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The Best Method of Teaching Mathematics to Reduce Math Anxiety Using Data Envelopment Analysis (DEA) Ranking in a Two-Stage Network

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Abstract

Mathematics education and math anxiety are closely intertwined. Math anxiety is a psychological phenomenon that can negatively impact an individual's ability to learn and perform mathematical tasks. Various teaching methods can effectively reduce this anxiety, as math anxiety is a significant barrier to effective learning in this subject. Identifying and implementing the best teaching methods to alleviate this anxiety can greatly enhance students' academic performance. One innovative approach for evaluating the efficiency and effectiveness of different teaching methods is the use of Data Envelopment Analysis (DEA).

In this study, Network Data Envelopment Analysis (NDEA) and Sexton's ranking method are employed to examine different methods of teaching mathematics and their impact on reducing math anxiety. In the two-stage DEA approach, various processes and outputs are analyzed in two stages. This allows for a more comprehensive evaluation of the efficiency of the educational system. The primary objective of this research is to propose an optimal method for teaching mathematics using two-stage DEA to reduce math anxiety among students. Additionally, this method facilitates a more precise identification of the strengths and weaknesses of the educational system, allowing for benchmarking against successful schools. In this study, several teaching methods were implemented in classrooms and subsequently evaluated using the proposed method. The results indicated that the game-based method achieved the highest ranking. Based on these findings, efforts will be made to apply this method in classrooms to reduce students' math anxiety effectively.

Keywords:
Math Anxiety
Network Data Envelopment Analysis (NDEA)
Ranking
Sexton Evaluation

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INTRODUCTION

Math anxiety is defined as a fear, tension, or concern regarding mathematical abilities, which can negatively affect academic performance and hinder active participation in math-related activities. This anxiety may manifest in various forms, such as avoiding math classes, feeling incapable of solving math problems, or experiencing intense anxiety during math exams (Ashcraft & Krause, 2007).

Math anxiety is a psychological state involving feelings of fear, worry, and lack of confidence when faced with mathematical concepts or problems. It can have numerous adverse effects on academic performance and even an individual's daily life. Math anxiety refers to an emotional and psychological condition marked by intense fear and concern when encountering mathematics. This condition can lead individuals to avoid mathematical activities, thereby impacting their academic achievements.

Mathematics anxiety is one of the common challenges among students, negatively affecting their academic performance and self-confidence. This type of anxiety refers to excessive fear and worry when dealing with mathematical problems and concepts, often leading to avoidance of math classes and a decline in academic performance. The significance of addressing this issue stems from the pivotal role mathematics plays as a foundational and essential subject in the educational system, contributing significantly to the development of students' analytical and logical skills.

One effective way to combat math anxiety is identifying the best teaching methods that can alleviate this anxiety while enhancing students' interest and motivation toward learning mathematics. Adopting and implementing appropriate teaching strategies can help students better understand mathematical concepts and enjoy the learning experience. This not only improves their academic performance but also boosts their confidence and motivation.

To this end, leveraging scientific tools to evaluate and rank the effectiveness of teaching methods is crucial. Data Envelopment Analysis (DEA) is one such tool that, due to its unique capabilities in assessing efficiency and performance, can effectively identify the most impactful teaching methods. Two-stage DEA models are particularly suitable for analyzing the performance of complex and multi-criteria systems, enabling the identification of methods with the greatest impact on reducing math anxiety.

The objective of this study is to evaluate and rank various mathematics teaching methods using a two-stage DEA model to determine the best approach for reducing math anxiety. This research aims to provide valuable insights for teachers and educational administrators in selecting and implementing more effective teaching methods, ultimately improving the quality of math education and alleviating students' anxiety.

In the following sections, we discuss the definition and importance of math anxiety, review the DEA and two-stage DEA models, and then propose a model using Sexton ranking to identify the most effective teaching methods for reducing math anxiety.

This article includes a case study on the ranking of schools in Semnan and examines the role of mathematics education in reducing math anxiety. It applies the two-stage Network Data Envelopment Analysis (NDEA) method to rank and evaluate the efficiency of network units. The results obtained from the ranking and network efficiency analysis are also discussed and reviewed.

Math anxiety

Kazelskis et al. (2000) argue that there is no unified definition of math anxiety among researchers. Some focus on the physical reactions experienced during mathematical tasks, while others emphasize the feelings of worry and fear when faced with math-related situations. The contemporary perspective highlights negative emotional reactions and concerns related to mathematics. Below are some examples of researchers' definitions of math anxiety (Kazelskis, 2000).

Smith outlines the characteristics of math anxiety as follows: Difficulty when asked to perform a mathematical operation (e.g., adding the prices of purchased items). Avoidance of math classes whenever possible. Physical symptoms such as illness, weakness, pain, or panic. Inability to complete a math test. Reliance on remedial classes, which yield limited success (Vinson, 2001). Some experts in mathematics education argue that thriving in today's complex and advanced world requires creative thinking and dynamic, productive thought processes. Effective learning of mathematics can play a significant role in shaping and fostering these skills (Schoenfeld, 1989). Tobias (1993) reported that millions of individuals have lost educational and career opportunities due to their fear of mathematics and their poor performance in the subject. Many of the learning and teaching challenges in a math classroom arise because teachers often instruct based on their own preferences, without considering the individual differences among students. This approach neglects the diverse needs of many learners. Consequently, theories that help math teachers identify individual differences, capabilities, and learning styles are invaluable for enhancing teaching effectiveness.

Since math anxiety, math attitude, and achievement motivation are among the personal characteristics that influence learning, it is essential to consider these individual components in mathematics education and learning. It should be noted that anxiety and psychological pressure have a prominent place in school and even university-level mathematics teaching and learning. Math anxiety is, in fact, a psychological state that arises when individuals are confronted with mathematical content, the teaching-learning environment, problem-solving, or exams. This state is typically accompanied by excessive worry, mental disruption, confusion, intrusive thoughts, and psychological tension (Alamolhodaei & Farsad, 2009).

One of the significant sources of math anxiety is word problems (Alamolhodaei, 2009). Learners need a higher level of reasoning and understanding to solve these problems, and if these strategies are not taught, it leads to anxiety and, consequently, avoidance of mathematics. Research findings show that individuals with high math anxiety perform worse in solving math problems compared to those with lower math anxiety. Santrack (2003) also concluded in his research that anxiety depletes cognitive resources and disrupts any form of academic performance. Additionally, Ma (1999) demonstrated through a multi-analysis approach that reducing math anxiety leads to an improvement in individuals' math performance from a rank of 50 to 71, concluding that math anxiety plays a significant role in academic achievement in mathematics across different educational levels.

Mirzaei et al. (2016), in his research, identified the barriers to learning mathematics as students' lack of interest in math, the use of traditional teaching methods instead of modern ones, anxiety, lack of self-confidence, the large volume of textbook content, and time limitations. Amini et al. (2019), in his study, considers the main factors for students' learning difficulties to be the teachers' methods, the curriculum, the structure of the educational system, evaluation methods, family, and lack of resources and equipment. Given the existing methods, teachers are often confused in choosing the right approach and cannot determine which method is more effective in reducing math anxiety. This article attempts to find a way to reduce students' anxiety through ranking in NDEA.

A review of data envelopment analysis (DEA) method

Data Envelopment Analysis (DEA) is a non-parametric method for evaluating the efficiency of Decision-Making Units (DMUs) based on a performance comparison of their resource utilization to produce outputs. DEA can be used to calculate the relative efficiency of educational methods and identify optimal approaches. This method was first introduced by Charnes, Cooper, and Rhodes in 1978 and has since been widely applied across various fields, including economics, engineering, management, and even public and non-profit sectors. DEA uses a mathematical model to assess the performance of decision-making units based on multiple inputs and outputs. In other words, this method evaluates the relative efficiency of decision-making units using data related to inputs (e.g., resources consumed) and outputs (e.g., products produced or services delivered).

In many applications, the need to improve the accuracy and detail of analyses has led to the adoption of new methods, such as two-stage parallel networks in DEA.

In a two-stage network, the analysis is divided into two separate stages that independently analyze the data in parallel. This structure enables analyses to be conducted more accurately and comprehensively. Two-stage networks in DEA consist of two distinct stages operating in parallel to provide a more precise assessment of unit efficiency. This approach is typically used in cases where the data is more complex and multidimensional, requiring deeper analysis.

The first research on two-stage data was developed in 2004 with the introduction of network DEA models by Lewis and Sexton (2004). Network DEA models (NDEA) measure the overall efficiency of an organization as well as the efficiency of each sub-process within the organization. These models also allow the decomposition of overall productivity through mathematical relationships between the organization's productivity, process efficiency, and effectiveness. Unlike hierarchical activity structures, NDEA models utilize a network structure.

In classical DEA models, a system is usually treated as a black box for efficiency measurement, with little attention given to its internal structure.

However, production operations often consist of a combination of series and parallel processes, necessitating the use of network structures. Kao and Huang (2008) developed a relational network DEA approach, commonly referred to as the two-stage DEA model. This model measures the efficiency of processes and the system using two connected processes in a series structure, where the system efficiency is the product of the outputs of these two processes.

In two-stage DEA, the overall efficiency of each unit and the relationship between its stages are evaluated by considering shared inputs and intermediate outputs. Amirteimouri (2013) developed a DEA method for measuring the efficiency of decision-making processes, dividing them into two interconnected stages arranged in series. In this method, outputs were considered either complete or partial with shared resources.

Amirteimouri et al. (2015) used a network DEA model to evaluate the efficiency of 25 gas companies in Iran and ranked them using the cross-efficiency method Zhang et al. (2019) proposed a two-stage DEA model for resource allocation based on zero-sum and constant-sum profit assumptions, dividing all inputs into discretionary and non-discretionary categories. They presented two models for resource allocation based on environmental efficiency scores.

Wang et al. (2019) analyzed the uniformity of decomposition weights in two-stage DEA models with shared resources. They found that these weights are unbiased concerning the second stage and that fixed weights improve the differentiation between efficient units. Tsai et al. (2020) examined the theoretical relationship between efficiency scores obtained from two-stage DEA models and the original CCR model. They also investigated how asymmetric weight sets influence efficiency scores.

One of the major challenges in using DEA is the issue of ranking decision-making units.

Various methods have been proposed for ranking units in DEA, among which the Sexton method is one of the most well-known. The Sexton method seeks to provide a more accurate ranking of decision-making units by improving basic DEA models and utilizing more advanced techniques.

This method considers different scales and employs multi-criteria analysis, helping researchers and managers gain a more comprehensive understanding of the performance of various units. Introduced in the 1980s, the Sexton method has since become a crucial tool for analyzing efficiency and productivity.

STATEMENT OF THE PROBLEM

The Sexton ranking model is one of the advanced methods in Data Envelopment Analysis (DEA) used to evaluate the efficiency of Decision-Making Units (DMUs). This model is specifically applied to two-stage structures that involve two sequential processes.

Classical DEA is typically used to measure the efficiency of DMUs with a single input and output. Initially, the classical DEA model is applied separately to each stage, determining the efficiency of each unit in each stage individually. The overall efficiency of each DMU is then calculated by combining the efficiencies of the two stages. Various methods are available for this combination, with the geometric mean being one of the common approaches. The Sexton ranking model is employed to rank the units.

Step 1: Calculating the Efficiency of Units

First, the efficiency of each Decision-Making Unit (DMU) is calculated using the classical DEA model. Assume there are n decision-making units, each with mmm inputs and s outputs. For this purpose, the CCR model is utilized. The model is formulated as follows:

$$\text{Max}\, \theta_1 = \sum_{r=1}^{s} u_r z_{rj} \tag{1}$$

S.t.

$$\sum_{i=1}^{m} v_i x_{ij} = 1, \quad j = 1,2,\dots,n$$

$$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r z_{rj} \ge 0 \quad ,j = 1,2,,\dots,n$$

$$u_r\, , v_i \ge 0\, ,\ i = 1,2,\dots,m \quad , \quad r = 1,2,\dots,s$$

u_r Represents the output weights (r=1,…, s) v_i represents the input weights (i=1,…,m), $y_{rj}$are the outputs of the j-th unit, and x_{ij} are the inputs of the j-th unit.

Model of the second stage:

$$\text{Max}\, \theta_2 = \sum_{r=1}^{s} u_r y_{rj} \tag{2}$$

S.t.

$$\sum_{i=1}^{m} v_i z_{ij} = 1\, ,\ \ j = 1,2,\dots,n$$

$$\sum_{i=1}^{m} v_i z_{ij} - \sum_{r=1}^{s} u_r y_{rj} \ge 0 \quad ,j = 1,2,,\dots,n$$

$$u_r\, , v_i \ge 0 \quad i = 1,2,\dots,m \quad , \quad r = 1,2,\dots,s$$

Step 2: Ranking Efficient Units

In this stage, the Sexton method, based on cross efficiency, is used. Each Decision-Making Unit (DMU) uses its own optimal weights to assess the efficiency of other units. In other words, each DMU acts as an evaluator.

Calculation of cross efficiency:

The cross efficiency of unit k is calculated using the optimal weights of unit j as follows:

$$E_{kj} = \frac{\sum_{r=1}^{s} u_r^* y_{rk}}{\sum_{i=1}^{m} v_i^* x_{ik}} \tag{3}$$

Where u_r^* represents the optimal output weights for the jth unit, and v_i^* represents the optimal input weights for the jth unit. y_{rk} Denotes the outputs of unit k, and x_{ik} denotes the inputs of unit k. The final ranking of the units is based on the average of their mutual efficiencies.

$$\frac{1}{n}\sum_{j=1}^{n} CE_{kj} = CE_k$$

CASE EXAMPLE

In this study, 20 girls' schools and 20 boys' schools from the city of Semnan were selected. In each school, 5 classes were randomly chosen, and a uniform entrance test was administered to all students. Based on the test results, the schools were divided into four groups in such a way that their average evaluations did not have significant differences. Each group consisted of 5 schools, each school had 5 classes, and each class comprised 20 students. In total, this study involved 4,000 students and 200 teachers.

In the first stage, questionnaires were completed by students, teachers, and parents. Then, the teaching methods were introduced to the teachers of each school, and they were asked to implement the assigned method in their teaching process. Each group of schools was randomly assigned one of the following teaching methods: the explanatory method, the cooperative learning method, the game-based method, and the brainstorming method. After completing the instructional period, a standardized test was administered to the students, and an educational task was given to reinforce learning.

This study is based on the Data Envelopment Analysis (DEA) model with a two-stage network structure. In the first stage, the following variables were considered as inputs: students' scores before teaching, students' stress levels before teaching, students' interest before teaching, the number of correctly solved questions before teaching, and the time spent on teaching. The intermediate outputs of this stage included: students' stress and anxiety levels after teaching, students' interest after teaching, and the number of correctly solved questions after teaching.

In the second stage, the intermediate outputs from the first stage were considered as inputs, and the following variables were defined as final outputs: students' scores after teaching and the number of students who are no longer anxious.

Based on the Eq1, Eq2, Eq3 model, the efficiency of each school was calculated, and a comparison of teaching methods was conducted. The results of this analysis can help identify the most effective teaching method in reducing anxiety and improving students' academic performance.

Table 1 presents the data for boys' schools, and Table 2 shows the corresponding results. Table 3 ranks the Boys' schools. Similarly, Table 4 provides data for girls' schools, Table 5 presents the results for girls' schools, and Table 6 ranks the girls' schools.

Table 1: Boys' Schools Data

DMU	Input 1	Input 2	Input 3	Input 4	Input 5	Intermediate Output 1	Intermediate Output 2	Intermediate Output 3	Final Output1
DMU1	2.15	2.2	1.2	3.6	3.3	3.6	2.95	2.8	2.55
DMU2	2.55	2.4	1.4	3.6	3.5	3.6	2.7	3.35	3.5
DMU3	2.6	2.1	1.4	3.6	3.6	3.7	2.6	3.3	3.15
DMU4	2.3	2.4	1.2	3.8	3.3	1.2	2.8	3.3	2.9
DMU5	2.45	2.2	1.4	3.6	2.95	3.2	2.65	3.45	3.1
DMU6	2.25	2.3	1	1.8	2.95	3	2.3	2.6	2.3
DMU7	2.65	2.35	1	1.4	3.4	3.4	2.35	3.05	2.7
DMU8	2.6	2.4	1.2	1.6	3.45	3.45	2.4	2.9	2.7
DMU9	2.55	2.3	1	1.4	3.2	3.2	2.3	2.85	2.7
DMU10	2.9	2.25	1	1.4	3.8	3.8	2.3	3.15	2.95
DMU11	2.15	2.3	4.6	3.8	3	3.4	3.15	3.35	3.05
DMU12	2.8	2.2	3	4	3.45	3.7	2.95	3.8	3.5
DMU13	2.35	2.3	3.8	4	3.45	3.75	3.1	3.5	3.05
DMU14	2.6	2.4	3.8	3.6	3.5	3.7	3.1	3.75	3.3
DMU15	2.45	3.35	3.8	3.6	3.6	3.95	3.2	3.55	3.15
DMU16	2.4	2.4	1.4	3.6	3.45	3.65	2.75	3.5	2.95
DMU17	2.75	2.25	1.8	3.8	3.65	3.75	2.85	3.35	3
DMU18	2.85	2.25	1.4	3.6	3.9	3.65	3.05	3.4	3.25
DMU19	2.4	2.1	1.6	3.8	3.35	3.45	2.8	3.1	2.75
DMU20	2.4	2.2	1.2	3.6	3.25	3.45	2.85	2.85	2.7

Table 2: Boys' school results

DMU	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Cross efficiency
1	0.9597	0.7866	0.8656	0.8752	0.7425	0.8058	0.8332	0.854	0.692	0.73	0.8028	0.7297	0.8156	0.7858	0.8289	0.8684	0.8258	0.8332	0.8796	0.9339	0.82161
2	0.9515	1	0.8994	0.8695	0.8812	0.9041	0.9654	0.9555	0.8331	0.9394	0.7956	0.8466	0.8531	0.8488	0.9149	0.8613	0.9012	0.9654	0.9818	1.0459	0.90885
3	0.9754	0.9165	1	0.8935	0.8348	0.9264	0.9154	0.9292	0.8069	0.9329	0.8153	0.9413	0.9608	0.9351	0.8907	0.8834	1.0515	0.9264	1.0498	1.017	0.9356
4	1.0877	0.8631	0.9708	1	0.8738	0.9603	0.9297	0.9493	0.8009	0.7677	0.9085	0.7872	0.9111	0.8847	0.9212	0.9858	0.9226	0.9603	0.9631	1.1049	0.92425
5	1.0189	0.9933	0.9874	0.9265	0.9905	1.0433	0.9638	0.952	0.8925	0.8875	0.8528	0.885	0.9419	0.9189	0.9162	0.9214	1.0023	1.0433	1.0207	1.0935	0.959335
6	0.8407	0.7713	0.7605	0.7866	0.7566	0.9429	0.8935	0.9211	0.8546	0.7317	0.6998	0.6334	0.7114	0.8092	0.8546	0.7647	0.7818	0.8935	0.7729	0.9837	0.7997
7	0.7847	0.8263	0.7695	0.7457	0.748	0.9589	0.926	0.9519	0.9172	0.8716	0.6513	0.7015	0.725	0.8631	0.8686	0.7159	0.8512	0.9589	0.8198	1.0286	0.82596
8	0.7829	0.8102	0.7495	0.7297	0.7243	0.9068	0.9068	0.9348	0.8698	0.8417	0.6522	0.6805	0.708	0.829	0.8583	0.7115	0.8135	0.9068	0.797	0.9241	0.799595

DMU	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Cross efficiency
9	0.7721	0.8629	0.7499	0.7311	0.7705	0.955	0.9382	0.9514	0.9306	0.8883	0.6413	0.6969	0.7063	0.838	0.8687	0.7039	0.8235	0.7705	0.8138	1.0277	0.822715
10	0.6929	0.85	0.7294	0.6635	0.6895	0.8431	0.8818	0.8949	0.852	0.9894	0.5743	0.7512	0.6932	0.825	0.8122	0.6331	0.8519	0.8949	0.8331	0.9819	0.794015
11	1.1195	0.9075	0.9568	0.7692	0.847	0.94	0.9654	1.0173	0.8429	0.833	1	0.8535	0.9865	0.9439	1.0006	0.9495	0.9858	0.94	0.906	0.4721	0.90474
12	0.974	0.9828	0.9967	0.7995	0.8969	0.9699	0.9336	0.9397	0.8616	0.9731	0.8327	0.993	0.9977	0.9575	0.9054	0.8618	1.0969	0.9397	1.0293	0.7049	0.935195
13	1.0314	0.8508	0.9325	0.7686	0.7742	0.8612	0.8944	0.9385	0.7646	0.8214	0.902	0.8469	0.9432	0.8963	0.9179	0.8925	0.9614	0.9385	0.9086	0.529	0.862975
14	1.0053	0.9012	0.9398	0.769	0.8231	0.9402	0.9425	0.9815	0.8497	0.8857	0.8735	0.8735	0.9482	0.945	0.9466	0.8752	1.0088	0.9402	0.929	0.567	0.89305
15	0.992	0.7727	0.7436	0.7474	0.7578	0.8618	0.9118	0.9606	0.7866	0.652	0.8652	0.5901	0.7203	0.758	0.93	0.8606	0.7057	0.9606	0.7131	0.5301	0.773495
16	1.0697	0.8547	0.9769	0.9702	0.8502	0.9675	0.9355	0.9648	0.8154	0.7918	0.8958	0.806	0.9238	0.9142	0.9308	0.9668	0.9553	0.9355	0.968	1.0215	0.92416
17	0.8783	0.8366	0.8915	0.7844	0.774	0.8552	0.8298	0.8392	0.7457	0.8326	0.7378	0.839	0.8628	0.8421	0.805	0.7913	0.9429	0.8298	0.9278	0.8379	0.838065
18	0.8662	0.8807	0.8997	0.8018	0.7735	0.851	0.8619	0.8681	0.7636	0.9152	0.7225	0.8778	0.8632	0.8582	0.8264	0.7861	0.9626	0.851	0.9716	0.9734	0.86449
19	0.8708	0.8322	0.8534	0.7756	0.7515	0.7889	0.8084	0.8119	0.6952	0.8021	0.7318	0.7992	0.8214	0.7802	0.7849	0.7841	0.8658	0.8084	0.8999	0.8232	0.80722
20	0.8468	0.8296	0.813	0.7823	0.7664	0.7998	0.8095	0.8051	0.706	0.773	0.7066	0.7424	0.7704	0.7501	0.7746	0.7682	0.8116	0.8051	0.8639	0.9512	0.79479

Table 3: Ranking of Boys' schools

rank	
1	〖DMU〗 _5
2	〖DMU〗 _3
3	〖DMU〗 _12
4	〖DMU〗 _4
5	〖DMU〗 _16
6	〖DMU〗 _2
7	〖DMU〗 _11
8	〖DMU〗 _14
9	〖DMU〗 _18
10	〖DMU〗 _13
11	〖DMU〗 _17
12	〖DMU〗 _7
13	〖DMU〗 _9
14	〖DMU〗 _1
15	〖DMU〗 _19
16	〖DMU〗 _6
17	〖DMU〗 _8
18	〖DMU〗 _20
19	〖DMU〗 _10

rank	
20	〖DMU〗_15

In the above Table, DMU_5, DMU_3, DMU_12, DMU_4, and DMU_16 e-based method was applied have higher rankings compared to other schools. The schools where the cooperative method was taught are ranked next. It is also observed that in the schools where the game-based method was implemented, both the reinforcement of learning and the students' interest in mathematics are higher than in other schools.

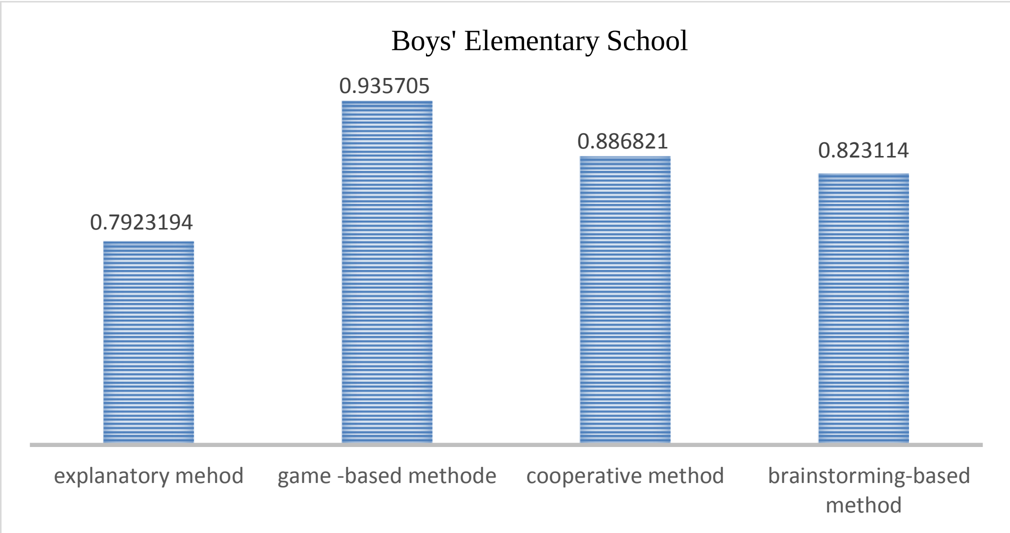

Fig. 1. Evaluation Chart of Teaching Methods in Boys' School

Table 4: Girls' schools data

DMU	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Cross Efficiency
1	0.8055	0.7842	0.6615	0.6988	0.6251	0.0087	0.2901	0.3032	0.62	0.678	0.6673	0.6309	0.6759	0.6814	0.6575	0.7047	0.7039	0.6984	0.6962	0.7679	0.61796
2	0.9651	0.9916	0.8367	0.6824	0.8202	0.0097	0.394	0.4118	0.8089	0.6627	0.8107	0.7977	0.8466	0.8669	0.7988	0.8428	0.9037	0.8672	0.874	0.9698	0.758065
3	0.9696	1.0556	1	0.7296	0.8326	0.0101	0.4168	0.4357	0.8319	0.7084	0.8108	0.9534	0.9664	0.9106	0.7988	0.8472	1.0038	1.0268	1.038	1.1061	0.82261
4	0.9184	0.9292	0.8074	1	0.8764	0.0103	0.3577	0.3739	0.8403	0.9709	0.7516	0.7697	0.809	0.8036	0.7405	0.805	0.9008	0.8601	0.8514	0.9714	0.76738
5	0.8792	0.9101	0.8425	0.7614	0.8489	0.0107	0.3401	0.3555	0.8009	0.7387	0.7285	0.8035	0.8285	0.7833	0.7177	0.7692	0.901	0.8801	0.8811	0.9829	0.73819
6	0.9479	0.8252	0.5983	1.1856	0.9378	1	0.5915	0.6183	0.9249	0.6566	0.7749	0.7822	0.7717	0.9329	0.7634	0.8208	0.9059	0.7966	0.7923	0.9225	0.827465
7	0.7059	0.8824	0.6453	0.7829	0.6562	0.0097	0.7599	0.7943	0.7725	0.7598	0.5772	0.6153	0.6402	0.7993	0.5687	0.6188	0.7717	0.6868	0.6798	0.7794	0.675305
8	0.6987	0.8535	0.597	0.6808	0.6106	0.0091	0.7337	0.7669	0.7196	0.6607	0.575	0.5693	0.6033	0.7795	0.5665	0.6119	0.7161	0.6332	0.6289	0.7207	0.63675
9	0.7322	0.9072	0.6593	0.7826	0.6964	0.0096	0.7598	0.7942	0.8113	0.7598	0.5998	0.6286	0.6568	0.8223	0.5909	0.6417	0.7971	0.7008	0.6944	0.802	0.69234
10	0.718	0.9187	0.7289	0.8418	0.6552	0.0089	0.7282	0.7612	0.77	0.8175	0.5856	0.6949	0.7026	0.821	0.577	0.6296	0.8257	0.7735	0.7656	0.8527	0.70883
11	0.9726	1.0362	0.8913	0.23	0.9265	0.0094	0.3784	0.3956	0.7762	0.2233	0.9616	0.8498	0.9246	0.9348	0.9474	0.8319	0.9135	0.7885	0.877	0.9391	0.740385
12	0.8332	0.9325	0.9111	0.3482	0.8468	0.01	0.3578	0.374	0.7647	0.3379	0.7385	0.8689	0.8806	0.8128	0.7276	0.7223	0.917	0.8664	0.9187	0.9828	0.70759
13	0.797	0.8412	0.757	0.2368	0.7111	0.0092	0.3024	0.3161	0.6276	0.2296	0.7476	0.7222	0.7698	0.746	0.7365	0.686	0.7573	0.6959	0.7557	0.8009	0.612295

DMU	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Cross Efficiency
14	0.7793	0.8772	0.7723	0.2519	0.7466	0.0093	0.3613	0.3776	0.6808	0.2444	0.7192	0.7366	0.7741	0.7832	0.7086	0.6721	0.7979	0.7153	0.7725	0.8295	0.630485
15	0.7769	0.7751	0.5291	0.2417	0.6967	0.0086	0.3461	0.3618	0.6414	0.2345	0.7221	0.5046	0.5758	0.7164	0.7115	0.6695	0.6321	0.5162	0.5427	0.6278	0.54153
16	0.8401	0.8355	0.6959	0.6364	0.6997	0.0103	0.321	0.3355	0.6852	0.617	0.7022	0.664	0.7113	0.7299	0.6919	0.7341	0.758	0.7278	0.7301	0.8153	0.64706
17	0.7319	0.7946	0.7489	0.4835	0.6719	0.0089	0.3111	0.3252	0.6508	0.469	0.6181	0.7142	0.7274	0.6873	0.609	0.6368	0.7679	0.7604	0.7745	0.8371	0.616515
18	0.7647	0.8487	0.7887	0.6599	0.6876	0.0089	0.3562	0.3724	0.6959	0.6405	0.6337	0.7521	0.7603	0.7339	0.6244	0.669	0.8158	0.8191	0.822	0.8903	0.667205
19	0.8325	0.8939	0.7997	0.5254	0.7191	0.0088	0.306	0.3199	0.682	0.51	0.7058	0.7625	0.7906	0.7363	0.6953	0.726	0.8114	0.8133	0.8283	0.893	0.66599
20	0.833	0.8627	0.7786	0.7072	0.7276	0.0087	0.3292	0.3441	0.7125	0.6867	0.691	0.7423	0.7708	07451	0.6808	0.7287	0.8186	0.8136	0.8147	0.8949	0.68454

Table 6: Ranking of Girls' Schools

rank	
1	〖DMU〗_6
2	〖DMU〗_3
3	〖DMU〗_4
4	〖DMU〗_2
5	〖DMU〗_11
6	〖DMU〗_5
7	〖DMU〗_10
8	〖DMU〗_12
9	〖DMU〗_9
10	〖DMU〗_20
11	〖DMU〗_7
12	〖DMU〗_18
13	〖DMU〗_19
14	〖DMU〗_16
15	〖DMU〗_8
16	〖DMU〗_14
17	〖DMU〗_1
18	〖DMU〗_13
19	〖DMU〗_17
20	〖DMU〗_15

In the above Table, DMU_6, DMU_3, DMU_4, DMU_2, and DMU_{11} e-based method was applied have higher rankings compared to other schools. The schools where the cooperative method was taught are ranked next. It is also observed that in the schools where the game-based method was implemented, both the reinforcement of learning and the students' interest in mathematics are higher than in other schools.

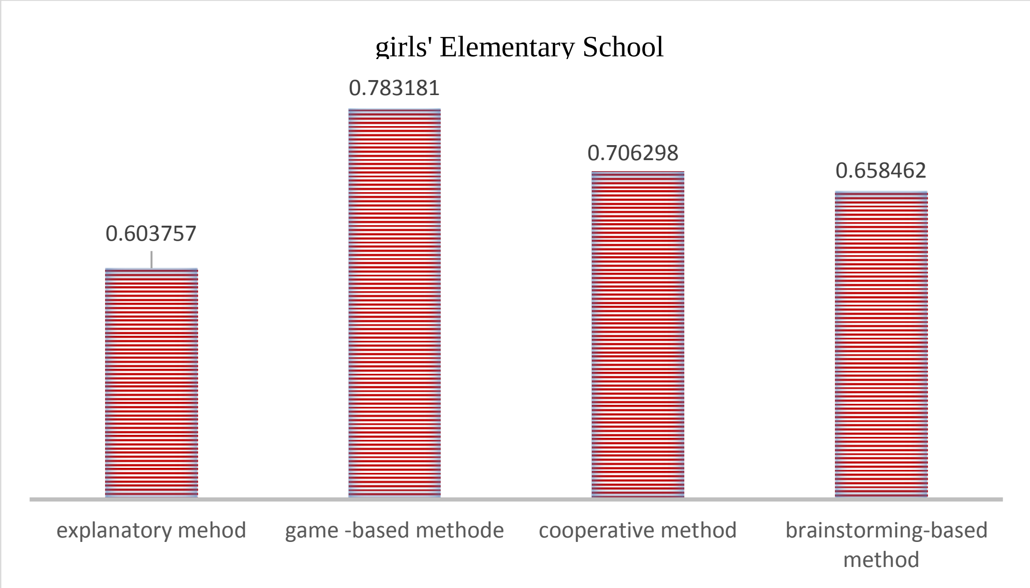

Fig. 2. Evaluation Chart of Teaching Methods in girls' School

DISCUSSION AND CONCLUSION

Mathematics anxiety is a common issue among students that can significantly impact their academic performance. This study examines the effect of mathematics instruction on reducing students' math anxiety using a two-stage network data envelopment analysis (DEA) model. In the first stage, the efficiency of each network unit in generating inputs was measured, and in the second stage, their ability to convert inputs into outputs was evaluated. This approach allows for assessing the performance of educational units at both stages and can also be applied in various fields such as transportation, production, healthcare services, and finance.

Based on the findings of this study, the game-based teaching method achieved the highest ranking in both boys' and girls' schools compared to other teaching approaches. These results indicate that integrating mathematics education with games enhances students' motivation and reduces their anxiety. When mathematical concepts are presented in an engaging manner and aligned with students' real-life experiences, they become more interested in learning and take greater responsibility for their own education. The more comprehensible and tangible a problem is for students, the easier it becomes for them to find solutions. Additionally, using concrete examples, interactive exercises, and game-based methods leads to better understanding and increased enthusiasm for mathematics.

These findings can guide teachers and educational policymakers in adopting innovative teaching methods that improve the effectiveness of mathematics learning while reducing anxiety among students.

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ETHICAL APPROVAL

All research was conducted in accordance with the regulations of the Education Department of Semnan and relevant ethical guidelines.

CONSENT

Informed consent was obtained from all participants and/or their legal guardians for participation in the study.

CONFLLICT of INTEREST

The authors declare that they have no conflict of interest related to this work.

DATA AVAILABILITY STATEMENT

The data generated and analysed during this study are not publicly available but are available from the corresponding author upon reasonable request.

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