Gamification of Learning Scratch in Elementary School

Serhii D. Prykhodchenko
Department of Software Engineering, Dnipro University of Technology, Ukraine
prykhodchenko.s.d@nmu.one

Oksana Yu. Prykhodchenko
Department of Finances, National Metallurgical Academy of Ukraine, Dnipro, Ukraine
oksana.prykhodchenko@gmail.com

Olha S. Shevtsova
Department of Software Engineering, Dnipro University of Technology, Ukraine
shevtsova.o.s@nmu.one

Sergii Yu. Semenov
Department of Software Engineering, Dnipro University of Technology, Ukraine
semenovs@gmx.com

Abstract

The article deals with the problem of gamification for primary school students. The main idea of creating a software product was to create the correct programming sequences for solving simple programming problems in the Scratch programming environment. The technological preconditions for creating an application are described; a review of gamification basics has been carried out. In this article, we first illustrate the current art of state of gamification. Then we discuss requirements for teaching and studying Scratch for primary school students, and then we describe the development of a game application for teaching Scratch programming constructions. In the experimental section we compare the results of the experimental and control groups of primary school students, which showed differences in the levels of knowledge of primary school students after the experiment, where the results of the experimental group are higher than results of the control group

2012 ACM Subject Classification Social and professional topics → Computing education programs; Social and professional topics → Computing education; Social and professional topics → Informal education

Keywords and phrases Education, Gamification, Scratch, Game Mechanic, Programming Language

Digital Object Identifier 10.4230/OASIcs.ICPEC.2020.20

1 Background

The relevance of research: creating a simulator program in the form of games will help make learning process exciting and interesting. Competitions and rewards for achievement allow students to improve their status and get another form of expression but also get an incentive for persistence, creativity.

Gamification is a concept that means using of scenarios specific to computer games in computer tools, in areas far from gaming [6, 12, 13, 10]. However, the use of games does not replace traditional lessons. On the contrary, it provides an additional opportunity for learning. There are 7 trends among modern teaching technologies in elementary education: mLearning or mobile learning [9, 3]; Storytelling [16, 18]; Edutainment (education entertainment) [8, 17]; Microlearning [10, 4]; Blended learning [5]; STEM-projects (education) (science, technology, engineering, mathematics) and robotics, LEGO-construction [7, 15]; Gamification (e-learning) [6, 10, 8, 17, 4].

First International Computer Programming Education Conference (ICPEC 2020).
Editors: Ricardo Queirós, Filipe Portela, Mário Pinto, and Alberto Simões; Article No. 20; pp. 20:1–20:11
OpenAccess Series in Informatics
OASICS Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Gamification can be used in the following cases:

- to develop certain skills or behaviors [19, 1];
- to visualize and emphasize activities and skills that are difficult to demonstrate using traditional techniques [4, 19, 1];
- to interest students, to create a kind of competition between them [6, 12, 19];
- to monitor students' progress [19, 11].

Research aim: study gamification teaching influence on the quality of learning new material by elementary school students. Research question: Influence of gamification on the quality of learning in primary school programming lessons. Therefore, we have the objectives: to analyze and test effectiveness, efficiency, and possibility of applying modern direction in education – gamification, in the work of elementary classes teacher. Gamification methods have become widespread in the educational field. Educational computer game is a software tool that allows you to direct activities of a child to achieve a certain didactic goal in the form of play. It is not isolated from the pedagogical process and is offered alongside traditional games and training; it does not replace ordinary lessons, but complements them, enriching the pedagogical process with new opportunities. Most of educational computer games offer such elements of knowledge that under normal conditions are difficult to understand or learn [6, 12].

The computer world is always secondary, it has nothing that would not be contained in the real world or imagination of its creator, but at the same time it is not limited by frames of physical laws, it has any resources to recreate the situation, a virtual realization of most fantastic ideas.

An unusualness of an imaginary situation in a training computer game is that the player acts within its frames, but cannot change it. The computer imaginary situation is external to a child. A player does not create it but gets into it.

In computer reality, it is always possible to go back to tasks, replay, try other options. The pre-orientation stage in a computer-based educational game is not at the semantic level, but above all at the action level.

Rules of educational computer game exist before its beginning, may be disclosed, but are not generated during the game. Computer learning games and exercises should be considered as a special means of stimulating children's creative activity. They are interesting and accessible, and their game tasks contain motive and purpose, as well as ways and means of solving them. Scratch is an object-oriented visual programming environment that enables you to create computer animations, multimedia presentations, interactive stories, games, models, and more. Scratch is a freely distributed educational program that can be downloaded from the developer's official site (`https://scratch.mit.edu/`).

The programming is as follows: users "assemble" in "drag-and-drop" style the program from blocks that have objects and scenes. An object that is associated with a particular image, set of variables, and command blocks to determine its behavior is called a sprite. You can modify the sprite by importing it from the built-in library (categories include animals, fiction, letters, people, things, transport), or create using a built-in graphic editor or other software. Commands-blocks are grouped into certain groups: "Movement" (performing the movement of sprites), "View" (changing the sprite patterns, its text dialogues), "Sound" (sound commands, volume, tempo), "Pencil" (graphical construction) images), "Manage" (looping, branching), "Sensors" (information about touching objects and determining distances between them), "Operators" (performing mathematical and logical operations, selecting a random number), "Variables" (creating variables, assigning them certain values). As a whole, Scratch can be described as easy to use and powerful enough to meet the challenge of creating your own programming for beginners.

In the curriculum of Ukrainian elementary schools, the subject "Informatics" is related to the study of computer technologies. This discipline is studied from the second grade, while under the curriculum, in the third grade, students begin to study the Scratch programming language. Scratch is not always clear to students in Ukraine, especially in the initial stages, as well as in another countries [14].

2 Designing the game logic

As we said before, the constructions of the Scratch language for elementary school students are not always clear. Thus, to better understanding the language constructions, it is proposed to create a game in which the student will create a Scratch structure in a game with prompts from the teacher or from the game itself.

We have set the following requirements for the upcoming game:

- it should be interesting, develop attention, speed of reactions, train memory;
- completing all play tasks should teach a child to think analytically in unusual situations, to classify and summarize concepts; develop fine motor skills and visual-motor coordination;
- the game should be thoughtful and simple at the same time, with low levels of aggression.

We have also developed rules of the game:

- the number of minutes per game is equal to a child's age multiplied by 1.5. For example, for an eight-year-old child, the game lasts 12 minutes.
- the number of sessions per game is a maximum of 3 per day.
- after work that is mandatory to have eye exercises and rolling games.

The initial purpose of the work was to make a learning game that would be understandable and interesting for the children.

The main goal is to test the game, to draw some conclusions about the students' interest in game learning technologies, to test students' knowledge, and to find out how the game influenced learning of the material.

The game has two modes – "Assembling without false targets" and "Assembling with false targets". The main character is a robosphere. The design was chosen in a way that it was not difficult for the children to adjust to the game. The main map is "located" in space (similar to the game "Ballance" (Fig. 1)).

The purpose of the game is to assemble an answer to a test question that is randomly selected from database. Movements of main actor is controlled using the WASD buttons and the arrow keys.

The database of Scratch expressions is formed; then it divided into single elements – keywords and their parameters. Each expression is associated with test question, and each element has its serial number in the expression. At the beginning of the round, elements of one of the random test expressions called "correct elements" are randomly placed on the game board and test question is displayed over board to the player.

There are two game modes:

- in the first, you need to collect the test expression in the correct order from the elements of only the test expression itself.
- In the second mode, not only "correct elements" are placed on the playing field, but also random elements from other expressions called "false targets".

Figure 1 Ballance Computer Game.

The player must move the robotic sphere to assemble in the correct order the "right elements" into a full Scratch expression.

Game algorithm as steps sequence:

1. Select a game mode.
2. Extract a test expression from the expression base
3. Divide it in order into the "correct" elements.
4. Store in memory the length of the expression.
5. Extract the test question associated with expression for the student.
6. Assign each of the "correct elements" its serial number in the expression.
7. Set each of the correct elements weight = 1.
8. If the second game mode is selected, then randomly add a random number of "false targets", limited by the number of elements of the test expression.
9. Set for each "false target" serial number = -1 and weight = -0.5.
10. Distribute the "correct elements" and "false targets" as items randomly across the playing field.
11. Create an empty list for the "Correct Elements" sequence
12. Assign the last element the number 0. Assign the total points = 0.
13. Start the game.
14. Display the test question for the student on the screen.
15. Wait for student's action.
16. If the student has collected the item, then
17. If the item serial number is 1 more than the last item in the list and weight = 1, then add this item to the list of "correct elements" as the last element and add weight to the total points.
    a. Otherwise, subtract the weight from the total points, and put the collected item on a random free space on the board.
18. Check if the length of the list is equal to the length of the test highlight, then end the game by going to step 19.
    a. Otherwise, go to point 14.
19. Display the test question again and the complete test expression for the student.

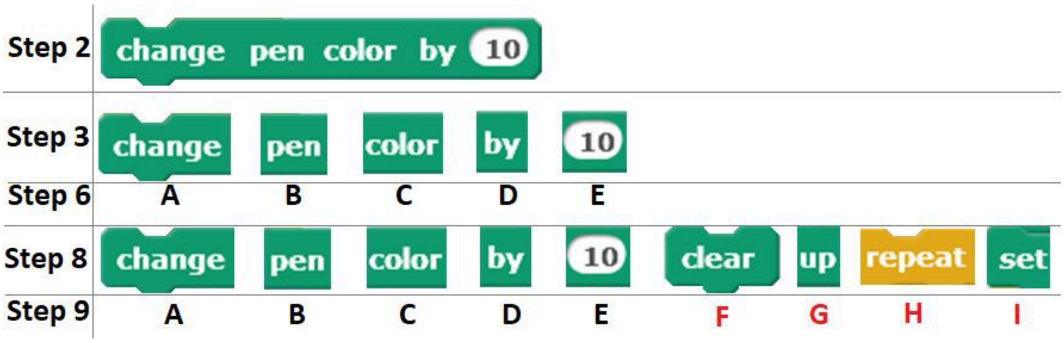

Figure 2 Illustrated steps of algorithm.

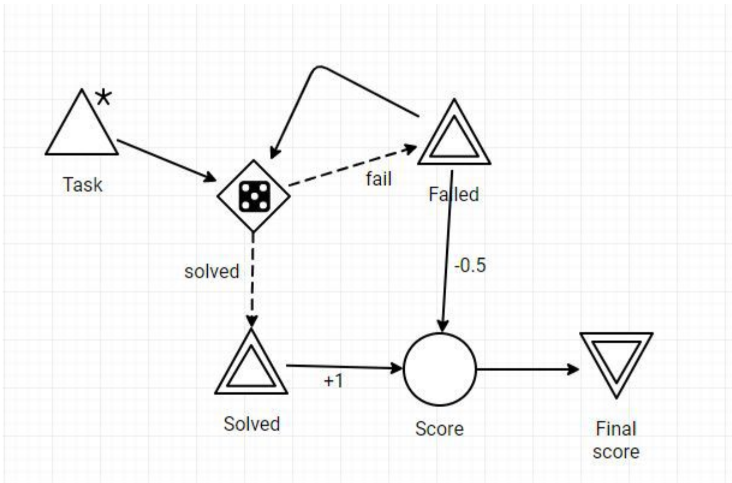

Figure 3 "Scratched ballance" rule model.

20. Display the final score. If it is equal to the length of the test expression, then congratulations on a complete victory

- **a.** If the sum of the points is greater than 0, but less than the length of the test expression, then congratulations on the success.
- **b.** If the score is less than 0, then congratulate player on test completion and wish him success and efforts in learning.

An example of the operation of some steps of the algorithm is presented in Fig. 2.

At the second step, one of the test expressions is retrieved from the database. At the third step, the expression is divided into separate "correct" elements. At the sixth step, each of the elements is assigned a serial number A = 1; B = 2; C = 3; D = 4; E = 5. In the eighth step, false targets are added. On the ninth, false targets are assigned serial numbers equal to "−1" so that F = −1; G = −1; H = −1; I = −1.

The game logic proposed in the developed game "Scratched Balance", based on "Gamification patterns for gamification applications" [2], and can be represented in the form of the scheme shown in Fig. 3 where Task is a result of Player's action, diamond – model for good/bad choice, Failed and Solved imitates rules for scoring. When the Score is full, so we get a final Score of the round.

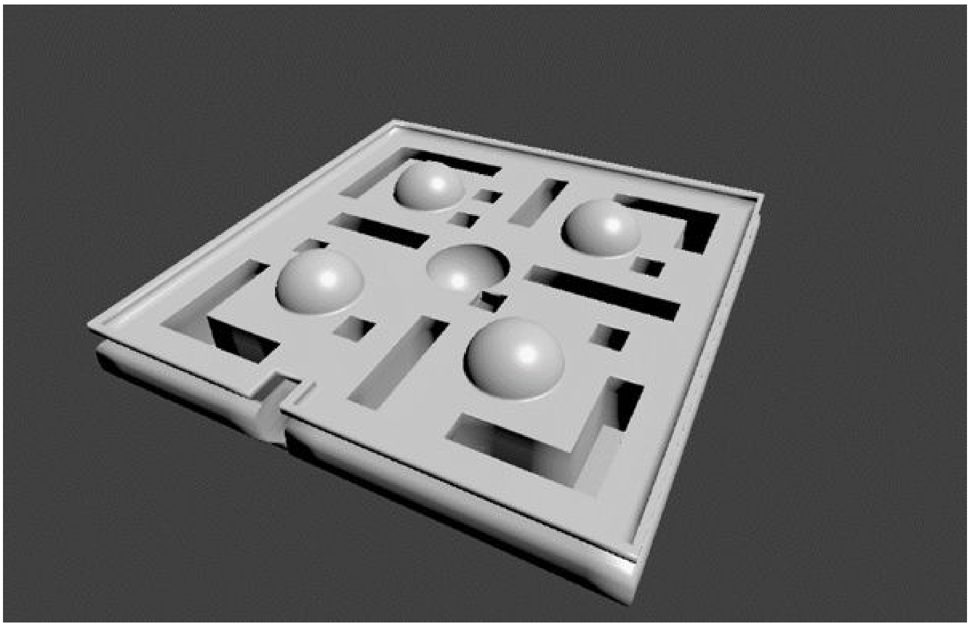

Figure 4 Model of the playing surface.

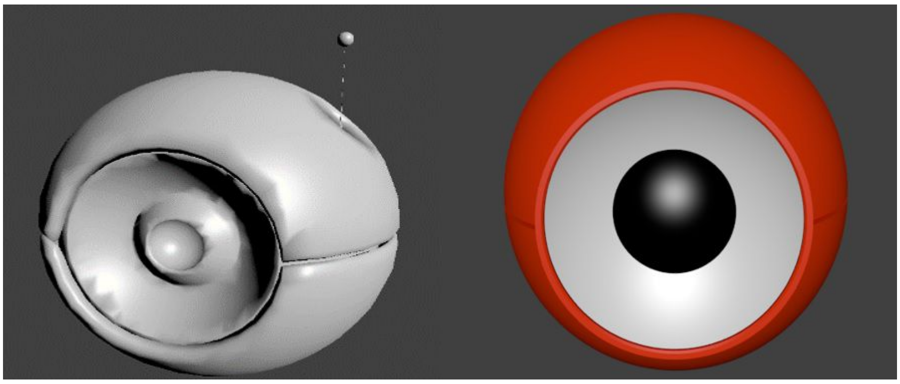

Figure 5 The main character – Robo-sphere.

2.1 Landscape of the Game

To increase the interest of children, elements of balancing the robosphere on uneven surfaces were introduced into the game, which makes it difficult to achieve the goals of the game. This raises the interest of children in the game. The difficult stage is to come up with an interesting and unusual design of the game board itself (Fig. 4).

Then, paint our model. To do this, we need to find textures and "overlay" them on the model. We chose the texture of wood and stone.

The main character of our game – Robo-sphere (Fig. 5).

For the player to be able to move around the terrain, we need to create a control unit – a script, which we will call "Roll". It will be responsible for moving the character around the area. In the main game function that is responsible for the game itself, we set a simple task to assemble the correct sequence of Scratch language operators capable of performing the simple operation asked in the "test question". After creating the interface, we got the following look at the field (Fig. 6).

Figure 6 Game board.

The main goal for the player is to create a simple structure in the Scratch language that will fulfil the set condition. For example: "set the property "colour" of the object "pen" to 5"; "Wait 10 seconds", "move to position 10, 5", etc. At the beginning of the game, the task is issued in capital letters for 5 seconds, after which the game begins. If the student has forgotten the task, or wants to read it again, he can call the task in a pop-up window by pressing the F1 key. The gameplay are series of the robosphere movements to collect the correct sequence of operators on the playing field. For example, for the test question "Assign the property "Colour" of the object "Pen" to 5", the player must collect the sequence of operators "SET", "PEN", "COLOR", "TO" and "5" (Fig. 6)

3 Experimental methodology

To study the impact of gamification on learning, we have selected students of grade 3 of school №15. The study was conducted in the 1st semester when the Scratch course has not been studied before. Knowledge quality control was performed through testing (each child was given a task consisting of 16 examples containing Scratch action). The experiment took place in two stages and lasted for three weeks.

In the first stage, the rules of simply Scratch operators were explained to the children and tested. After that, they had the opportunity to play "Scratched Balance". The training game was installed on an Acer laptop that was connected to a 40-inch TV that was used as a display. This made it easy for all children to follow the play process. But according to our observations, most of the students watched the game directly through the laptop and tried to give the player immediate advice (Fig. 7). At the end of the experiment, we retested the same tasks.

Figure 7 Testing the game.

4 Results of the study

The students of the third grade of the school studying computer science were divided into two groups based on the classes in which they study: “3A” class was a control group and consisted of 24 students, “3B” class was the experimental group consisted of 26 students.

As a first step students of both classes were tested. First test consisted of 16 problems and student got 1 point for each, so 16 points were maximal result. The test results were processed using the t-test. According to the statistical results of preliminary testing, the average score of the experimental group was 4,615 points, and the average score of the control team – 4,625 points. Thus, we compare the value of the t-criterion ($t = 0.01416$) with the critical value at $p = 0.05$, which is 1.677. Since the calculated value of the criterion is less than the critical one, we conclude that the observed differences are statistically insignificant. These calculations showed that the students of the experimental and control groups had the same level of knowledge in computer science before the experiment. After three weeks we conducted the second test. Then we compared the results of the experimental and control groups after the learning. Test results of first and second tests (annex 1) were used for the both groups.

The table presents the results of the data processing after excluding the influence of covariance (test points before the experiment) on the test results after the experiment.

Table 1 The ANCOVA test results for learning achievement from post-test of the two groups.

Group	M	S.D.	Adjusted Mean	S.E.	N
Control group	7.25	2.56	7.24541	0.264455	24
Experimental group	11.88	2.55	11.88885	0.25408	26

Source: own

Since the calculated value of criterion $F = 160.32$ is more critical, we conclude that the observed differences are statistically significant ($p < 0.05$).

The mean score of students in the experimental group was 11.88, and the standard deviation was 2.55, the mean score in the control group was 7.25, and the standard deviation was 2.56.

These calculations showed that the students of the experimental and control groups had different levels of knowledge of computer science after the experiment.

5 Conclusions

The idea of the game was to introduce an element of the game into the study of standard Scratch language constructions to attract the interest of elementary school students. The game can be used by elementary school teachers as supporting material in the learning process of Scratch students, because the calculated value of criterion $F = 160.32$ is more critical and we conclude that the observed differences are statistically significant with $p<0.05$.

This research showed that Game-based learning have some influence on the performance of elementary school students. It's obvious that understanding the material in the discipline under consideration has increased when comparing student groups, which can serve as an indicator of the success of game application.

Based on the results of our work, we recommend introducing the elements of gamification into teaching the Scratch language in Ukrainian elementary schools, since our study showed a marked excess of the results of the experimental group on the results of the control group of students.

References

1 Raed S Alsawaier. The effect of gamification on motivation and engagement. *The International Journal of Information and Learning Technology*, 2018. doi:10.1108/IJILT-02-2017-0009.

2 Darius Ašeriškis and Robertas Damasevicius. Gamification patterns for gamification applications. *Procedia Computer Science*, 39:83–90, December 2014. doi:10.1016/j.procs.2014.11.013.

3 M. S. Bhullar. A new method of learning: M-learning (mobile learning). In *2014 9th International Conference on Computer Science Education*, pages 322–325, 2014. doi:10.1109/ICCSE.2014.6926478.

4 Laurie Butgereit. Gamifying mobile micro-learning for continuing education in a corporate it environment. In *2016 IST-Africa Week Conference*, pages 1–7. IEEE, 2016. doi:10.1109/ISTAFRICA.2016.7530597.

5 D Randy Garrison and Norman D Vaughan. *Blended learning in higher education: Framework, principles, and guidelines*. John Wiley & Sons, 2008. doi:10.1002/9781118269558.

6 Thomas Hainey, Thomas M. Connolly, Elizabeth A. Boyle, Amanda Wilson, and Aisya Razak. A systematic literature review of games-based learning empirical evidence in primary education. *Computers & Education*, 102:202–223, 2016. doi:10.1016/j.compedu.2016.09.001.

7 JP Holdren, C Marrett, and S Suresh. Federal science, technology, engineering, and mathematics (stem) education 5-year strategic plan. *National Science and Technology Council: Committee on STEM Education*, 2013.

8 U. Jayasinghe and A. Dharmaratne. Game based learning vs. gamification from the higher education students' perspective. In *Proceedings of 2013 IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE)*, pages 683–688, 2013. doi:10.1109/TALE.2013.6654524.

9 Agah Tugrul Korucu and Ayse Alkan. Differences between m-learning (mobile learning) and e-learning, basic terminology and usage of m-learning in education. *Procedia - Social and Behavioral Sciences*, 15:1925–1930, 2011. 3rd World Conference on Educational Sciences - 2011. doi:10.1016/j.sbspro.2011.04.029.

10 A. Martens and W. Mueller. Gamification - a structured analysis. In *2016 IEEE 16th International Conference on Advanced Learning Technologies (ICALT)*, pages 138–142, 2016. doi:10.1007/978-981-4560-52-8_66-1.

11 A Matallaoui, N Hanner, and R Zarnekow. Gamification: Using game elements in serious contexts. *Springer, Cham, Switzerland*, 2016.

12 Manuel Ninaus, Kristian Kiili, Jake McMullen, and Korbinian Moeller. Assessing fraction knowledge by a digital game. *Computers in Human Behavior*, 70:197–206, 2017. `doi:10.1016/j.chb.2017.01.004`.

13 Manuel Ninaus, Korbinian Moeller, Jake McMullen, and Kristian Kiili. Acceptance of game-based learning and intrinsic motivation as predictors for learning success and flow experience. *International Journal of Serious Games*, 4(3), September 2017. `doi:10.17083/ijsg.v4i3.176`.

14 Ana Maria Ortiz-Colon and Jose Luis Maroto Romo. Teaching with scratch in compulsory secondary education. *International Journal of Emerging Technologies in Learning (iJET)*, 11(02):67–70, 2016. `doi:10.3991/ijet.v11i02.5094`.

15 Margarita Elizabeth Ortiz Rojas, Katherine Chiluiza, and Martin Valcke. Gamification in higher education and stem: A systematic review of literature. In *8th International Conference on Education and New Learning Technologies (EDULEARN)*, pages 6548–6558. Iated-int Assoc Technology Education A& Development, 2016. `doi:10.21125/edulearn.2016.0422`.

16 Panagiotis Psomos and Maria Kordaki. Pedagogical analysis of educational digital storytelling environments of the last five years. *Procedia - Social and Behavioral Sciences*, 46:1213–1218, 2012. 4th World Conference on Educational Sciences (WCES-2012) 02-05 February 2012 Barcelona, Spain. `doi:10.1016/j.sbspro.2012.05.277`.

17 Jihan Rabah, Robert Cassidy, and Robert Beauchemin. Gamification in education: Real benefits or edutainment? In *European Conference on e-Learning*, pages 489–XIX. Academic Conferences International Limited, 2018. `doi:10.13140/RG.2.2.28673.56162`.

18 Bernard Robin. The educational uses of digital storytelling. In Caroline M. Crawford, Roger Carlsen, Karen McFerrin, Jerry Price, Roberta Weber, and Dee Anna Willis, editors, *Proceedings of Society for Information Technology & Teacher Education International Conference 2006*, pages 709–716, Orlando, Florida, USA, March 2006. Association for the Advancement of Computing in Education (AACE). URL: `https://www.learntechlib.org/p/22129`.

19 Michael Sailer and Lisa Homner. The gamification of learning: A meta-analysis, 2019. `doi:10.1007/s10648-019-09498-w`.

A Results (number of correct answers) of every student

Table 2 Annex A. Results (number of correct answers) of every student.

№	Group	First test	Second test	Group	First test	Second test
1	Control group	1	3	Experimental group	8	14
2	Control group	2	4	Experimental group	2	8
3	Control group	4	5	Experimental group	8	13
4	Control group	1	3	Experimental group	7	12
5	Control group	5	8	Experimental group	1	6
6	Control group	2	6	Experimental group	3	10
7	Control group	6	9	Experimental group	7	14
8	Control group	7	9	Experimental group	6	15
9	Control group	4	5	Experimental group	4	10
10	Control group	3	6	Experimental group	8	15
11	Control group	5	9	Experimental group	3	10
12	Control group	8	11	Experimental group	2	10
13	Control group	7	9	Experimental group	7	15
14	Control group	4	8	Experimental group	8	15
15	Control group	7	9	Experimental group	2	10
16	Control group	8	12	Experimental group	5	12
17	Control group	7	10	Experimental group	3	11
18	Control group	2	6	Experimental group	1	9
19	Control group	3	6	Experimental group	2	9
20	Control group	5	8	Experimental group	7	15
21	Control group	7	10	Experimental group	4	11
22	Control group	6	9	Experimental group	5	13
23	Control group	6	4	Experimental group	3	12
24	Control group	1	5	Experimental group	2	12
25	—	—	—	Experimental group	8	16
26	—	—	—	Experimental group	4	12

Source: own