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Research Paper

Investigating the Effect of a Researcher-Made Educational Simulation Software for Science on the Learning and Academic Achievement Motivation of Sixth Grade Students in Smart Schools of Tehran

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Abstract
The purpose of this study is to examine the effect of a researcher-made educational simulation software for science on the learning and academic achievement motivation of sixth-grade students in smart schools in Tehran. This research, in terms of its nature, subject, objectives, and hypotheses, is applied in type and falls under the category of quasi-experimental designs. The statistical population of the study consisted of all sixth-grade male students in smart schools of Tehran who were studying during the 2023–2024 academic year. For sampling, Nezam Mafi Smart Elementary School was selected using a purposive sampling method. The dependent variables of this research were learning and academic achievement motivation, which were measured using the relevant tests for each variable. The instruments of the study included: (1) a researcher-made science learning test for sixth grade, and (2) Hermans' academic achievement motivation questionnaire. The validity of the learning test was confirmed by the supervisors, advisors, and experienced science teachers, and the validity of the academic achievement motivation questionnaire was also approved by supervisors, advisors, and experts in the field. The reliability coefficient of the learning test was calculated using the Kuder–Richardson method and was 0.75, and the reliability coefficient of the academic achievement motivation questionnaire, calculated using Cronbach's alpha, was 0.84. The data obtained from these tests were analyzed using analysis of covariance (ANCOVA) with SPSS software. The findings indicated that the learning and academic achievement motivation of students who were taught using the educational simulation software were significantly higher at the 95% confidence level than those who were taught using the traditional school method.

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Introduction

In the current era, the accelerating pace of transformations in various aspects of human life has brought about profound changes in the realm of existence and intellectual scope. These transformations, which are global and transnational in nature, have placed educational institutions and their teaching and learning strategies in the face of major challenges (Chahardah Masoumi, Azhdari, Karbasian, & Shahbazi, 2024). The survival of educational systems is no longer feasible through traditional instruction, reliance on textbook content, viewing students as passive recipients, and considering the teacher as the central axis of the teaching process in this rapidly changing world (Assadisharif, Rezaei, Adib, & Kamran, 2024).

Over the past three decades, several fundamental changes have taken place in the education systems of various countries. These changes can be categorized into three main groups: (1) active, participatory, learner-centered, and process-oriented teaching and learning; (2) integration of information technology into the teaching and learning process; and (3) emphasis on global skill training and contextual awareness (Estakhrian Haghighi, 2019). Given the extent of these changes, merely filling students' minds with information in schools is no longer sufficient and can never adequately prepare them for real life outside the classroom. Therefore, educators and teachers should focus not just on imparting various types of knowledge, but also on methods and strategies of teaching and learning (Mosalanejad, Rayatdost, Abiri, & Bahrebar, 2024). Teachers need to adopt an open and progressive mindset, be willing to experiment with diverse approaches, and remain receptive to new insights about learning and learners. Teachers must shift away from traditional roles and evolve into what Carl Rogers calls a "facilitator of learning" and what Keller refers to as an "instructional engineer" or "contingency manager" (Amerstorfer & Freiin von Münster-Kistner, 2021). As previously noted, entering the realm of modern educational management reveals that technology has affected all aspects of human life, and education is no exception. The digital world and emerging technologies provide a fertile ground for collaborative, learner-centered, and skill-based learning (Golzar Aziz, Khoshneshin, Mahdavinasab, & Rajabi, 2024). Educational experts and instructional technologists believe that in order to achieve diverse curricular goals, it is essential to make the most of modern teaching methods and media. Educational e-content (such as software and multimedia materials) represents just one of the tools that can be easily developed and produced using computers (Besalti & Smith, 2024). Among the various types of e-content that significantly enhance learning and retention thereby improving educational quality are simulation programs (Zolfaghari, Abasi, & Pourfakhr, 2021). One example of educational technology in the instructional process is the use of simulations of scientific events and phenomena. Today, the use of simulations in teaching subjects such as medical sciences, biology, physics, mathematics, astronomy, and geology has grown considerably (Vasefian, 2019). Simulation is a representation of real devices or work situations that attempts to replicate certain behavioral aspects of a physical or abstract system through the behavior of another system. Using a simulator in a constructed situation allows for the recreation of realistic outcomes in hypothetical conditions (Nyström & Ahn, 2024). Educational simulation software provides learners with an environment that closely resembles reality but without the associated costs and risks of actual exposure. This makes them highly effective for instructional use (Elendu et al., 2024). Teaching with simulations has captured the attention of educators and learners alike due to its ability to deepen scientific knowledge and understanding (Richardson & Long, 2003). Today's world requires students who take an active role in their own learning process and are trained in ways that empower them to manage real-life problems and environmental or social challenges by adopting appropriate and effective strategies (Keivani & Jafari, 2015). Research shows that educational simulations are among the most effective methods for fostering academic engagement and motivation by activating the learner's role in the educational process (Nsabayezu et al., 2023). Researchers argue that academic engagement occurs when students are deeply immersed in learning activities and become cognitively and emotionally absorbed in the subject matter (Talan, 2020). Field trips, peer learning, hands-on activities, and particularly educational simulations are various forms of active learning and academic engagement (Amerstorfer & Freiin von Münster-Kistner, 2021). Therefore, methods and tools that enhance interest and enthusiasm in learning can indirectly improve student learning outcomes and ultimately contribute to the quality of the education system (Mansoori & Khodaei, 2022). According to studies, given the benefits of technology in enhancing motivation and diversifying learning experiences, one of the most promising tools in the teaching and learning process is educational simulation (Sharifati, Nili Ahmad Abadi, & Maghami, 2021). Accordingly, the development and implementation of educational simulations in smart schools which already provide a digital infrastructure for electronic education can facilitate meaningful, problem-based learning (Tonapa, Mulyadi, Ho, & Efendi, 2023). Based on the presented discussion and existing research, it appears that despite the significant potential of educational simulations in promoting interactive learning, contextualizing lesson content, and enhancing academic motivation by involving learners in the process, this topic has received limited attention. Furthermore, although smart schools in Iran are equipped with technological capacities, these capabilities often remain underutilized and are mostly showcased for promotional purposes. Therefore, by developing electronic content particularly simulation software for these schools, the proper use of available resources can be promoted and enhanced.

Research methodology

In this study, a quasi-experimental method was employed with two groups of participants: an experimental group and a control group. A purposive sampling method was used. First, from among the smart boys' elementary schools in Tehran, one school was selected as the research sample. Then, from the sixth-grade classes of the selected school, two groups of 30 students were chosen. For teaching science, a researcher-developed educational simulation software for sixth-grade science was used for the experimental group, while the control group received instruction through the conventional smart school method.

Both the experimental and control groups were administered a pretest on learning and a pretest on academic achievement motivation. The statistical population of this study included all sixth-grade students in smart elementary schools in Tehran. The sample consisted of 60 sixth-grade students from Nezam Mafi Smart School in Tehran.

Three instruments were used in this study:

1. **Learning Pretest:** This test consisted of 20 researcher-developed multiple-choice questions based on the science topic "The Wonders of Plants."
2. **Learning Posttest:** This test also included 20 researcher-developed multiple-choice questions, designed parallel to the pretest.
3. **Academic Achievement Motivation Questionnaire:** To measure academic achievement motivation, Hermans' Achievement Motivation Questionnaire was administered as both a pretest and posttest. The questionnaire consists of 29 incomplete statements with four response options each. The scoring method assigns values from 1 to 4 or 4 to 1, depending on the direction of motivation intensity. Higher scores indicate stronger achievement motivation, while lower scores reflect weaker motivation.

To confirm the content validity of the learning pretest and posttest, the tests were reviewed and approved by academic supervisors and experienced science teachers. The teachers evaluated the tests for relevance, clarity, comprehensibility, and appropriateness in addressing the research questions. Hermans (1970) assessed the validity of the achievement motivation questionnaire based on content validity derived from prior research on academic motivation and calculated the item-total correlation coefficients, which ranged from 0.30 to 0.57. Additionally, Akbari (2007), in a study evaluating the validity and reliability of Hermans' questionnaire among secondary school students in Gilan province, confirmed its acceptable validity.

In the present study, the reliability of the researcher-developed learning test was calculated using the Kuder–Richardson method, yielding a reliability coefficient of 0.75. Hermans (1970) reported a reliability coefficient of 0.84 for the achievement motivation questionnaire using Cronbach's alpha.

For data analysis, descriptive statistics (frequency, mean, and standard deviation) and inferential statistics (multivariate analysis of variance and analysis of covariance), following the assumption testing procedures, were employed using SPSS software.

Research Findings

Descriptive Statistics Findings

As previously mentioned, the research sample consisted of 60 sixth-grade male students from Nezam Mafi Smart Elementary School in Tehran, of whom 30 were assigned to the experimental group and 30 to the control group (Table 1).

Table 1. Frequency of Participants by Group

Group	Frequency	Percentage
Experimental	30	50%
Control	30	50%

Following the implementation of the study, students' pretest and posttest scores were collected to assess the variables of learning and academic achievement motivation. This section presents a descriptive analysis of these results.

Table 2 provides descriptive statistics, including minimum, maximum, mean, standard deviation, and sample size, for the learning pretest and posttest, categorized by the experimental and control groups. As shown, the mean scores of the learning pretest in both groups were approximately equal. However, the mean scores in the learning posttest, following the application of the independent variable, demonstrate superior performance in the experimental group compared to the control group.

Table 2. Descriptive Statistics of the Learning Variable by Group

Group	Test Time	Minimum	Maximum	Mean	Standard Deviation	Sample Size
Experimental	Pre-test	3	16	8.73	2.89	30
	Post-test	9	19	15.26	2.79	30
Control	Pre-test	1	16	8.36	3.13	30
	Post-test	5	19	13.13	3.37	30

Table 3 presents the descriptive statistics, including mean, standard deviation, and sample size, for the pre-test and post-test of the Academic Achievement Motivation Questionnaire for both the experimental and control groups.

Table 3. Descriptive Statistics of the Academic Achievement Motivation Variable by Group

Group	Test Time	Minimum	Maximum	Mean	Standard Deviation	Sample Size
Experimental	Pre-test	52	77	63.6	6.83	30
	Post-test	56	80	76.46	7.65	30
Control	Pre-test	54	75	63.2	5.35	30
	Post-test	57	77	65.13	4.68	30

By comparing the obtained means of the academic achievement motivation variable in the pre-test and post-test for both the experimental and control groups, it can be implicitly concluded that the academic achievement motivation of students in the experimental group, who received instruction through the educational simulation software, increased in the post-test compared to the control group.

Inferential Statistics Findings

In this section, the hypotheses of the study were tested using Analysis of Covariance (ANCOVA) and t-tests. The reason for employing ANCOVA is that the researcher, in the present study design, aimed to control the effect of prior readiness by using the pre-test as a covariate to adjust for this variable's influence.

Before conducting ANCOVA, it is essential to verify several key assumptions of this statistical test, including the normality of the data distribution, homogeneity of error variances, and the homogeneity of regression slopes. Failure to meet these assumptions may lead to biased or invalid results.

Initially, prior to hypothesis testing, the assumptions of ANCOVA were examined using the statistical data analysis software, and the results are presented as follows.

Assumptions of ANCOVA

a) Normality of Interval Data

According to Table 4, which shows the results of the nonparametric Kolmogorov-Smirnov test for the pre-test and post-test data of both groups related to the variables of learning and academic achievement motivation, the significance levels (sig) for the learning variable in the pre-test and post-test were 0.185 and 0.054, respectively. Likewise, for the academic achievement motivation variable, the significance levels in the pre-test and post-test across both groups were 0.060 and 0.200, respectively. Since all these values exceed the 0.05 significance level, the null hypothesis of normal distribution cannot be rejected. Therefore, there is no statistically significant difference between the distribution of these variables and a normal distribution. Consequently, the dependent variables conform to and follow a normal distribution.

Table 4. Kolmogorov-Smirnov Nonparametric Test for Pre-test and Post-test Data of Both Groups

Significance (Sig.)	Degrees of Freedom (df)	Test Statistic	Group	Variable
0.185	29	0.133	Experimental	Pre-test Learning
0.054	29	0.170	Experimental	Post-test Learning
0.145	29	0.188	Control	Pre-test Learning
0.175	29	0.122	Control	Post-test Learning
0.060	29	0.177	Control	Pre-test Academic Achievement Motivation
0.200	29	0.098	Control	Post-test Academic Achievement Motivation
0.080	29	0.145	Experimental	Pre-test Academic Achievement Motivation
0.115	29	0.127	Experimental	Post-test Academic Achievement Motivation

According to Table 4, the Kolmogorov-Smirnov test for normality confirmed the normal distribution of the pre-test and post-test scores for the learning variable and the academic achievement motivation variable in both the control and experimental groups, with significance levels greater than 0.05.

b) Homogeneity of Variances

Based on the one-way ANOVA output, the Levene's test statistics for the pre-test and post-test scores of the learning variable were 0.005 and 0.143, respectively. For the pre-test and post-test scores of academic achievement motivation, the test statistics were 0.942 and 3.862, respectively. These results were not significant at the 0.05 level, indicating that the assumption of homogeneity of variances for the dependent variables is met (see Table 5).

Table 5. Results of Levene's Test for Pre-test and Post-test Scores of Learning and Motivation

Test	Statistic	df1	df2	Significance (Sig.)
Pre-test Learning	0.005	1	58	0.945
Post-test Learning	0.143	1	58	0.707
Pre-test Motivation	0.942	1	58	0.336
Post-test Motivation	3.862	1	58	0.054

c) Homogeneity of Regression Slopes

According to Table 6, which presents the Pearson correlation test results, the significance levels for the correlations between the dependent variables in the pre-test and post-test exceed 0.05. Therefore, no significant relationship exists between the variables in the pre-test and post-test. Additionally, the correlation coefficients between the variables are below 0.3, indicating a very weak correlation. Consequently, multicollinearity is not present, and ANCOVA can be appropriately applied.

Table 6. Pearson Correlation Test Results for Examining the Correlation Levels of Dependent Variables in Pre-test and Post-test

Test	Pre-test Learning	Post-test Learning	Pre-test Motivation	Post-test Motivation
Pre-test Learning	Correlation: 1	0.269	-0.169	0.143
	Significance (p): —	0.151	0.372	0.452
Post-test Learning	Correlation: 0.269	1	-0.079	-0.006
	Significance (p): 0.151	—	0.678	0.975
Pre-test Motivation	Correlation: -0.169	-0.079	1	0.018

	Significance (p): 0.372	0.678	—	0.927
Post-test Motivation	Correlation: 0.143	-0.006	0.018	1
	Significance (p): 0.452	0.975	0.927	—

d) Reliability of the Researcher-Designed Questionnaire and Test

Hermans (1970) calculated a reliability coefficient of 0.84 for the questionnaire using Cronbach's alpha. To assess the reliability of the researcher-designed test, the Kuder-Richardson method was employed. The obtained reliability coefficient for the test was 0.75, which is considered acceptable for this number of items. This value indicates that the test items are internally consistent and exhibit significant correlation with the overall test, demonstrating sufficient accuracy for measurement. Therefore, it can be concluded that the reliability assumption of the tests required for conducting ANCOVA is satisfied (see Table 7).

Table 7. Reliability Coefficients of the Tests

Reliability Method	Number of Items	Test
Kuder-Richardson (0.75)	20	Learning
Cronbach's Alpha (0.84)	29	Academic Achievement Motivation

Results of the Analysis of Covariance

Considering the set of established assumptions, it is evident that the data in this study meet the requirements for conducting ANCOVA. Therefore, the results of the covariance analysis related to each of the research hypotheses are presented below.

Hypothesis 1

The use of educational simulation software in experimental science classes of smart schools has an effect on learners' learning outcomes.

Table 8. Results of ANCOVA on Students' Post-test Learning Scores Adjusted for Pre-test Scores

Source of Variation	Sum of Squares	Degrees of Freedom (df)	Mean Square	F Value	Significance (p)
Adjusted Model	80.878	2	40.439	4.247	0.019
Intercept	107.916	1	107.916	112.474	0.000
Pre-test	12.612	1	12.612	6.534	0.020
Group (Independent Variable)	64.445	1	64.445	6.768	0.012
Error	542.722	57	9.521		
Total	12722.000	60			

According to Table 8, the effect of the covariate variable is represented by an F value of 6.534, which is significant at the 0.05 level ($p = 0.02$). Therefore, the assumption of correlation between the covariate and the independent variable is satisfied.

Furthermore, the F value for the independent variable is 6.768, which is significant at the level of $p < 0.05$ with degrees of freedom ($df = 1$). This indicates that after controlling for the pre-test effect, there is a significant difference between the mean post-test learning scores of the two groups (the group trained with the simulation software and the group taught using conventional methods) in the subject of "The Wonders of Plants." Consequently, the null hypothesis of no significant difference between the two groups' post-test means, after removing the potential effect of the pre-test, is rejected.

Therefore, the difference in learning outcomes between the control and experimental groups is confirmed at the 0.05 significance level, with 1 degree of freedom and 95% confidence. In other words, there is a statistically significant difference in learning between the control and experimental groups after adjusting for the pre-test effect, with the experimental group demonstrating a notably higher learning gain compared to the control group.

Hypothesis 2

The use of educational simulation software in experimental science classes of smart schools affects learners' academic achievement motivation.

Table 9. Results of ANCOVA on Students' Post-test Academic Achievement Motivation Scores Adjusted for Pre-test Scores

Source of Variation	Sum of Squares	Degrees of Freedom (df)	Mean Square	F Value	Significance (p)
Adjusted Model	266.211	2	133.106	7.144	0.002
Intercept	1209.491	1	1209.491	64.918	0.000
Pre-test	145.795	1	145.795	7.825	0.007
Group (Independent Variable)	129.211	1	129.211	6.935	0.011
Error	1061.972	57	18.631		
Total	244917.000	59			

According to Table 9, the effect of the covariate variable is represented by an F value of 7.825, which is significant at the 0.05 level (p = 0.007). Therefore, the assumption of correlation between the covariate and the independent variable is satisfied.

Furthermore, the F value for the independent variable is 6.935, which is significant at $p < 0.05$ with degrees of freedom (df = 1). This indicates that after controlling for the pre-test effect, there is a significant difference between the mean post-test motivation scores of the two groups (the group trained with the simulation software and the group taught using conventional methods). Consequently, the null hypothesis of no significant difference between the two groups' post-test means, after adjusting for the pre-test, is rejected.

Thus, the difference in motivation levels between the control and experimental groups is confirmed at the 0.05 significance level, with 1 degree of freedom and 95% confidence. In other words, there is a statistically significant difference in academic achievement motivation between the control and experimental groups after removing the potential pre-test effect, with the experimental group demonstrating a notably higher motivation level than the control group.

To confirm and extend these findings, a t-test was conducted, the results of which are presented below.

Hypothesis 1

The use of educational simulation software in experimental science classes of smart schools affects learners' learning outcomes.

According to Table 10, which shows the results of the t-test, the mean difference between the pre-test and post-test learning scores of the learners is 6.53, indicating that learners' learning increased by 6.53 points from the pre-test to the post-test. Therefore, as shown in Table 10-4, with 29 degrees of freedom, 95% confidence, and a significance level of 0.000, it can be concluded that there is a significant difference between learners' pre-test and post-test learning scores. In fact, learning outcomes in the experimental group significantly improved following the intervention.

Furthermore, Table 10 shows that the difference between the pre-test and post-test scores of the control group in the learning variable is 4.76. Based on this, it can be stated that the learning performance of the experimental group, which was trained using the educational simulation software, was markedly better than that of the control group, which received conventional school instruction.

Table 10. Results of the t-Test for Pre-test and Post-test Learning Scores in Both Groups

Group	t-value	Degrees of Freedom (df)	Mean Difference	Significance (p)
Experimental	10.39	29	6.53	0.000
Control	5.85	29	4.76	0.000

Hypothesis 2

The use of educational simulation software in experimental science classes of smart schools affects learners' academic achievement motivation.

According to Table 11, which presents the results of the t-test, the mean difference between the pre-test and post-test scores of academic achievement motivation among learners is 12.86. This indicates that learners' motivation increased by 12.86 points from the pre-test to the post-test. Therefore, based on Table 11, with 29 degrees of freedom, 95% confidence, and a significance level of 0.000, it can be concluded that there is a significant difference between learners' pre-test and post-test motivation scores. In fact, motivation in the experimental group significantly increased following the intervention.

Furthermore, Table 11 shows that the difference between the pre-test and post-test scores of the control group in the academic achievement motivation variable is 1.93. Based on this, it can be stated that motivation levels in the experimental group, which was trained using the educational simulation software, increased compared to the control group, which received conventional school instruction.

Table 11. Results of the t-Test for Pre-test and Post-test Academic Achievement Motivation Scores in Both Groups

Group	t	df	Mean	Significance Level (p-value)

Experimental	6.93	29	12.86	0.000
Control	2.88	29	1.93	0.007

Discussion and Conclusion

Over the past two decades, the development of Information and Communication Technology (ICT) has brought about profound transformations across all aspects of human life, particularly in the field of education. Educational simulation software constitutes a significant facet of these technologies, having become one of the most crucial learning resources for children, adolescents, youth, and even adults in the modern era.

This study aimed to investigate the impact of a researcher-developed educational simulation software for the science course on students' learning outcomes and academic motivation. The findings indicate that one of the most influential factors affecting students' learning and motivational progress is the method of instruction and the mode of educational content delivery.

Educational simulators, through clear and comprehensible articulation of learning objectives, delivering lessons in a structured and systematic manner, activating students' roles in the learning process, applying the material in daily life contexts, and connecting new content with prior knowledge, not only enhance the quality of teaching and instruction but also improve students' learning. This, in turn, can effectively increase learners' motivation for purposeful learning and knowledge acquisition.

The current findings regarding the effects of computer-based instruction, particularly educational software, on effective learning and motivation are consistent with those reported by (Farhoomand, 2021; Li, Chen, & Deng, 2024; Maghami, Rajabiyan Dehzireh, & Sharifati, 2020; Sabbagh Hasanzadeh & Farzadpor, 2023). These studies collectively suggest that computer-based education, compared to traditional (teacher-centered) methods, offers advantages such as immediate feedback provision, avoidance of cognitive biases and subjective judgments, facilitation of individualized learning processes, enhancement of learners' attention span and motivation, diversified learning experiences, adaptation of instruction to learners' capabilities, and creation of stimulating learning environments free from unhealthy competition.

On the other hand, considering that effective teaching-learning processes must evoke cognitive engagement and pleasure, transforming students from passive recipients of information into active knowledge producers, engaging learners meaningfully can present challenges for educators. Educational simulation software serves as an effective pedagogical tool to engage students actively in the learning process. Such software environments enable content delivery that, beyond stimulating learners' sensory modalities through visuals, color, sound, and motion, also remains challenging and engaging.

Based on the presented research outcomes, it is expected that educators will develop a renewed perspective towards computer-based instructional methods, especially embracing opportunities offered by educational simulation software. By adopting a positive stance on the integration of computers and software in teaching, educators can harness these tools to better prepare learners for the complexities of today's world.

Therefore, considering the significance of this topic and the research findings, it is recommended to organize in-service training courses for teachers across all educational levels focusing on computer literacy, the use of simulation software, and workshops on the design and production of educational software, particularly in smart schools. Additionally, teachers who incorporate innovative methods such as educational simulations in their instructional practices or develop electronic content themselves should be duly encouraged and supported.

Investment in the development and production of high-quality simulation software that complies with technical and pedagogical standards for all subjects and educational levels should be prioritized. Finally, equipping schools with computer labs will facilitate the extensive benefits of technology for both teachers and students.

Resource

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