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The effects of robotics training on students' creativity and learning in physics

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Abstract
The ever-increasing advances in technology have made it necessary to make use of new educational methods in educational systems. Therefore, in this study, the effects of robotics training on students' creativity and learning physics were investigated. The research design was pretest posttest quasi-experimental, including one control and one treatment groups. The participants of the study included 120 males and females from 11th grade, studying at different schools in Tehran, Iran (members of the robotic schools training plan) in the educational year 2016–17. They were selected and studied through multistage random cluster sampling. After an eight-session treatment period, the data were collected through employing the Torrance Creativity Questionnaire (1979) including four dimensions namely fluidity, flexibility, innovation, and detailed explanation in the format of 60 items, a test of 10 learning points, and a package of training on robotic constructs in physics. For data analysis, Covariance analysis was employed. The findings indicated that Robotics training influenced and improved creativity and learning in physics among the participants.

Keywords Robotics training · Creativity · Learning · Students · Physics

1 Introduction

The use of educational technology in teaching-learning processes has become an important topic in the field of education around the world. E-learning, as the most prominent use of information communication technology (ICT), has added a new dimension to the charter of education at basic and advanced levels (Alinezhad 2014; Sangrà et al. 2011; Conole 2010). Modern technologies play important roles in students' acquisition of skills, knowledge, and motivation to learn (Najafi et al.

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2016). Our current educational system strives to use technology to improve quality of education so that it could foster people with creative thinking and analyze the problems they are experiencing and overcome these problems by using creative ideas (Karami et al. 2014). One of these technologies is robotics, which today has revolutionized the world. Robotics can be an entertaining platform to learn about computers, electronics, mechanical engineering, and languages (Mubin et al. 2013). It has been shown (Han et al. 2008) that young children perform better on post-learning examinations and generate more interest when language learning take place with the help of a robot as compared to the employment of audiotapes and books in the learning process.

The positive effect, to a large extent, is gained from the “embodiment” and physical presence of robots which make the outcomes of programming very vivid and immediately accessible, providing a continual formative assessment of learning progress and encouragement for students. Following these ideas, some institutions in developing countries have recently made some efforts to make new efforts by introducing theoretical and presentation-based lecturing and robotic activities to improve the quality of teaching and learning (Mills-Tettey et al. 2007).

Robotics involves designing, constructing, launching, and using robots. The world of robotics is very diverse and widespread, resulting in satisfying the curiosity and diversity-seeking tendencies of adolescent students (Bouvier and Connors 2011). Today, there are many suggestions for using robotic systems in training at schools, because training by robotics creates an active and interactive learning environment which emphasizes learners’ participation; therefore, the use of robotic training technology in school curriculum can enrich the achievement of the specified educational goals through introducing innovative and modernized training. (Frangou et al. 2008).

Robotics, due to its interdisciplinary nature, is an attractive approach to education as it requires expertise in mathematics and aesthetics. Mathematics reinforces students’ problem-solving thinking and creative thinking; therefore, it can be argued that robotics is effective for students’ problem-solving thinking and creativity (Lough and Fett 2002). The tendency to employ technological advances in education, especially in robotics-mediated education, is still rare. The main reasons for little use of technology in the educational system are as follows: Lack of technology-based educational thinking, inappropriateness of physical structure of schools for running robotics training workshops, inability to design and produce robotic particles in the country, and the high amount of cost required to apply such an educational approach in schools.

According to Kerr and Gagliardi (2006), creativity is the creation of new ideas and innovative products, and it is considered as one of the cognitive characteristics of mankind. They consider creativity as a process that leads to problem solving, creating ideas, conceptualizing, making art forms, theorizing, and producing of unique products (Azimpoor et al. 2017). In general, creativity is a process which develops over time, and its prominent features are innovation, adaptability, and fulfillment which can help one to find solutions to problems. One of the factors associated with creativity is intelligence (Kazemi Haghighi 2016). According to the surveys, although it is necessary to have a certain level of intelligence, it is not enough. Furthermore, intelligent people are not necessarily creative, while those with average intelligence can be prominently creative people. In fact, creativity is more acquisitive and can be enhanced by effective training (Ghorbanlu 2015).

Highly creative people have an informal and friendly character, and due to their curiosity, they possess high motivation, broad knowledge, high confidence, and high-risk taking tendencies (Mogi and Tokoro 2014). Some of the factors contributing to low creativity are the ability to restrict one's thinking and curiosity, relying too much on gender, emphasizing highly on prevention, instilling fear and shyness, and emphasizing on the verbal skills (Hoseini 2015). There are a lot of factors affecting creativity such as motivations and some tools (Sirt and Lamimen 2017).

Iiori and Watchorn (2016) argued that robotics training affects students' learning, which is a relatively stable change in behavior resulting from experience (Kadivar 2015). Experts believe that childhood education and learning should be based on active participation in the learning process (workgroup and social interaction) (Arghiani et al. 2017). In terms of neuroscience, learning occurs due to the formation of neural links existing in the brain (Kharazi 2006). One of the factors influencing learning is the learning environment which consequently impacts learners' practices, participation, collaboration and social communication (Arghiani et al. 2017).

The Robotic Autonomy Mobile Robotics Course: Robot Design, Curriculum Design and Educational Assessment, it has been concluded that the positive impact of robotics on student learning is further the scope of specific technical concepts in robotics (Nourbakhsh et al, 2005). In another study carried out by Robinson (2005), entitled "robotic activities: can LEGO-based Robotics in Higher Education: 15 Years of Student Creativity" concluded that by combining a modular computer programming language with a modular building platform, LEGO Education has allowed students (of all ages) to become active leaders in their own education as they build everything from animals to robots for a robotic zoo that play children's games. Most importantly, it allows all students to interact in order to find different solutions to the same problem as a learning community. In this article, we look first at how the recent developments in the learning sciences can help in promoting student learning in robotics. We then report four case studies of successful college-level implementations that build on these developments.

In this regard, Karahoca et al. (2011), in a study aiming at examining the effects of robotics training on elementary teaching with project-based training to support science and technology courses, concluded that robotics training have a positive effect on academic performance and relationships between students and their friends in class.

Alternatively, Barreto and Benitti (2012) systematically examined the potentials of robotics at schools. Based on the related literature they concluded that instructional robotics is usually the element that improves learning. By the same token, Bredenfeld et al. (2010) inquired into the effects of robotics on educational inventions in the Europe –situation, shortcomings and open questions. They concluded that robotics training should be stronger, more serious, and more stable in European educational systems. In another study, Alemi et al. (2016), examining the effects of assistant social robots in English language classes in Iranian schools, concluded that the combination of simultaneous training by humans and robots as teacher assistants is an intelligent interaction which improves language learning. Quite on par with these studies, Cejka et al. (2006) investigated the robotic effects on students' motivation in mathematics, science, and technical literacy in an elementary school. It was concluded that robotics affects learning motivation, technical literacy, and solving mathematical problems. Moreover, Tetty et al. (2007) concluded that small robotics systems are effective in developing students' technical creativity. Cavas et al. (2012), examining the effect of robotics on students' performance in the science process, scientific creativity skills, humans and society concluded that training courses using robotics are effective for improvong students' scientific creativity as well as on the social relationships of students with each other and with the society (Cavas et al. 2012).

According to the studies, it can be stated that robotics is one of the factors affecting students' training and learning because robotics has diversified the educational environment and satisfied students' curiosity. In addition, robotics leads to simultaneous involvement of mental, intellectual, and physical faculties of students and their interactions with each other. Furthermore, it forms the basis for making use of different parts of the body and their development. Therefore, it is highly important to study whether robotics can really bring any fundamental changes to the educational system or not. Because of this, the objective of this survey is to study the effects of robotics training on students' learning and creativity in physics. To this aim, the following hypotheses are evaluated:

1. Robotic training has no effects on the creativity of the 11th grade students in physics.
2. Robotic training has no effects on the learning of the 11th grade students in physics.

2 Methodology

The present study is an applied survey which is quantitative. In this study, a pretest posttest quasi-experimental design was used because it was not possible to control or manipulate variables completely. The statistical population of the survey included all 11th grade male and female students in 40 schools in Tehran, capital of Iran, in the educational year 2016–17; these schools were members of the robotics training plan. The sample was chosen thorugh cluster sampling strategy, thus the educational districts of Tehran were divided into 5 geographic regions: north, south, central, east, and west, and from the whole geographical area, one educational district was randomly selected. Then, 6 high schools with active robotics workshops, in which physics was taught, were randomly selected. Finally, out of the girls' schools, the 11th grade classes of Abu Ali Sinai School, Rabbani, Farzanegan, and Salam-Zeinaldin schools were randomly selected, and out of the boys' schools, Rah-e Roshd and Allameh Helli were randomly selected to conduct the research. The robotics students of the six schools (three girls' schools and three boys' schools) were 173 individuals out of which 120 students were randomly selected (60 male and 60 female) and were divided into two experimental and control groups.

3 Research tools

Students' creativity was measured using the Torrance Creativity Questionnaire (1979) which included four dimensions of fluidity, flexibility, innovation, and detailed explanations in 60 items in the format of 3 options Likert scale. The questionnaire was developed and validated by Torrance (1979) and it enjoyed good psychometric properties. According to Abedy, the total validity of the test was 27%, while the validity of fluidity was 9%, that of flexibility was 13%, that of innovation was 15% and finally, that of explanation dimension was 24%. The achieved coefficients are significant at the level of 5% (Abedy 1993). The reliability of the questionnaire was achieved.96 by the use of Cronbach's alpha, which indicates the high reliability of the questionnaire. The scores gained from answering the questionnaire could range from 60 to 180. The higher the respondents scores on the questionnaire, the higher their level of creativity is. Furthermore, a 10-item test was used to measure students' learning. The validity of the test was verified by two examiners and one teacher with experience in teaching physics. The average difficulty and severity of the questions were 92.69 and 91.73 respectively, which indicated an appropriate difficulty index and discrimination index for items.

Research tools included a package of training for robotic structures, including a complete package of tools and instruments to build a rescuer robot and in 8 sessions, students were trained to use these tools to build a rescuer robot. The validity of this training package was verified by technical experts at the Education Department and its reliability was evaluated as appropriate by the supervision of experts from the Ministry of Education.

4 Implementation method

In order to run the test and make the control and experimental groups equal, each one of the two groups of male and female students, which included 60 members, were equally divided into two groups of 30 students according to their marks in their school marks cards. One group was determined as the control group and the other group as the Experimental group. Therefore, two control groups ($N = 30$ for each) and two experimental groups (N = 30 for each) were formed. In addition, the physics teacher of all these groups was the same person. Then, the control groups were taught chapter 1 of the 11th grade Physics book entitled "Static electricity" from page 2 to 23, by the use of traditional teaching methods. The treatment groups, on the other hand, were taught the same chapter by robotics specialists with bachelor's degrees in Electronics from University of Tehran who also had certificates of Advanced Programming, Microcontrollers, ARM, AVR, Altium Designer Circuit, and Circuit Designing by FPGA from Tehran Technical Complex. The materials were taught by a physics teacher (common in all four groups) accompanying a robotics teacher for the treatment groups. Each session of the class lasted for 50 min. Every session, after presentation of the materials theoretically, discussions were conducted by giving applied examples, and the students were trained by the robotics teacher in presence of the physics teacher to build robots according to the textbook contents. The students also built robots in cooperation with each other and by the use of their knowledge from the physics classes during the eight sessions. The order of the sessions was as follows (Table 1):

After the end of the eighth session, when the training for building robots was completed, students were given the Torrance Creativity questionnaire for measuring their creativity and learning level. They completed the questionnaire items in 80 min. Also, the control group, which had been trained in physics for eight sessions by the use of traditional teaching methods, filled out the Torrance Creativity scale and the level of learning test for 80 min at the end of the eighth session. After the completion of the tests by both control

Table 1 Operational Stages of Training in the Physics for the Electricity Class

Activity	Training subject	Media and training tools	Training method	Training by the use of robot in the physics class
First session	Condenser- condenser capacity	Condenser-connection cable-multimeter	Closing the circuit and calculation of the condenser capacity by multimeter	General acquaintance with rescuer robot-remembering the learned subjects – introduction to physical components of rescuer robots
Second session	Electrical breakdown- condenser energy	Smart board – animation	By the use of animation, we observe electrical breakdown	Building the initial component (building the circuit) of rescuer robot
Third session	Electrical circuit – the law of ohm	Cable – battery – resistance – ammeter - voltammeter	Closing resistance and measuring resistance of the object	Building sensors of rescuer robot
Fourth session	The effect of temperature on resistance and linking the resistances to each other	Cable – battery – resistance – ammeter – voltammeter - lamp	Doing the experiment on the circuit	Testing the rescuer robot
Fifth session	Magnet – magnetic field	Magnet – paper – magnet filing	By doing the test, we observe the magnetic field through the test	Finalization of building the rescuer robot
Sixth session	Magnetic field of the straight cable, solenoid and coil	Using animations on the website	Using animations on the website and giving explanations during teaching	elevating the performance of the rescuer robot
Seventh session	Magnetic features of paramagnetic objects-paramagnetic objects- paramagnetic objects	Slides and pictures from molecular and atomic view	Explanations on the pictures	Elevating the performance of the robot
Eighth session	The phenomenon of electromagnetic induction and the law of lens	Solenoid- magnet, galvanometer	We study the law of lens and electromagnetic induction by the use of lab tools	Controlling and final testing of the rescuer robot
After the last session	posttest	Researcher-made test	Conducting the test	

Table 2 Descriptive statistics for the research variables before and after robotics training

Groups Variables		Means before instruction		Means after instruction	
		Mean	SD	Mean	SD
Creativity	Experimental	48.2	29.	4	.31
	Control	10.2	30.0	19.3	88.
Learning	Experimental	15.18	71.1	53.19	76.0
	Control	61.16	93.1	48.16	36.2

and treatment groups, in order to analyze the data, independent paired samples t-test and multivariate covariant (ANCOVA) measures were used.

5 Findings

From the selected sample of the study, 60 (50%) participants were placed in the control group and 60 (50%) participants were placed in the experimental group. The age of 27% of the participants were 14, 41% of them were 15, and 32% were 16. In Table 2, descriptive statics related to the variables of the study are classified according to the groups of the study:

According to Table 1, Mean and Standard deviation of the students' learning and creativity in the robotics-based classroom was higher in comparison to their Mean and Standard deviation scores before instruction. In order to answer research hypothesis of the study, ANOVA was employed. The assumptions of ANOVA are mentioned in the following sections.

5.1 Examining ANOVA assumptions in order to implement ANOVA

1. Normality of the data

According to Table 3, in this test, all p values for all the research variables are larger than .05. Considering the value of p and being unable to reject the null hypothesis, data distribution was found to be normal. As a result, for research hypothesis testing, parametric tests were utilized.

Table 3 Results of Normality of the Research Variables

	One-Sample Kolmogorov-Smirnov Test			
	Creativity (pre-test)	Creativity (post-test)	Learning (pre-test)	Learning (post-test)
Kolmogorov-Smirnov Z	.832	1.034	.801	.752
Asymp. Sig. (2-tailed)	.481	.231	.456	.512

a. Test distribution is Normal

2. Equivalence of ANOVA assumptions

Statistical index	F	df1	df2	Sig.
learning	002/0	1	118	96/0
creativity	13/0	1	118	71/0

According to Table 3, the obtained F was not significant. Therefore, variances are equal and the employment of Covariance is possible.

3. The existence of homogeneity hypothesis (regression) (Table 4)

According to the data in the above table, the bidirectional effect between pre-test and the group is not significant.

1. Hypothesis 1: Robotic training has no effects on the creativity of the 11th grade students in physics (Table 5).

Table 4 Results of regression analysis for homogeneity hypothesis, regression slopes of learning and creativity variables in the experimental groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Group learning effect	34/38	1	34/38	18/1	28/0
Group creativity effect	24/831	26	97/31	45/2	12/0

Table 5 Summary of ANCOVA results for creativity in control and experimental groups while excluding the bidirectional effect

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Pre-test	18.690	1	18.690	66.884	.000	.364
group	1.834	1	1.834	6.564	.012	.553
Error	32.694	117	.279			
Total	1624.154	120				
Corrected Total	70.873	119				

As can be seen in the above table, (F (1, 120) = 6/56, p = 0/012, Eta = 0/55) shows that there is a significant difference between the two groups. In other words, there exists a significant difference between the experimental and control groups' creativity post-tests. The effect is equal to .55 which means that 55% of improvement of creativity in the experimental group can be ascribed to the effect of robotics-based instruction. Consequently, based on the results it can be inferred that robotic-based instruction could influence creativity level of the 11th grade level students.

Pairwise Comparisons

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	95% Confidence Interval for Difference[a]	
experimental	control	.295*	.115	Lower Bound	Upper Bound
				.012	.067
Control	experimental	−.295*	.115	.012	−.522

The mean difference at the .05 level

5.2 Adjustment for multiple comparisons: Bonferroni

The results of Bonferroni analysis indicated that there is a significant difference between creativity of the students in the control and experimental groups after robotic-based instruction ($p < 0/05$).

2. Hypothesis 2: Robotic training has no effects on the learning of the 11th grade students in physics.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Pre-test	173.611	1	173.611	105.626	.000	.474
group	133.896	1	133.896	81.463	.000	.410
Error	192.306	117	1.644			
Total	39561.000	120				
Corrected Total	644.992	119				

a. R Squared = 702 (Adjusted R Squared = 697)

Table 6 Balanced means for the research groups and standard error and lower and upper bounds

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
experimental	control	2.232*	.247	.000	Lower Bound	Upper Bound
					1.742	2.721
Control	experimental	2.232*	.247	.000	−2.721	−1.742

The mean difference is significant at the .05 level

As can be seen in the above table, (F (1, 120) = 81/46, p = 0/000, Eta = 0/41) shows that there is a difference between the two groups. In other words, between the two groups of experiment and control exists a significant difference. The effect is equal to .41 meaning that .41% of the improvement of the experimental group can be ascribed to robotic-based instruction. Therefore, based on the results, it can be mentioned that robotic-based instruction influences learning of the 11th grade students in physics (Table 6).

6 Discussion and conclusion

The importance and productivity of teaching approaches and learning methods have always been considered by researchers of educational sciences. Teaching methods are effective for students' educational progress, creating motivation and satisfaction, personality development and improvement of their creativity. Teachers' duty in the teaching process is not only transferring knowledge to students, but also providing opportunities and appropriate conditions for learning, and teaching the students how to think and learn. The educational systems make efforts to create and employ innovative educational methods which can lead to the enhancement of creativity in students. Moreover, educational teaching and learning methods are directly connected to learners' development of creativity (Rahimimand and Abbaspour 2015).

In this regard, the objective of this study was to investigate the effect of robotics training on students' creativity and learning physics. The findings of the study showed that there is a significant and direct relationship between robotics training and creativity of the 11th grade students in physics. In this way, by increasing the use of robotics training, students' creativity increased. The findings of the present study were consistent with those of Cavas et al. (2012). Considering that in the robotics training-based method, students need to work together and collaborate with each other, this group activity enhances the development of creativity in the students. Additionally, group work enhanced creative thinking skills in the students and led to better learning, concentration, and recall of learning. Besides, it increased accuracy and creativity in solving various problems (Halpern 2008). The results showed that robotics training significantly influenced the students' learning and creativity in physics classes.

According to the findings, 0.55% improvement in creativity and 0.41% improvement in students' learning in the experimental group can be attributed to the impact of robotics education. Also, the findings of the study showed that there is a direct relationship between robotics training and students' creativity dimensions. That is, by increasing the use of robotics training, the amount of fluidity, flexibility, innovation and detailed explanation of the students increase.

Due to the high level of verbal communication between students in robotics training, students will learn leadership skills, social participation, communication in different platforms and media, identification of their own feelings and interests, and how to do group work. Students also need to study structures of different dimensions of robotics, which will increase their flexibility. In robotics training, students creatively use their thoughts in order to create a new robot, which increases their ingenuity, and since in robotics training, precision and sharpness are of great importance, the element of expansion with details of creativity concept will be strengthened in students. Studying robotics during students' education will increase levels of creativity and provoke new ideas. Robotics is an example of learning based on production. Students have the opportunity to make something that is touchable based on what they are supposed to do. Robotics teaches students how to turn disappointment into innovation. Through robotics training, students are capacitated to solve more difficult problems. Robotics training not only teaches students how to solve problems, but it also helps them to increase their intellectual ability, prepare themselves for future job opportunities, and provide students with teamwork and group collaboration. Furthermore, the research findings showed that there is no difference between the effect of robotics training on the creativity of male and female students, which means that the gender of students does not affect the level of the effectiveness of robotics training on their creativity, and robotics training has the same effect on the creativity of male and female students.

Teaching robotic structures helps students increase their attention and therefore links physics lessons to their real life issues, helps them actively participate in learning, uses visual methods, uses organizers, creates coordination between concepts, helps them repeat and practice, explains materials and discuss, makes the materials meaningful for students, applies effective ultra-conceptive strategies, and in this way, helps them learn the physics materials better.

The present study had some limitations which are as follows: the need for laptops with high capabilities and increase of internet bandwidth, inaccessibility of scientific resources, filtering, parents' lack of awareness of the importance of certificates of robotic tournaments, geographical and educational limitations, training costs for advanced workshop equipment, and unavailability of the original software.

Therefore, it is suggested that the subject of robotics is to be included in the curriculum of students in order to improve their skills of problem solving and creativity. There should be opportunities for students in their curriculum so that they can achieve the sense of qualification in problem-solving and start building robotic structures together in small and big groups. In this way, their problem-solving and creativity can be improved. Moreover, robotics workshops should be started in schools and with the help of robotics teaching centers, and robotics classes should be held in schools. Professional and experienced robotics instructors and also robotics engineers and experts should be used to hold and organize robotics classes in primary and secondary schools.

Encouragement style sheets should be provided for students who win robotics competitions, and ultimately, other researchers are suggested to do this study in other educational levels including elementary schools, and also do comparative studies to take advantage of the experiences of other countries on the effects of robotics on learning skills and students' creativity..

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