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| RESEARCH ARTICLE

Investigating the Effectiveness of Gamification Teaching Method on Self-directed Learning in Mathematics among High School Students of Herat City

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| ABSTRACT
Math education faces an ongoing challenge - many students struggle with fundamental concepts and lack the confidence to direct their own learning. Traditional teacher-centered approaches often leave learners dependent on instructors, hesitant to tackle difficult problems. Yet fostering independent, curious students who take ownership of their math education remains a critical goal. This study explored how gamification - using game elements in teaching - could help high school students develop self-directed math skills like planning, self-monitoring, and problem-solving. The study conducted on 194 tenth-grade high school students of Herat City, dividing them into experimental (gamification) and control (traditional teaching) groups. Over eight lessons, the experimental group learned challenging math concepts through gamified activities, while the control group received conventional instruction. Using a validated self-assessment questionnaire ($\alpha = 0.89$ overall), we measured four key skills: motivation, planning, self-monitoring, and communication. The results of the data analysis showed that teaching by gamification has an effect on promoting the independence and responsibility of students' learning in mathematics and on the three components of self-directed learning in mathematics. In other words, teaching by gamification had a positive effect on students' self-directed learning by creating a feeling of need to learn and accepting their role and responsibility in it. The study showed that teaching by gamification had a positive effect on the students' mathematical performance by increasing the level of interactive learning and creating independence in students. Teachers, authors of textbooks, planners, and educational experts can benefit from the results of this research to improve and modify educational methods.

| KEYWORDS

Teaching method, gamification, self-directed learning, Herat City.

| ARTICLE INFORMATION

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1. Introduction
Today, with the rapid advancement of technology and changes in techniques and sciences, how learners refer to learning methods and topics related to their learning is very important (Khakshour, 2020, p.127). One of the main challenges for individuals in the 21st century is to be able to learn from multiple sources (Takaendegan & Santosa, 2018). Learning in the 21st century focuses on cognitive skills and critical thinking. In addition to learning academic content, individuals must know how to continue learning, use their learning effectively, and develop thinking and learning skills, including critical thinking and problem-solving skills, communication skills, and creative skills for themselves (Arayathamsophon et al., 2020). Therefore, learners need appropriate learning skills such as self-directed learning skills (Takaendegan & Santosa, 2018). Self-directed learning is defined as a process by which individuals, with or without support, identify their learning needs, formulate learning goals, allocate human and financial resources for learning, select and implement appropriate learning strategies for the knowledge they need to learn, and evaluate their own learning outcomes (Sirakaya & Ozdemir, 2018, p.76-91).

In addition, self-directed learning is the increase in knowledge, skill, or performance that each individual pursues using anything at any time and place and takes the initiative to meet their learning needs without the help of others (Sokardjo & Salam, 2020, p.275).

According to definitions, self-directed learning focuses on the learner's independence in the learning process (Nazari, 2019, p.143).

In other words, self-directed learning is the awareness of individuals to acquire knowledge with or without the encouragement of others. Several components in self-directed learning are related to learning motivation, planning, execution, self-monitoring, and interpersonal communication (Nuri, 2019, p.44).

Learners who have self-directed learning skills are those who can design their own learning, so they put in their best effort and, since they are responsible for what they have determined, they do whatever is necessary to succeed and take responsibility for their learning process (Nuri, 2019, p.44).

People with high levels of self-directed learning are active in the learning process and have self-control; this means that these people have the necessary ability to carry out learning activities independently and the ability to analyze and plan for their learning activities.

Another characteristic of these people is self-management, and with this characteristic, they will be able to identify the needs of their learning and control their time and energy for learning.

Motivation and enthusiasm for learning and problem solving to achieve the best learning results are other characteristics of these people, because they are highly motivated to acquire knowledge and benefit from learning resources and strategies to solve problems that arise in the learning process (Nazari, 2019 & Vasheghani & Rostaminijad, 2021).

Promoting self-directed learning has become an important educational goal (Bohuis and Voeten, 2001, p.835). One of the main goals of any educational system is to develop independent learners who can be curious, creative, and capable of leading their own learning (Bishara, 2021, p.82).

Since educational goals are complex, students must be aware of how to manage their learning process independently (Baidowi et al., 2020, p.103).

2. Literature review

According to studies, self-directed learning skills in students are a major outcome of the learning approach and can improve the level of critical, analytical, logical, and problem-solving thinking.

Self-directed learning skills in students are not necessarily related to a specific domain; but various studies have shown a positive relationship between this skill and students' mathematical progress. According to research in this area, students with high self-directed learning skills perform better than other students in solving mathematical problems [12, 13]. Alotaibi & Alanazi have shown in their research that this skill can reduce the effect of the belief that mathematical concepts are scattered. In other words, it can increase the effect of the belief that mathematical concepts are coherent (Alotaibi & Alanazi, 2021, p.117).

Such an achievement is necessary to increase students' progress in mathematics, to change their perceptions of mathematics, which assume its concepts are scattered, and to understand mathematical concepts coherently. Self-directed learning skills allow students to use their creativity in understanding information (Alotaibi & Alanazi, 2021 & Nasir et al., 2020) and reduce their urgency and disinterest (Ntibi & Efiong, 2020, p.75).

On the other hand, it can increase students' self-confidence, independence, learning capacity to remember materials over a long period of time, motivation, and ability to transfer concepts, and develop lifelong learning skills in them (Shahmohammadi et al., 2020, p.77).

Also, a student with the characteristic of self-directed learning always strives to complete the tasks and assignments presented by the teacher and to do everything according to his/her abilities in a desirable manner and relies less on others (Yoesya et al., 2020, p.18).

Students' self-directed learning can be increased if efforts are made to create independent learning in students. These efforts should not always be made by other people to help students, but in fact should be created by students themselves. However, in some cases, students' self-direction is low, and they need a lot of help from others (Nuri, 2019, p.44). For example, in many cases, students are dependent on the teacher in mathematics lessons and have no desire or interest in solving challenging problems (Nazari, 2019, p.143).

Students' dependence on learning, especially in the field of mathematics education, hinders the understanding of concepts and affects students' problem-solving ability (Harini et al., 2023, p.150). Also, due to the nature of mathematics, students' communication skills are usually lower in mathematics and they need self-directed learning Ramadan & Satyaningrum, 2024, p.378). In this situation, the teacher plays a role as a facilitator to improve self-directed learning (Nuri, 2019, p.44).

Nowadays, the goal of education is not simply to transfer knowledge through traditional methods; rather, students should be able to acquire knowledge independently Bishara, 2021, p.82). One of the important goals of educators is to develop students' self-directed learning skills in mathematics Mann & Wilans, 2020, p.55). This creates independence for students in the mathematics classroom (Nazari, 2019, p.143). The teacher can prepare them for independent learning by providing abundant learning resources that students have access to everywhere (Takaendegan & Santosa, 2018) and also motivate students to develop this ability in themselves, because a student with higher motivation also has higher levels of self-directed learning skills.

In addition, the teacher can consider the appropriate learning methods in order to improve students' interpersonal communication skills Heo & Han, 2018 & Nuri, 2019).

Active teaching ensures that students are engaged in the activity and it has been observed that when the teacher asks questions, pays attention to students' answers and gives feedback, it motivates students to act and teaches them to participate (Bohuis and Voeten, 2001, p.835). One of the active teaching methods that can be used to improve self-directed learning skills is the use of gamification.

Gamification is an emerging approach to education to increase student motivation and engagement that can indirectly teach students academic and cultural concepts and skills in an engaging environment (Azizabadi et al., 2018, p.151).

Gamification does not simply mean playing games, but is a catch-all term for using game design elements in non-game contexts to create a playful environment that makes people feel good (Kaviyanifar et al., 2017 & Deterding et al., 2011).

Researchers believe that the main idea of gamification is to use simple game elements, such as points, medals, time, and other elements, to turn a boring task into a fun activity. Points are used to encourage people to do the task, and badges are visual representations of achievements that are achieved as a result of winning the game (Araya et al., 2019). Leaderboards also allow people to compare their progress with others (Werbach et al., 2012 & ABDI, 2020).

Research results show that teaching by using games enables students to solve problems better. For example, using this method in teaching mathematics, given that it creates interest in the teaching process, creates a happy environment, reduces students' stress, has a positive effect on their mathematical performance, and reduces their mathematical problems (Mirzai, 2017, p.76). In other words, gamification can be considered as one of the teaching and learning approaches that aims to promote participation and make teaching sessions more attractive for students (Yan et al., 2023, p.433). With this teaching method, students will have more enthusiasm for learning and remove the feeling of compulsion in learning from students (Salari, 2020, p.179). It also increases their interest and motivation in learning and encourages them to achieve better academic results (Lampropoulus, 2024, p.1-94). Gamification can provide students with quick feedback and allows them to identify their weaknesses (Jamil et al., 2023, p.43).

Also, teaching in the gamification method has a positive effect on students' self-directed learning by creating a sense of need to learn and accepting their role and responsibility in it (Salari, 2020 & Akhmadalieva, 2023). In addition, gamification can be implemented in all environments and with any facilities, because it can be used both with and without the use of technology (Salari, 2020, p.179).

The technological tool can be an interactive educational website, while the non-technological tools can include colored paper, pens, whiteboards, stickers, and score stamps. One of the advantages of using non-technological tools is that participants are more physically involved in the activity. They also make maximum effort to perform the activities and reach the correct answer (Zianuddin & Keumala, 2021, p.156).

The findings of the research by Mohd. Yusof & Shahrill (2021) show that learning with non-technological tools has a positive effect on students' progress. The benefits of using mixed media, that is, using technological and non-technological tools, should not be overlooked because it improves students' cognitive engagement (Qiao et al., 2022, p.394).

In fact, the media can create new and useful teaching opportunities and methods in education (Yan et al., 2023, p.433). Research has shown the effect of the gamification teaching method on self-directed learning. Yang & Chan used a gamification platform for mathematics lessons in their research to increase students' self-direction and mathematical abilities. In this study, 42 people volunteered to implement the gamification teaching method as mathematics teachers for third grade. The results of this study showed that the level of students' self-direction increased compared to before (Yang & Chan, 2022).

Palaniappan & Noor (2011) conducted a study to support gamification in self-directed learning in an online environment. The results of this study, which was conducted on 29 second-year undergraduate students, indicated the positive effect of gamification on increasing learners' self-directed learning. Lindberg (2011) investigated the effect of gamification on self-directed learning over 6 years of teaching with this method. This teaching method has been used since 2013. The results of this study showed that teaching with the help of gamification had an effect on three dimensions of self-directed learning, namely self-management, self-monitoring, and motivation.

In summary, self-directed learning is a process that encourages learners to identify their own learning goals and needs, and this approach allows them to use learning strategies to achieve their learning needs (Saberi, 2014, p.165).

Considering the importance of self-directed learning, especially mathematical self-directed learning, which is an effective factor in students' progress, independence, and motivation in learning, numerous international studies have been conducted in the field of self-directed learning and mathematical self-directed learning, in which they have presented various teaching methods to improve the level of self-directed learning and mathematical self-directed learning; however, little attention has been paid globally to the importance of teaching in a re-orientation style to improve the level of self-directed learning of individuals.

Another innovation of the present study is the implementation of gamification teaching in a hybrid manner, that is, using technological and non-technological tools. Hybrid gamification allows students to benefit from the potential benefits of both types of gamification and makes the learning experience more attractive for them (Qaio et al., 2022, p.394) and also, due to the use of non-technological tools, they have more physical mobility in carrying out educational activities. Due to the importance of awareness of the effects of using gamification teaching on mathematical self-direction and its components in education, especially mathematics education, it is necessary to conduct more research in this field. The present study aims to examine the effectiveness of using the teaching method on mathematical self-direction and its related components so that educational designers, curriculum planners, education experts, teachers, and other researchers in this field can use it and benefit from it to improve the mathematics education process.

Considering the importance of the role of self-directed learning in mathematics learning, the present study seeks to answer the question of whether teaching with a gamification approach has an effect on the components of mathematical self-directedness of tenth-grade high school students.

3. Research Method

To answer the research question, students' responses to each item of the 4-component Math Self-Direction Questionnaire were examined.

The present study aimed to investigate the effectiveness of teaching using the gamification method on students' math self-direction, which was conducted in a quasi-experimental manner with a pre-test and post-test design with a control group. The statistical population of the study was tenth-grade high school students of Herat city, and the statistical sample included 194 of these students, 96 of whom were taught some of the math concepts in the experimental group using gamification and 98 others in the control group using the conventional method. To collect data, the Math Self-Direction Questionnaire of Noori and Marsigite (Nuri, 2019, p.144), which included 15 items, was used, and it was based on the Shen et al. (2014) self-direction questionnaire.

Also, this questionnaire's items are divided into four factors, including learning motivation (items 1 to 5), planning and implementation (items 6 to 8), self-monitoring (items 9 to 12), and interpersonal communication (items 13 to 15).

Learning motivation is the component that every individual should have. Motivation is an effort by an individual to make certain choices, to engage in an activity and strive for it, and a stimulus to move an individual towards learning. Planning and implementation are the ability to independently determine learning goals and use appropriate strategies and useful learning resources to achieve learning goals.

Self-monitoring is the moment-to-moment awareness of an individual to maintain the skills and knowledge necessary to act in certain situations. In general, self-monitoring is the evaluation of an individual's behavior or the ability to evaluate and monitor learning results, which is referred to as knowledge at this stage. The student is presented with sentences related to awareness of weaknesses in learning and study of learning outcomes.

Interpersonal communication is the ability of students to interact with others to present their knowledge. In addition, interpersonal communication refers to the ability of a person to manage interpersonal relationships in a communication environment (Nuri, 2019, p.144).

In the study of Shen et al. (2014), to examine the reliability of the self-management questionnaire, the Cronbach's alpha value for all items of the questionnaire was 0.916 and the alpha value separately for each of the factors of learning motivation, planning and implementation, self-monitoring and interpersonal communication was reported to be 0.813, 0.825, 0.759 and 0.755, respectively.

In the present study, to examine the reliability, the questionnaire was administered to 30 tenth grade high school students prior to the experiment, and Cronbach's alpha was 0.892 for all items in the questionnaire, and for the factors of learning motivation, planning and implementation, self-monitoring, and interpersonal communication, these values were 0.846, 0.787, 0.735, and 0.704, respectively.

In the questionnaire used, students had to indicate their level of agreement with each item on a five-point Likert scale from "strongly agree" to "strongly disagree." The scoring method on the five-point Likert scale was as follows: "strongly agree" = 5, "agree" = 4, "neither agree nor disagree" = 3, "disagree" = 2, and "strongly disagree" = 1, and the questionnaire did not have a reverse item. In the process of administering the questionnaire, students were asked to read the items carefully and mark their desired option. A pre-test was first administered to both groups to measure students' mathematical self-direction level. Then, teaching was done using a gamification method in 8 sessions, The experimental group was taught one of the challenging mathematical concepts (trigonometric ratios) using a game-based teaching method, each session lasting approximately 60 minutes. The game-based teaching sessions were implemented in a combined manner, that is, with technological and non-technological tools.

In each session, students were given appropriate feedback, and in some cases, in addition to appropriate feedback based on the desired situation, a second opportunity was provided to solve the questions.

In the present study, to apply different elements of gamification, game-based PowerPoints and various scoring and timing methods were used, such as using the sounds of conventional bells in games, hourglasses, etc. In the control group, the same concepts were taught in the usual and conventional way. Finally, in order to compare and learn about the effect of game-based teaching on mathematical self-direction in the two groups, a post-test was implemented. The game-based teaching sessions for the experimental group are as follows:

First session: Reviewing the fourth module and playing a game to level up the questions, timing with a timer.

Second session: Teaching the topic of similarity and solving the textbook activity, with scoring wooden clips, timing with a timer.

Third session: Teaching the concept of the tangent of an angle, solving the book activity, scoring with spray bottles and stickers, timing using an hourglass.

Fourth session: Teaching the concept of the sine of an angle and solving related questions, scoring groups with paper money, timing using an hourglass.

Fifth Session: Teaching the concept of the cosine of an angle, solving the book activity using PowerPoints and interactive games.

Sixth session: Teaching the values of trigonometric ratios of angles and solving related questions, scoring with number labels, timing using an hourglass.

Seventh session: Reviewing the module and solving sample questions, scoring with colored papers, and ending the time to solve the question with the usual bells in games.

Eighth session: Second review of the module virtually and using PowerPoints and games organized on the student social network.

Figure 1 shows scoring systems using non-technological tools. For example, in the leveling envelopes, questions were placed according to each level, and the score of each question was equal to the number of the question level number. In the scoring of colored papers, the score value of each color was written on it, and, considering the level of the question, the groups were given the appropriate color. The score labels also ranged from 1 to 9 and were considered appropriate to the level of the questions. The bottles were also specified to each group, and students were given star stickers to stick on the bottles after providing the correct answer. Each piece of paper was also used as a point for the correct answer, like the colored papers; each piece of colored paper had a point appropriate to the question.

Figure 1: Scoring Method in Gamification.

Figure 2 shows one of the questions using PowerPoint software. The first figure from the left shows the question form with options for the answer. If the student chooses the correct option, he sees the second picture from the right, and the sound of applause is played and then moves on to the next question. Also, if the student answers incorrectly, he receives feedback like the third figure from the left to realize his mistake and is given another chance.

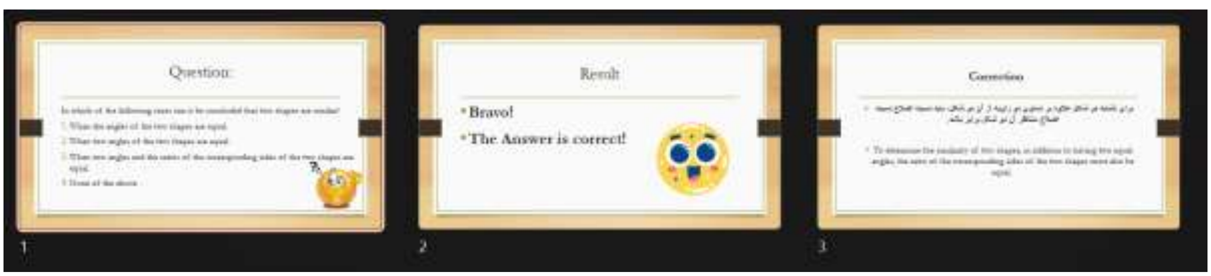

Figure 2: One of the questions using PowerPoint

Descriptive and inferential statistical methods were used to analyze the data using SPSS version 27 software. At the descriptive level, indicators such as mean and standard deviation were used, and at the inferential level, the multivariate analysis of covariances method was used.

4. Results

Table 1 shows the frequency, mean, and standard deviation of mathematical self-direction of students in the experimental group (n = 96) in each of the questionnaire items in the pre-test and post-test.

Table 1: Frequency, mean and standard deviation of the experimental group in the pre-test and post-test

Component	Item	Phase	Response Frequencies (n)					*M*	*SD*
			Strongly Agree (5)	Agree (4)	Undecided (3)	Disagree (2)	Strongly Disagree (1)		
1. Learning Motivation	1	Pre-test	7	18	33	17	21	2.72	1.21
		Post-test	15	19	28	15	19	2.96	1.34
	2	Pre-test	48	39	8	0	1	4.39	0.73
		Post-test	44	29	17	4	2	4.14	0.99
	3	Pre-test	24	31	30	5	6	3.65	1.11
		Post-test	30	29	28	6	3	3.8	1.05
	4	Pre-test	20	19	25	17	15	3.13	1.36
		Post-test	21	27	34	8	6	3.51	1.11
2. Planning & Implementation	5	Pre-test	8	15	39	21	13	2.83	1.11
		Post-test	12	17	38	14	15	2.97	1.21
	6	Pre-test	10	24	36	17	9	3.09	1.11
		Post-test	12	23	35	20	6	3.16	1.09
	7	Pre-test	8	32	33	17	6	3.2	1.03
		Post-test	17	24	38	12	5	3.38	1.08
	8	Pre-test	23	29	21	12	11	3.43	1.3
		Post-test	27	25	20	16	8	3.49	1.29
3. Self-Monitoring	9	Pre-test	8	24	31	17	16	2.91	1.2
		Post-test	15	17	38	13	13	3.08	1.22
	10	Pre-test	35	39	15	3	4	4.02	1.02
		Post-test	41	33	13	6	3	4.07	1.05
	11	Pre-test	25	26	38	5	2	3.7	0.99
		Post-test	26	37	21	8	4	3.76	1.07
	12	Pre-test	19	39	28	8	2	3.68	0.96
		Post-test	22	38	28	6	2	3.75	0.95
4. Interpersonal Communication	13	Pre-test	22	23	32	11	8	3.42	1.2

		Post-test	24	27	25	14	6	3.51	1.2
	14	Pre-test	29	19	19	14	15	3.34	1.44
		Post-test	32	19	23	15	7	3.56	1.3
	15	Pre-test	25	23	32	10	6	3.53	1.17
		Post-test	36	26	22	10	2	3.88	1.1

According to Table 1, the highest mathematical self-direction in the pre-test of the experimental group is related to items 2 and 10 with final means of 4.39 and 4.02 (standard deviations of 0.731 and 1.015, respectively). In the post-test, the highest mean of mathematical self-direction is related to these two items, namely items 2 and 10 with means of 4.14 and 4.07, (standard deviations of 0.991 and 1.049, respectively), indicating high mathematical self-direction of students when they hope to improve their learning results and are aware of their strengths and weaknesses, and these items have also increased in the post-test. The lowest mathematical self-direction in the pre-test is related to items 1 and 5 with final means of 2.72 and 2.83, (standard deviations of 1.211 and 1.111, respectively). The lowest mathematical self-direction in the post-test is related to these two items, namely items 1 and 5, with a final mean of 2.96 and 2.97, (standard deviations of 1.337 and 1.209, respectively), indicating that students have low mathematical self-direction when they are interested in studying mathematics even when they do not receive a good grade in this subject and do not give up learning mathematics if they encounter problems.

By comparing the frequency and means of mathematical self-direction of each item in the experimental group's pre-test and post-test in Table 1, the means of mathematical self-direction of the experimental group in the post-test for all items except item 2 is higher in the pre-test, but the frequency of responses in the option "Agree" of this item has increased. This increase can be attributed to the effect of the independent variable and teaching with the game-based method.

Table 2: Frequency, mean and standard deviation of the Control group in the pre-test and post-test

Component	**Item**	**Phase**	**Response Frequencies (n)**					***M***	***SD***
			Strongly Agree (5)	Agree (4)	Undecided (3)	Disagree (2)	Strongly Disagree (1)		
1. Learning Motivation	1	Pre-test	15	22	41	12	27	2.88	1.31
		Post-test	18	23	38	18	20	3.01	1.29
	2	Pre-test	46	48	21	2	0	4.18	0.78
		Post-test	30	50	28	6	3	3.84	0.96
	3	Pre-test	29	34	33	13	8	3.54	1.18
		Post-test	28	33	34	12	10	3.49	1.21
	4	Pre-test	21	26	34	17	19	3.11	1.32
		Post-test	17	25	37	21	17	3.03	1.25
	5	Pre-test	7	25	35	26	24	2.7	1.19
		Post-test	9	18	45	23	22	2.74	1.16
2. Planning & Implementation	6	Pre-test	9	17	50	22	19	2.79	1.12

		Post-test	6	23	42	25	21	2.73	1.13
	7	Pre-test	16	28	39	19	15	3.09	1.21
		Post-test	8	27	43	21	18	2.88	1.14
	8	Pre-test	10	29	36	29	13	2.95	1.14
		Post-test	15	24	34	24	20	2.91	1.27
	9	Pre-test	12	31	28	31	15	2.95	1.21
		Post-test	9	16	47	24	21	2.73	1.14
3. Self-Monitoring	10	Pre-test	31	53	23	6	4	3.86	0.98
		Post-test	20	46	28	15	8	3.47	1.13
	11	Pre-test	15	44	41	13	4	3.45	0.97
		Post-test	21	37	42	10	7	3.47	1.07
	12	Pre-test	15	38	44	16	4	3.38	0.99
		Post-test	16	29	51	15	6	3.29	1.03
	13	Pre-test	31	30	28	18	10	3.46	1.27
		Post-test	23	33	34	16	11	3.35	1.21
4. Interpersonal Communication	14	Pre-test	27	24	28	16	22	3.15	1.42
		Post-test	22	23	33	17	22	3.05	1.36
	15	Pre-test	25	23	32	10	6	3.39	1.32
		Post-test	30	24	34	11	18	3.32	1.36

According to Table 2, the highest mathematical self-direction in the post-test is also related to item 2 with a mean of 3.84 (standard deviation 0.956), indicating high mathematical self-direction of students when they hope to improve their learning outcomes. The lowest mathematical self-direction in the pre-test is related to item 5 with a mean of 2.70 (standard deviation 1.191). In the post-test, the lowest mathematical self-direction is related to items 5, 6, and 9 with final means of 2.74, 2.73, and 2.74, respectively. 2.73 (standard deviations are 1.163, 1.127, and 1.142, respectively). These items indicate students' low mathematical self-management when they encounter problems; but they do not give up learning mathematics, carry out the plans they have set for learning mathematics in any situation, and relate their new mathematical knowledge to personal experiences.

Table 3: Descriptive findings of the mathematical self-management components of the two control and experimental groups in the pre-test and post-test

Component	Level	Group	M	SD
1. Learning Motivation	Pre-test	Experimental	16.6	3.813
		Control	16.83	4.01
	Post-test	Experimental	17.17	4.229
		Control	16.5	4.238
2. Planning & Implementation	Pre-test	Experimental	9.66	2.436
		Control	9.05	2.641
	Post-test	Experimental	9.9	2.618
		Control	8.7	2.641
3. Self-Monitoring	Pre-test	Experimental	14.23	2.72
		Control	13.89	2.52
	Post-test	Experimental	14.5	3.185
		Control	13.15	2.94
4. Interpersonal Communication	Pre-test	Experimental	10.23	2.712
		Control	10.23	2.724
	Post-test	Experimental	10.82	2.492
		Control	10.04	2.872

Note. Experimental group *n* = 96; Control group *n* = 98. M = Mean, SD = Standard Deviation.

By comparing the frequency and mean of the mathematical self-direction of each item of the pre-test and post-test of the control group in Table 2, the mathematical self-direction of most participants in the control group was low. Table 3 shows the descriptive findings, including the mean and standard deviation of the mathematical self-direction components of the two control and experimental groups in the pre-test and post-test. As can be seen in the Table, the mean of the mathematical self-direction components of the experimental group is high in the post-test, while this is low in the control group. In the following, the multivariate analysis of covariance or MANCOVA test, has been used to examine the effectiveness of teaching in the reconstruction method. Before using multivariate analysis of covariance, its most important assumptions are examined, which are the normality of the data distribution, the similarity of the slopes of the regression lines, the equality of variances, and the homogeneity of the variance-covariance matrices, which are examined in the following. Table 4 shows the normality of the components in the two stages of pre-test and post-test using skewness and kurtosis. Based on the data in the Table, the data can be considered almost normal.

Table 5 shows the results of the homogeneity of the slopes of the regression lines between the components of mathematical self-direction at the factor levels (experimental and control groups).

Table 4: Skewness and kurtosis of math self-management components in pre-test and post-test

Component	Level	Group	Skewness	Kurtosis	Skewness SE	Kurtosis SE	Skewness Ratio	Kurtosis Ratio
1. Learning Motivation	Pre-test	Experimental	0.1	-0.61	0.25	0.49	0.39	-1.25
		Control	-0.41	-0.3	0.24	0.48	-1.66	-0.62
	Post-test	Experimental	-0.3	-0.37	0.25	0.49	-1.22	-0.76
		Control	-0.29	0.01	0.24	0.48	-1.17	0.02
2. Planning & Implementation	Pre-test	Experimental	0.01	-0.61	0.25	0.49	0.03	-1.48
		Control	0.04	-0.19	0.24	0.48	0.17	-0.38
	Post-test	Experimental	-0.14	0.02	0.25	0.49	-0.5	0.02
		Control	-0.4	-0.18	0.24	0.48	-1.61	-0.37
3. Self-	Pre-	Experimental	-0.02	0.33	0.25	0.49	-0.07	0.68

Monitoring	test	Control	-0.34	-0.22	0.24	0.48	-1.39	-0.5
	Post-test	Experimental	-0.38	0.19	0.25	0.49	-1.54	0.38
		Control	-0.37	0.18	0.24	0.48	-1.53	0.36
4. Interpersonal Communication	Pre-test	Experimental	-0.38	-0.39	0.25	0.49	-1.54	-0.78
		Control	-0.15	-0.88	0.24	0.48	-0.62	-1.82
	Post-test	Experimental	-0.13	-0.39	0.25	0.49	-0.51	-0.8
		Control	-0.15	-0.88	0.24	0.48	-0.62	-1.82

The table shows that the significance level for the interaction between group and the components of mathematical self-direction in the pre-test is greater than 0.05 and the data support the hypothesis of homogeneity of slopes of the regression lines, and this assumption was confirmed. Levine's test was used to examine the hypothesis of homogeneity of variances in the experimental and control groups. Results of Levene's test confirmed the homogeneity of variance assumption for all self-directed learning components: learning motivation (F[1,192] = 1.93, p = .166), planning & execution (F[1,192] = 0.21, p = .644), self-monitoring (F[1,192] = 0.07, p = .787), and interpersonal communication (F[1,192] = 1.20, p = .274). All p-values exceeded α = .05, indicating equal variances between groups and satisfying this key ANCOVA assumption.*

Table 5: Test of Homogeneity of Regression Slopes for Self-Directed Learning Components

Source of Variation	SS	df	MS	*F*	*p*
Learning Motivation × Group	3.469	1	3.469	0.4	0.528
Planning & Implementation × Group	1.458	1	1.458	0.352	0.554
Self-Monitoring × Group	0.748	1	0.748	0.123	0.727
Interpersonal Communication × Group	5.612	1	5.612	1.109	0.294

Note. SS = Sum of Squares; df = degrees of freedom; MS = Mean Square. All interaction terms represent Group × Pre-test score relationships. N = 194 (Experimental = 96, Control = 98).

Also the Box's M test of equality of covariance matrices yielded M = 8.38, F(10, 176069) = 0.82, p = .819, indicating no significant violation of the homogeneity assumption (α = .05). This satisfies the MANCOVA assumption of equal variance-covariance matrices across groups. *

Table 6: Multivariate Analysis of Covariance for Gamification Teaching Effects on Self-Directed Learning Components

Effect	Test	Value	*F*	Hypothesis df	Error df	*p*	Partial η^2	Power
Group	Pillai's Trace	0.068	3.361	4	185	0.011	0.068	0.84
	Wilks' Lambda	0.932	3.361	4	185	0.011	0.068	0.84
	Hotelling's Trace	0.073	3.361	4	185	0.011	0.068	0.84
	Roy's Largest Root	0.073	3.361	4	185	0.011	0.068	0.84

Note. MANCOVA = Multivariate Analysis of Covariance. Analysis controlled for pre-test scores. Partial η^2 effect size interpretation: .01 = small, .06 = medium, .14 = large (Cohen, 1988). Power computed with α = .05.

Considering the establishment of the main assumptions of multivariate analysis of covariance, the use of this test to investigate the purpose of the research is confirmed. The results of the multivariate analysis of covariance test for the effect of re-education training on the components of mathematical self-directed learning are shown in Table 6. It can be seen that by controlling the pre-test, the significance level for all tests (Pillai's trace, Wilks' lambda, Hotelling's trace, and Roy's largest root) is less than 0.05, which indicates the existence of a significant difference between the control and experimental groups in at least one of the components of mathematical self-management (learning motivation, planning and execution, self-monitoring, and interpersonal communication). To find out which of the components of mathematical self-direction differed between the control and experimental groups, four univariate analyses of covariance were conducted within the multivariate analysis of covariance. The results are presented in Table 7.

Table 7: Univariate Analysis of Covariance for Self-Directed Learning Components

Component	Source	SS	df	MS	*F*	*p*	Partial η^2	Power
1. Learning Motivation	Group	22.6	1	22.6	2.65	0.105	0.014	0.37
	Error	1604.41	188	8.53				
2. Planning & Implementation	Group	38.9	1	38.9	9.52**	0.002	0.048	0.87
	Error	767.92	188	4.09				
3. Self-Monitoring	Group	61.63	1	61.63	10.25**	0.002	0.052	0.89
	Error	1130.7	188	6.01				
4. Interpersonal Communication	Group	27.97	1	27.97	5.60*	0.019	0.029	0.65
	Error	940.26	188	5				

Note. SS = Sum of Squares; MS = Mean Square. Analyses control for pre-test scores.

p < .05, **p* < .01. Partial η^2 interpretation: .01 = small, .06 = medium, .14 = large (Cohen, 1988).

Power computed with $\alpha = .05$. Experimental group *n* = 96; Control group *n* = 98.

As can be seen in the Table, the significance level for the components of planning and implementation, self-monitoring, and interpersonal communication is less than 0.05. Therefore, the effect of teaching through the gamification method on these three components of mathematical self-direction is confirmed, but it was not confirmed on the component of learning motivation.

5. Discussion and Conclusion

In the present study, combined methods, namely technological and non-technological gamifications, were used to examine the effect of the gamification teaching method on mathematical self-directed learning. The results of the present study showed that the average of mathematical self-direction in the three components of planning and execution, self-monitoring, and interpersonal communication of the students in the experimental group was significantly higher than the average of the control group in the post-test, indicating that teaching in the gamification method significantly increases these three components of mathematical self-direction skills. In fact, based on the results of the study, it can be concluded that teaching in the gamification method has a significant effect on the components of mathematical self-direction, except for the component of students' learning motivation, compared to the traditional method. In other words, the difference in the average of the experimental and control groups in these three components was significant, but not in the component of learning motivation. The results of limited studies (Yang & Chan, 2022 & Lindbberg, 2019) also show that the game-based teaching method has an effect on learners' self-direction and are consistent with the results of the present study. For example, the results of Yang & Chan's (2022) indicated that game-based teaching in mathematics increases students' self-direction. Also, the results of Lindberg's research state that gamification has an impact on three components of self-directed learning, namely self-management, self-monitoring, and motivation (Lindberg, 2019). Palaniappan & Noor (2022) found that gamification has a positive effect on increasing learners' self-directed learning. In the present study, one of the important observations during teaching the experimental group using gamification was that students volunteered to solve exercises and explain to their classmates using the blackboard. Before using gamification in teaching, students used to solve math problems by depending on the math teacher and did not feel responsible for solving the questions.

The present study's findings can have scientific and practical implications for the educational system. Firstly, teachers can use the gamification method in their teaching to increase students' self-direction, because gamification plays an important role in students' interest and self-directed learning.

In addition, school administrators should provide the necessary facilities and equipment to implement gamification to increase students' self-directed learning, so that there is no shortage of facilities in schools.

Furthermore, Schools should organize workshops and training courses to help teachers learn about new methods—like gamification—that support students' self-directed learning. Textbook authors can also contribute by including gamified activities in practice sections to make learning more engaging and student-centered.

Ultimately, gamification has been shown to increase students' motivation and independence in math class, encouraging them to participate more actively. Teachers and educators can use this approach to create a more dynamic classroom environment, moving away from traditional passive learning and fostering greater responsibility in students.

However, while gamification offers opportunities for active learning, it must be implemented thoughtfully. Without proper planning, its benefits may be limited. By deepening their understanding of gamification techniques, teachers can maximize student engagement and create a more interactive, motivating learning experience.

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