelling, perceiving and reflecting on the results and experiences; orientation of the

study process towards the development of initiative, creativity, skills of self-control, reflection and goal-setting as well as independence and responsibility of a pupil for the results of his/her work; stimulating the increase of the students' interest in learning; activating their study process; revealing their cognitive and personal potentials; developing students' digital competences, their independence, individuality etc. Students' motivation for mastering new study material increases considerably as learning parts of the study materials takes place in the course of active creative search outside the classroom, primarily, with the help of innovative tools, using a wide spectrum of digital technologies. At the same time, an important intellectual capacity of teachers and their task is to be able to use and develop their own digital learning tools. The stated organizational-pedagogical conditions allow conducting flipped learning more effectively, in a humanistic and personality-oriented way.

2. In the course of the research, we determined the organizational-pedagogical conditions for implementing the flipped learning method using virtual learning environments. Based on the analysis of the survey results conducted among school teachers, master students, university professors, the following main organizational-pedagogical conditions were defined: forming positive motivation among the students towards studying the topic "Geometrical Transformations" using flipped learning; the use of flipped learning in order to form the necessary competences in students; the use of current digital educational tools and techniques (e.g. the educational websites).

3. The use of flipped learning based on virtual learning environments requires thorough preparation. In order of prepare for such kind of educational process, an educational website "Geometrical Transformations" was created; it is a technological foundation for the introduction of flipped learning at lessons of Geometry while studying the topic "Geometrical Transformations" in the 9th form. The website contains a topical plan, a short theoretical guide, lesson drafts and interesting materials that refer to the topic "Geometrical Transformations" (problems, educational games and videos).

4. The application of flipped learning based on virtual learning environments also requires a detailed selection of the study content as well as its adaptation to concrete groups of students. We assessed the effectiveness of flipped learning implementation on the basis of the stated environment and determined the ways of improving the components of the scientific-methodological system of flipped learning using machine learning techniques. The application of the Canopy, EM (Expectation Maximization) and Farthest First clustering algorithms on the basis of the Weka platform for grouping the results of students' educational achievements in the course of studying the topic "Geometrical Transformations" allowed us to detect the main typical mistakes made by the students. In our case, the main reason for making these mistakes was the students' incorrect application of the key notions of the topic "Geometrical transformations" to geometrical problems of a more general nature. The clustering model presented in the research can also be used for selecting study tasks under the "traditional" organization of the educational process.

5. The analysis of the results of the research using the bilateral Wilcoxon-Mann-Whitney criterion proved the effectiveness of using the stated method at the lessons of Geometry in the 9th form while studying the topic "Geometrical Transformations". It

has been determined that the level of educational achievements of the students from the experimental group is statistically higher than the level of educational achievements of the students from the control group. In addition, after studying the topic “Geometrical Transformations” using flipped learning and virtual learning environments, the experimental group demonstrated positive dynamics of educational achievements; and the control group also demonstrate positive changes, which are relatively insignificant. The average point was 6.6, the average level of educational achievements is “sufficient”; and 8.2 in the experimental group, average level of students’ educational achievements is “medium”; there was an increase of the average level of educational achievements from “sufficient” to “medium”.

The article determines the ways of increasing the effectiveness of flipped learning implementation using virtual learning environments on the basis of machine learning techniques: determining the individual learning trajectory, characteristic of a concrete group of students on the basis of clustering their educational achievements with the help of machine learning; selecting the study content and adapting it to concrete groups of students; searching for more effective and systemic ways of achieving pedagogical goals (selecting and correcting the theoretical materials and tasks, selection of digital tools for presenting the lecture material, development of tasks, motivating students to individually work with the study materials, the methods of problem-based learning, flipped learning etc.). Thus, flipped learning is effective if the teacher takes his/her professional activity creatively and, accordingly, modifies and controls the educational process. It is important to adapt the learning environment to the individual needs of the students and to timely correct the imperfections.

The theoretically and practically significant generalizations, concepts, proposals formulated in the research may be used for improving the quality of education and broadening the possibilities of the educational landscape: in the scientific-research field – for further scientific-practical developments in the stated field; in the course of designing and using virtual learning environments in the educational process.

References

1. Littlejohn, A.: Learning through the Open Creation of Knowledge, http://littlebylittlejohn.com/open-knowledge/ (2018), last accessed 2020/03/15.
2. Shyshkina, M., Kohut, U., Popel, M.: The Comparative Analysis of the Cloud-based Learning Components Delivering Access to Mathematical Software. Proc. of Integration, Harmonization and Knowledge Transfer (Kherson, Ukraine, June 12-15, 2019) ICTERI, 2019. [Online]. Available at: http://ceur-ws.org/Vol-2393/paper_241.pdf, (2019).
3. Glazunova, O., Shyshkina, M.: The Concept, Principles of Design and Implementation of the University Cloud-based Learning and Research Environment, Proc. of Integration, Harmonization and Knowledge Transfer (Kyiv, Ukraine, May 14-17, 2018) ICTERI, 2018. [Online]. Available at: http://ceur-ws.org/Vol-2104/paper_158.pdf, (2018).
4. Kolgatin, O., Kolgatina, L., Ponomareva, N., Shmeltser, E.: Systematicity of students’ independent work in cloud learning environment, Proc. of the 6th Workshop on Cloud Technologies in Education (Kryvyi Rih, Ukraine, December 21, 2018) CTE 2018. [Online]. Available at: http://ceur-ws.org/Vol-2433/paper11.pdf, (2019).

5. Kukharenko, V., Oleinik, T.: Open Distance Learning For Teachers. Proc. of Integration, Harmonization and Knowledge Transfer (Kherson, Ukraine, June 12-15, 2019) ICTERI, 2019. [Online]. Available at: http://ceur-ws.org/Vol-2393/paper_295.pdf.
6. Naidu, V., Singh, B., Farei, K., Suqri, N.: Machine Learning for Flipped Teaching in Higher Education – A Reflection. In: Al-Masri A., Al-Assaf Y. (eds). Sustainable Development and Social Responsibility, vol. 2, pp. 129-132. Springer, Cham (2018). doi:10.1007/978-3-030-32902-0_16.
7. Nouri, J., Saqr, M., Fors, U.: Predicting performance of students in a flipped classroom using machine learning: towards automated data-driven formative feedback. In 10th International Conference on Education, Training and Informatics (ICETI 2019), Vol. 17, no 4, pp. 17-21. [Online]. Available at: http://www.iiisci.org/Journal/CV$/sci/pdfs/EB614LI19.pdf, (2019).
8. Klochko, O., Fedorets, V.: An empirical comparison of machine learning clustering methods in the study of Internet addiction among students majoring in Computer Sciences. In: Kiv, A.E., Semerikov, S.O., Soloviev, V.N., Striuk, A.M. (eds.) Proceedings of the 2nd Student Workshop on Computer Science & Software Engineering (CS&SE@SW 2019), Kryvyi Rih, Ukraine, November 29, 2019, CEUR-WS.org, pp. 58–75. [Online]. Available at: http://ceur-ws.org/Vol-2546/paper03.pdf, (2019).
9. Staker, H., Horn, M.: Classifying K-12 blended learning. Innosight Institute. [Online]. Available at: https://files.eric.ed.gov/fulltext/ED535180.pdf, (2012).
10. Bykov, V.Yu., Shyshkina, M.P.: The conceptual basis of the university cloud-based learning and research environment formation and development in view of the open science priorities. Information Technologies and Learning Tools, 68(6), 1–19 (2018). doi:10.33407/itlt.v68i6.2609.
11. Cobb, J.: Leveraging the Flipped Classroom for Professional. Development and Continuing Education. Leading Learning. [Online]. Available at: https://www.leadinglearning.com/flipped-classroom-for-professional-development-and-continuing-education/, last accessed 2020/03/29.
12. Harman, J.: Serious Flipped Learning with Dr. Brian McGowan. Leading Learning. [Online]. Available at: https://www.leadinglearning.com/podcast-episode-29-brian-mcgowan-flipped-learning/, last accessed 2020/03/29.
13. Cobb, J.: Leveraging Microlearning for Professional Development and Continuing Education. Leading Learning. [Online]. Available at: https: https://www.leadinglearning.com/microlearning-for-professional-development-and-continuing-education/, last accessed 2020/03/29.
14. Gurevych, R, Klochko, O., Klochko, V., Kovtoniuk M., Opushko, N.: Computer science teachers’ readiness to develop and use computer didactic games in educational process. Information Technologies and Learning Tools, 75(1), 122-137 (2020). doi: 10.33407/itlt.v75i1.3394.
15. Ткаченко S. Geometrical Transformations. [Online]. Available at: https://sites.google.com/view/greatgeometry, last accessed 2020/03/29.
16. Sidorenko, E .: Methods of mathematical processing in psychology. (2010).
17. McCallum, A., Nigam, K., Ungar, L.: Efficient clustering of high-dimensional data sets with application to reference matching. In Proc. of the sixth ACM SIGKDD international conference on Knowledge discovery and data mining, pp. 169-178. [Online]. Available at: ftp://ftp.cse.buffalo.edu/users/azhang/disc/disc01/cd1/out/papers/kdd/p169-mccallum.pdf, (2018).

18. Keng, B.: The Expectation-Maximization Algorithm. [Online]. Available at: http://bjlkeng.github.io/posts/the-expectation-maximization-algorithm (2016), last accessed 2020/03/29.
19. Dasgupta, S., Long, P.: Performance guarantees for hierarchical clustering. Journal of Computer and System Sciences, 70(4), 555–569 (2005). doi:10.1016/j.jcss.2004.10.006.
20. Weka 3 – Data Mining with Open Source Machine Learning Software in Java. https://www.cs.waikato.ac.nz/~ml/weka, (2020).
21. da Silva, L.E.B., Melton, N.M., Wunsch II, D.C.: Incremental Cluster Validity Indices for Hard Partitions: Extensions and Comparative Study. arXiv:1902.06711 [cs.LG]. [Online]. Available at: https://arxiv.org/pdf/1902.06711.pdf (2019), last accessed 2020/03/29.
22. Moshtaghi, M., Bezdek, J.C., Erfani, S.M., Leckie, C., Bailey, J.: Online Cluster Validity Indices for Streaming Data. arXiv:1801.02937 [stat.ML]. [Online]. Available at: https://arxiv.org/pdf/ 1801.02937.pdf (2018), last accessed 2020/03/29.
23. Moshtaghi, M., Bezdek, J.C., Erfani, S.M., Leckie, C., Bailey, J.: Online cluster validity indices for performance monitoring of streaming data clustering. International Journal of Intelligent Systems, 34(4), 541–563 (2019). doi:10.1002/int.22064.