The Effect of Simulation Technique on Academic Achievement: A Meta-Analysis Study

Tarık Talan iD

Gaziantep Islam Science and Technology University, Turkey

To cite this article:

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Tarik Talan

Article Info	Abstract
	This research aims to examine the experimental studies on the impact of simulation technique on students' academic achievement using the meta-analysis method. The previous studies that could be meta-analyzed were examined based on the criteria set out in this study. Finally, 91 studies that were conducted between 2010-2020 years and met the inclusion criteria were subjected to meta-analysis. The sample of the research consisted of 7575 participants. According to the results of the analysis performed using the random-effects model, the mean effect size was calculated as g=0.759 with a standard error of 0.075. Based on the findings, the simulation technique can be said to have a broad impact on students' academic achievement. The results of the publication bias analysis revealed that the present meta-analysis study had no publication bias. On the other hand, the results of the moderator analysis revealed that the impact of the simulation technique on the students' academic achievement did not differ by the teaching levels, course/subject area, and application times, however, it differed by the sample size.

Introduction

Technology has been improving rapidly today. This progress of technological developments can also be seen in the field of education and makes it necessary to rebuild teaching environments. Therefore, it requires the use of various methods and techniques utilizing technological tools in education to facilitate and make sense of in-class teaching and to arouse the curiosity and interest of the students. The simulation technique is one of these methods that have become indispensable for today's technologies and can be used together with technology as part of computer-aided education. This method, which is widely used in educational settings in many countries, offers important opportunities to convey to the student several phenomena that are difficult or even impossible to explain and observe due to various reasons (Şengel, Özden and Geben, 2002). Simulation, a type of technology by which theoretical knowledge is transformed into practice, simplifies the difficult-to-comprehend, abstract activities and realistically embodies them and can reach a solution in a short time (Atalan and Donmez, 2019). Thus, a more concrete, realistic, and permanent learning environment is provided as well as saving time and material resources (Atam and Tekdal, 2010).

With the rapid developments in the field of informatics, it has become possible to conduct experiments with

accuracy close to true values using software types such as simulation. Simulation, which can be defined as the implementation of the model of a subject, system, and phenomenon in the computer environment to support the learning process, plays a very significant role in preparing individuals for life (Ateş et al., 2009). In other words, simulation is the creation of real-like (virtual) versions of environments that are natural and real by using computers (Demirel, Yağcı and Seferoğlu, 2004). It is the most effective way of training the student on a model of reality, especially when it is difficult, dangerous, and costly to train the student in a real environment, with real tools. Thus, extravagance and possible accidents are prevented. Also, it offers faster and permanent learning environments.

An application or environment must contain some features to be regarded as a simulation. First of all, the prepared simulation needs to conform with reality, that is, it should reflect reality one-by-one. With this feature, the behavior, activity, and similar situations experienced reflect reality. The other feature is that participants of the application are given a real-world-related role. In this way, the participant will be able to simulate possible situations that actually exist. The final feature is that there are different ways to be applied by the participant when the current situation, value, or variable changes. If the simulations have these characteristics, participants will be able to adapt the knowledge they learn through the simulation to situations they encounter in the real world (Babur, 2016; Maran and Glavin, 2003; Patrik, 2002).

Simulations are often preferred in all areas of human life in recent years because of their affordable costs, ease of access, and availability to repeat independently from time and space (Nerdel and Prechtl, 2004; Sarıçayır, 2007). Besides its uses for military purposes, simulations are also used as a training tool in many fields of science that require an application, such as industry, aerospace, engineering, and healthcare. It is also actively practiced in different disciplines of natural sciences such as physics, chemistry, and biology, social sciences such as geography, and other disciplines such as mathematics and language education. Therefore, as a new generation technology, the simulations have managed to draw attention to their use in education in a short time, from primary education to higher education, thanks to their features.

The inclusion of simulations in education programs has many contributions. In the literature, it was determined that simulations improved student success and performance (Abdel-Maksoud, 2019; Kibirige and Tsamago, 2019; Koç-Ünal, 2019; Yıldız, 2019), positively affected students' attitudes towards the course (Aydoğan, 2019; Daşdemir and Doymuş, 2012; Ebenezer, 2001; Güvercin, 2010), had a positive effect on their self-sufficiency, interests, and motivations (Abdel-Maksoud, 2019; Bayram, 2019; Duprey, Bruyere and Verriest, 2010; Pozo-Barajas, del Pópulo Pablo-Romero and Caballero, 2013), and enabled students to learn through experiences by taking them from the passive position (Uşun, 2000). Furthermore, it is reported that situations that are expensive, time-consuming, dangerous, and complicated to do in real environments can be performed safely and repeated as many times as desired (Akkağıt and Tekin, 2012; Bıçak, 2019; Hofstein and Lunetta, 2003; Şengel et al., 2002; Uşun, 2000). The studies in the literature, report that this method is effective in teaching the subjects that are boring, difficult to understand and complex, embody abstract concepts, and make the teaching and learning process easier and more understandable (Akkağıt and Tekin, 2012; Aykaç, 2014; Kutluer, 2008).

Some studies revealed that simulations are effective in facilitating the students' gaining 21st-century skills, such as creativity, problem-solving, discovery, effective communication, and critical thinkings (Aykaç, 2014; Konak, 2019; Sarıçayır, 2007). As a result, it can be said that simulation technique, which is a student-centered approach, makes learning apprehensible and facilitates permanent learning by structuring the knowledge (Çinici et al., 2013; Daşdemir and Doymuş, 2012; Dinçer and Güçlü; 2013; Koç-Ünal, 2019; Öner, 2017; Şimşek, 2017), and it includes activities aiming at improving the quality of education by ensuring the active participation of the student in the course (Sarı and Güven, 2013; Şahan, 2019). Therefore, including simulations in education programs as a complementary and augmentation tool can contribute to achieving effective, sensible, and permanent learning.

On the other hand, the studies also reveal several challenges and limitations of the simulations together with the educational opportunities they offer in many aspects. In particular, the reasons such as the difficulty in and cost of designing a software during its development, the time required to develop software suitable for each acquisition, and the difficulty in selecting and applying a model identical to reality are among the problems that prevent the use of simulations in education (Aykaç, 2014; Becker and Parker,2009; Yeroğlu, 2001). Furthermore, as the system becomes more complicated, the simulation model developed is also adversely affected in terms of time and cost factors (Koç-Ünal, 2019). Simulation tools are easily affected by power outages and user errors, and they can get out of order or even break down (Bıçak, 2019). On the other hand, the facts that it is possible to encounter situations in real life that are not encountered in its simulation, that it does not always yield definite results, that it is simplified because it is artificial, and that it partially distorts the truth can be expressed as other important issues (Erciyeş, 2012; Küçükahmet, 1998; Şahan, 2019). It can be stated that these problems must be eliminated to obtain the desired effect from simulation-based applications.

The Purpose of the Study

There has been an increase in studies on the effectiveness of the use of simulations in different areas and different sample groups in the teaching environment in recent years. However, there is limited comprehensive information obtained by examining the results of these studies by following a holistic approach. In this case, it can be said that meta-analysis studies are needed to analyze the results of different studies holistically and to reach a general judgment. Therefore, it is thought that up-to-date reviews in this area will shed light on the field and will create a source for new studies on the subject. Therefore, the research is considered to be important in terms of providing a general conclusion about the effectiveness of the use of simulations in education in terms of academic achievement.

The present study aims to determine the impact of simulation technique on students' academic achievement by collecting the studies on the subject using certain criteria. In other words, in this study, the findings of the studies on simulation techniques were examined comprehensively and holistically, and the findings were reanalyzed by the meta-analysis method. According to the findings, it was thought that examining the effectiveness of simulation technique based on sub-objectives would be useful for obtaining a general view of the field, and answers to the following questions were sought:

- What is the size of the effect of the simulation technique on academic achievement?

- What is the size of the effect of the simulation technique on academic achievement in terms of teaching levels?

- What is the size of the effect of the simulation technique on academic achievement in terms of application times?

- What is the size of the effect of the simulation technique on academic achievement in terms of course/subject areas?

- What is the size of the effect of the simulation technique on academic achievement in terms of sample size?

Method

A meta-analysis method was used in this study. Meta-analysis is the re-analysis, synthesis, and interpretation of results by combining similar studies, which are not related to each other in a particular subject or field, considering certain criteria (Lipsey and Wilson, 2001).

Data Collection

A detailed literature review was conducted about the topic to be able to find answers to the research questions within the scope of the study. Then, databases and search criteria were determined. National and international databases such as "Web of Science", "Science Direct", "Springer Link", "Scopus (A&I)", "Educational Resource Information Center (ERIC)", "Google Scholar", "Taylor & Francis Online", "ULAKBIM", "JSTOR", "ProQuest Dissertation & Thesis Global" and "Turkish Council of Higher Education Thesis Center" were used to access these studies. To reach the most up-to-date studies, the databases were screened repeatedly at regular intervals. The screening process was completed as of June 2020. The following terms were used together as keywords to access related studies in the databases:

- Simulation-related terms (i.e., 'simulation', 'computer simulation', 'simulator')

- learning-related keywords (i.e., 'learning', 'education', 'teaching', 'instruction', 'training', 'knowledge', 'success', 'performance')

At the end of the data collection process, a total of 91 studies on the impact of simulation techniques on academic achievement were analyzed.

Inclusion and Exclusion Criteria

Identifying the limits and criteria of the research is the most important and critical point of meta-analysis. In the research, the studies to be included in and excluded from the analysis are revealed within the scope of the identified criteria. The inclusion criteria for the studies to be used for the meta-analysis within this study are given in Table 1.

Table 1. Criteria for Inclusion in the Meta-analysis

Criteria	Description
Time interval	The study must be conducted between 2010 and 2020.
Appropriateness of teaching method	Studies on using simulation technique in education by using experimental and/or semi-experimental method models with pretest-posttest control groups
Resource of the study	Master's and Ph.D. theses, and articles published in academic journals
Statistical data	Numerical data required to calculate the effect size

In the studies containing data on the variable of academic achievement, data belonging to a total of 7575 people were examined, 3833 (%50.6) of which were in the experimental group, 3742 (%49.4) of which were in the control group.

The studies that are outside the research framework, those that cannot be accessed due to lack of access authority, those that have qualitative data, and those that do not contain sufficient data for analysis are excluded from the meta-analysis. Also, when the studies of the same author on the same subject were an article and a thesis, the article was included in the meta-analysis study. At the end of the screening process, it was determined that several studies were recorded in multiple databases; in this case, only the data from one database was used. Also, studies with no experiment section or experimental studies with a single group are excluded from this study. The PRISMA flow diagram (Moher et al., 2009) that shows the process of obtaining the studies included in the meta-analysis is given in Figure 1.
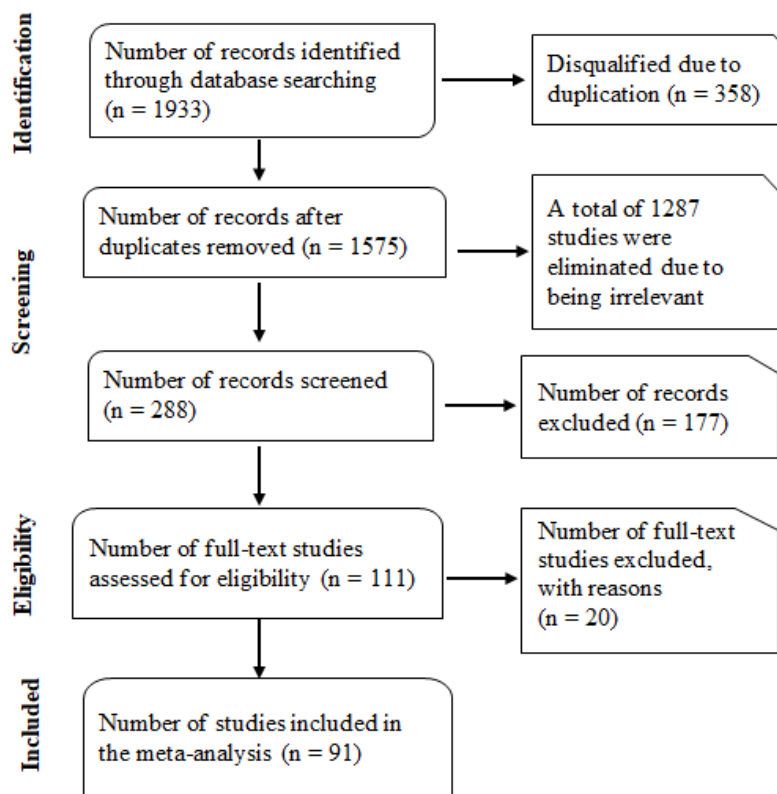
Figure 1. Flow Chart for Selection of Studies

According to Figure 1, the first searches resulted in a wide range of publications (n=1933) on the effects of simulation techniques on academic achievement. Filters were applied to these publications, and the scope of the search was narrowed. After the search criteria were applied, 358 of these studies were removed because they were duplications. Also, 1287 of them were excluded because their titles were found irrelevant after reading their abstracts.

Finally, 288 studies were left. Upon examining these studies within the context of inclusion criteria, 177 of them were also eliminated. Evaluating the remaining 111 studies in terms of their eligibility and quality, 20 studies that were found to be not eligible, i.e. those with poor quality and those that did not contain sufficient data, were removed. Thus, 91 studies were included in the meta-analysis.

The Coding of Data

After identifying the criteria in the study, a codification form was prepared to examine provided that the studies met the inclusion criteria for the meta-analysis. The said codification form was prepared in three chapters: "Identity of the Study", "Contents of the Study", and "The Data of the Study". The relevant data about the coding form are presented in Table 2.

Table 2. Chapters of the Codification Form and its Content

The Identity of the Study	Contents of the Study	The Data of the Study
The Title of the Study	Teaching Level	Sample Size (N)
Author/Authors of the Study	Implementation Period	Mean ($\overline{X}$)
Publication Year	Course/Subject	Standard Deviation (sd)
Publication Type	Class Size	
Publication Database		

To ensure coding reliability, which constitutes the basic structure of the research, the data of each study was coded by three instructors in the field of education technologies at different times and independently of the coding of the researcher. The consistency between the coders was found to be 87%. As a second way in the study, the coding process was repeated several times at different times by the researcher and the consistency of the coding process was examined.

Data Analysis

The term that constitutes the nature of meta-analysis is the effect size. Also referred to as the magnitude of the effect size in the literature, the effect size is used to obtain information about how much the independent variable in a study positively or negatively affects the dependent variable (Dinçer, 2014). Therefore, the measure of Hedge's g was used to calculate the effect size in the study, and the significance level in the statistical analyses was determined as 0.05.

The random-effects model was used to calculate the overall effect size of the study. Also, effect sizes were calculated for the fixed effects model, and the obtained values were given in the findings. However, since the random-effects model is the appropriate model for the study according to the results of the heterogeneity test, the interpretations were in line with this model. The effect size classification developed by Thalheimer and Cook (2002) was used to evaluate the level of effect size based on arithmetic averages, and the findings were interpreted by adhering to this information.

Publication bias is one of the most important factors that can affect the results in meta-analysis studies. Thus, the reliability of the study must be ensured (Dinçer, 2014). Publication bias in this study was evaluated using the Funnel Plot, which was based on visual interpretation, and it was and reported accordingly. In the study, the CMA statistical software package was used to calculate publication bias, effect size, and heterogeneity test values.

Results and Discussion

This section addresses the findings obtained from the meta-analysis are given. In this context, the magnitude of the effect size of the studies included in the meta-analysis are explained, and they were interpreted. In the study, the effect size of the studies on academic achievement and the moderator analyses are presented in separate sections of the study.

Findings Regarding the Effect Size of Studies on Academic Achievement

Regarding the effect of using simulation technique in education on academic achievement, the average effect size, standard error, and the lower and upper limits of the effect size were found using fixed and random effects model according to 95% confidence interval. According to the results given in Table 3, the Q-statistical value was calculated as 832.121. This value is well above the critical value (117.632) in the χ^2 table with a degree of freedom of 91, a significance level of 95%, and it is significant ($p<.001$). This result reveals that the studies included in the meta-analysis research had a heterogeneous structure (Dinçer, 2014).

Table 3. The Effect Size Results of Studies based on FEM and REM

Type of Model	k	Z	P	Q	df	g	SE	% 95 CI	
								Lower	Upper
FEM	91	31.382	0.000	832.121	90	0.763	0.024	0.716	0.811
REM	91	10.067	0.000	91.880	90	0.759	0.075	0.611	0.906

Note. k = number of effect sizes; *df* = degrees of freedom; *g* = Hedges' g; *SE* = standard error; *CI* = confidence of interval for the average value of ES.

According to the result of the analysis conducted using REM, the average effect size (Hedge's g) was calculated as g = 0.759 with a standard error of 0.075. Besides, the lower limit of the effect size in the 95% confidence interval was found to be 0.611, and the upper limit was found to be 0.906. Interpreting the findings according to

Thalheimer and Cook's (2002) approach, it can be stated that using simulation techniques in education is highly effective (0.75 < d < 1.10) in terms of improving academic achievement. In the studies included in the meta-analysis, the Funnel Plot was used to examine whether there was a publication bias and to visually evaluate the data set. The plot results are shown in Figure 2.
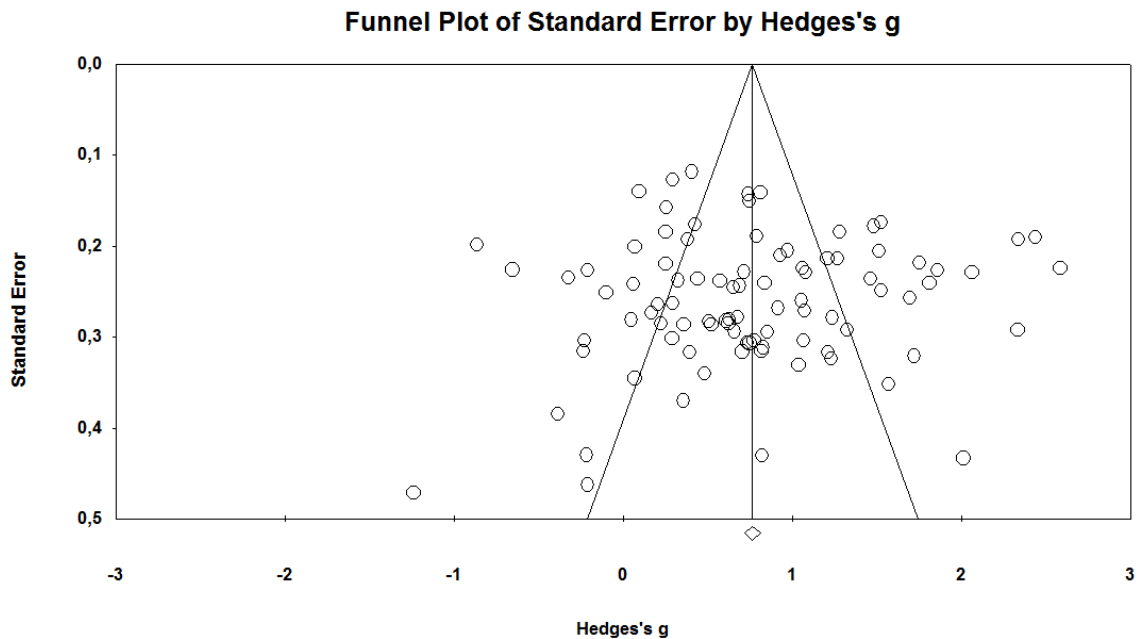
Funnel Plot of Standard Error by Hedges's g

Figure 2. Funnel Plot

Examining Figure 2, it is seen that the studies do not stack in one place asymmetrically around the overall effect size. This reveals that the study sample is not biased in favor of the simulation technique's effect on academic achievement and that this meta-analysis study is reliable.

The Effect Sizes of Studies according to Moderators

According to the examination of the studies, it was observed that the teaching level, course/subject area, sample size, and application times of the studies included in the research were different. Therefore, it was aimed to examine whether the effect sizes of the studies vary by the specified variables. The results of the moderator analysis of the studies included in the meta-analysis are given in Table 4.

Considering Table 4 in terms of teaching level, the intergroup homogeneity test value was found to be Q_B=3.334. From the χ2 table with a significance value of 95% and the degree of freedom of 3, the value was found to be 7.815. Since the Q_B statistical value is found to be less than the critical value of χ2 distribution with a degree of freedom of 3, it can be said that the distribution is homogeneous. Examining the studies according to the teaching level, it was found that the effect sizes of using simulation techniques on the students' academic achievement did not differ significantly (Q_B=3.334, p=0.343). On the other hand, the overall effect size of the teaching level can be stated to be a large level according to Thalheimer and Cook's (2002) classification.

Table 4. The Effect Sizes of Studies on Different Dimensions in terms of Academic Achievement

| | Variables | k | g | % 95 CI | | Q_B | Z | df | p |
				Lower	Upper				
Teaching Level	**Primary School**	2	0.193	-0.858	1.245	3.334	10.403	3	0.343
	Secondary School	29	0.861	0.619	1.103				
	High School	21	0.883	0.592	1.174				
	University	39	0.644	0.403	0.885				
	Sum	91	0.774	0.628	0.920				
Application Times	**≤4h**	12	0.772	0.375	1.168	1.423	10.340	5	0.922
	≥1, ≤4 weeks	38	0.756	0.553	0.959				
	>1, ≤2 months	9	0.724	0.156	1.293				
	>2, ≤3 months	12	0.620	0.136	1.104				
	>3 months	7	0.701	0.108	1.293				
	Not mentioned	13	0.969	0.571	1.367				
	Sum	91	0.769	0.623	0.914				
Course/Subject	**Science**	58	0.817	0.645	0.989	4.293	10.596	5	0.508
	Social Sciences	6	0.950	0.202	1.699				
	Maths	2	0.516	0.153	0.880				
	Computer	5	0.541	-0.603	1.685				
	Medical Science	16	0.532	0.205	0.860				
	Other	4	0.880	0.079	1.681				
	Sum	91	0.730	0.595	0.865				
Sample Size	**Small (n≤50)**	30	0.526	0.323	0.729	8.252	10.357	2	0.016
	Medium (51≤n≤100)	35	0.715	0.496	0.933				
	Large (n≥101)	26	1.051	0.755	1.347				
	Sum	91	0.702	0.569	0.834				

In terms of application times of the studies, the homogeneity test value was found as Q_B=1.423. From the χ2 table with a significance value of 95% and the degree of freedom of 5, the value was found to be 11.070. Therefore, since the statistical measure of Q_B is less than χ2, the effect sizes are homogeneous. In this case, it can be stated that the effect of using a simulation technique on academic achievement does not change according to the application times (Q_B=1.423, p=0.992). On the other hand, it can be said that the overall effect size is g = 0.769, and this is a large level of effect according to Thalheimer and Cook's (2002) classification.

In terms of course/subject area, the homogeneity test value was found to be Q_B= 4.293. From the χ2 table with a significance value of 95% and the degree of freedom of 5, the value was found to be 11.070. Since the statistical value of Q_B is less than the critical value of χ2 distribution with a degree of freedom of 5, it can be said that the distribution is homogeneous. According to these results, it can be said that the effect of using simulation techniques on academic achievement does not differ in terms of course/subject area (Q_B=4.293, p=0.508). Also, it can be said that the overall effect size is g=0.730, and this is a medium effect according to Thalheimer and

Cook's (2002) classification.

In terms of the sample size, the homogeneity test value was found to be Q_B= 8.252. From the χ2 table with a significance value of 95% and the degree of freedom of 2, the value was found to be 5.991. In this case, the distribution can be said to have a heterogeneous structure. According to these results, studies can be said to vary by the sample size.

Conclusions

The present study examined the studies in the literature by the meta-analysis method to determine the effect of using the simulation technique on academic achievement. In line with the purpose of the research, 91 studies have been included in the meta-analysis. The results of the meta-analysis application revealed that using the simulation technique had a positive and strongly significant effect on the students' academic achievement. This result shows that using the simulation technique affects students ' academic achievement positively. Several studies in the literature (Arıcı and Yılmaz, 2020; Kibirige and Tsamago, 2019; Topuz, 2018; Wen et al., 2020; Yıldız, 2019) revealed that using the simulation technique had positive effects on academic achievement. In this case, it can be stated that the result of the study is consistent with the relevant literature and that the method mentioned positively affects the academic achievement of the students. On the other hand, several studies that compared simulation technique with other methods reported that no significant increase was observed in academic achievement or that no significant differences were detected (Bayram, 2019; Bıçak, 2019; Koyunlu Ünlü and Dökme, 2011; Ünal, 2017). The reason for obtaining different results in these studies in the literature can be the use of simulation techniques in different ways, the type and nature of simulation tools used during the application, and the differences in activities used during the course. Besides, the management and planning of the process by the teacher may constitute another reason for this difference. Participants' adoption of simulation techniques, their attitudes towards the course, and their motivations may also result in obtaining different results. In this respect, it can be said that the courses designed according to the simulation technique should be planned well. Moreover, students should be encouraged to make activities to support and develop the required skills before the planning process of learning environments, such as simulation, that requires technical skills.

The reasons why the simulation technique positively affects academic achievement can be listed as follows: allows saving time, being reliable, offering the user an unlimited number of repetitions, and reducing the user-induced errors while performing these repetitions (Akpınar, 1999; Zorlu, 2006). It can be said that three-dimensional computer-aided materials, such as simulation, facilitate learning by increasing visuality; particularly, animation of abstract concepts in the computer environment enables students to envisage these concepts in their minds, and it increases permanence and facilitates remembering, thereby, increasing academic achievement by contributing greatly to learning (Ceylan and Saygıner, 2017; Kahraman, 2010). Moreover, it can be stated that simulation technique contributes positively to the academic achievement of the students as it enables the students to focus on the course, to learn by doing and living, to make them actively participate in the course, and also it makes the courses more enjoyable (Atayev, 2019). High-cost, dangerous, and difficult experiments can be presented in the teaching environment using simulation, and this can affect the students'

academic achievement (Öner, 2017). Furthermore, it can be argued that teaching by simulation positively affects students ' academic achievement as it appeals to more sensory organs of students and raises motivation levels by drawing their attention to the course (Okumuş, 2016).

In the study, also the moderator analysis was used to examine whether the effectiveness of the simulation technique on academic achievement varies in terms of the teaching level, course/subject area, sample size, and application times. The results reveal that the effect of using simulation techniques on academic achievement does not change by the teaching levels, course/subject area, and application times; however, it varies by the sample size. It was determined that the large sample (n≥101) provided the greatest value, while the small sample (n≤50) provided the smallest value of the effect size. According to the value of the publication bias that provides the reliability of the meta-analytic study, and examining whether the effect sizes of the studies show normal distribution, no negative results are encountered in the study. This can be interpreted as the results of the analyses are reliable.

Also, meta-analysis studies on the effects of the simulation technique on academic achievement are found in the literature. For example, in their meta-analysis study, Dinçer and Güçlü (2013) examined the use of computer-aided simulation technique in Science Education. A total of 18 studies published in Turkey between 2003 and 2012 have been determined to meet the criteria of the research. According to the results of the analysis, it was concluded that the simulation technique was generally effective and greatly increased the academic achievement of the students. Similarly, in the study conducted by Cook et al. (2012), 92 studies were meta-analyzed to examine the impact of simulation technique on health education (instruction for health professions learners). In the study, it was determined that the technology-augmented simulation technique had a "small" to "medium" level effect compared to other teaching methods. Also, Liao and Chen (2007) examined the impact of simulation techniques on students' academic success by performing a meta-analysis study. The researchers examined 29 scientific studies about simulation techniques in Taiwan to determine the overall effect size. According to the results of their analysis, the effect size of the simulation technique on academic achievement was found to be 0.54. The results of this study show that the simulation technique has a stronger positive effect on students' academic achievement compared to the traditional teaching method. Lorello, et al. (2014), on the other hand, conducted a meta-analysis study to evaluate the effectiveness of the simulation technique in anesthesiology training. Data from 77 studies (6066 participants) that fit the inclusion criteria were analyzed from different databases. According to the results of the research, it was determined that simulation-based training was more effective in anesthesiology compared to no intervention.

In the present study, the effectiveness of the simulation technique on the students' academic achievement was tried to be determined using the meta-analysis method. According to the results of the research, the number of studies conducted on primary education, particularly the pre-school period, is very limited. Considering Piaget's cognitive development processes, the effects of simulations on academic achievement at all levels of education should be investigated and evaluated. Studies in the literature on the use of simulation techniques in education generally consist of Science and Health Sciences in terms of course/subject. The applicability of simulation techniques in other courses can also be evaluated to better determine the level of benefits of simulation in

education processes. In future studies, the applicability and effectiveness of the simulation technique can be examined in a more detailed study by analyzing variables such as attitude, motivation, and permanence by sub-group analysis according to the subject, duration of application, sample size, age, and gender.

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The studies included in the meta-analysis are shown with one asterisks (*)

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Author Information

Tarık Talan

https://orcid.org/0000-0002-5371-4520

Gaziantep Islam Science and Technology University

Gaziantep

Turkey

Contact e-mail: *ttalan46@hotmail.com*