Simülasyon ile Öğrenme İçin Tasarlanmış Web Tabanlı Yeni Bir Elektrik Ticareti Oyunu

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Anahtar Kelimeler
Elektrik piyasaları,
Simülasyon ile öğrenme,
Piyasa takas fiyatı,
Gün öncesi piyasası,
Gün içi piyasası

Öz: Pek çok ülkede, elektrik endüstrisi, düzenlenmiş ve tekel veya oligopol bir sistemden liberal bir sisteme dönüşümü sağlayan bir yeniden düzenlenme (de regülasyon) sürecinden geçti. Yeni sistem, bağımsız üreticilerin elektrik piyasasına girmesine ve teklif yoluyla elektrik satmasına olanak tanımaktadır. Bazı pazarlarda, tüketiciler elektrik talep etmek için de teklif verebilir. Serbestleşen elektrik piyasası, yeni başlayanlar, öğrenciler ve genç profesyoneller için anlaması zor bir yapıdadır. Bu çalışmanın iki ana hedefi vardır: ilk olarak, yatırım ve ticaret dahil olmak üzere elektrik piyasasının dinamiklerini benzeten yeni bir web tabanlı elektrik ticaret oyunu sunmak ve ikinci olarak, karmaşık elektrik piyasası işleyişini anlatma açısından, simülasyon oyunu ile öğrenmeyi klasik sınıf öğretim yöntemleri ile karşılaştırmaktır. Anket sonuçları, öğrencinin bilgisinin başlangıçtaki durumuna göre yaklaşık %94 arttığını göstermektedir. Test sonuçları, oyunla ilgili sorular için ortalama %80'lik bir başarı oranı sergilemektedir. Klasik yöntemle öğretilen konuların ortalama başarısı ise yaklaşık %70'tir. Sonuçlar, simülasyon oyununun elektrik piyasası gibi karmaşık konular için daha iyi bir öğretim yöntemi olduğunu kanıtlamaktadır.

A Novel Web-Based Electricity Trading Game Designed for Simulation-based Learning

Keywords
Electricity markets, Simulation-based learning, Market-clearing price,
Day-ahead markets,
Intraday Markets

Abstract: In many countries, the electricity industry went through a deregulation process that changed it from a regulated and monopolistic/oligopolistic system to a liberal one. The new system allows independent producers to join the electricity market and sell electricity through bidding. In some markets, consumers can also bid to demand electricity. The characteristics of the liberalized electricity market in addition to its never-ending evolution make it difficult for students and young professionals to comprehend its structure and functioning. This paper sets out to achieve two goals. First, we will present a new web-based electricity trading simulation program that simulates the dynamics of the electricity market including investment and trading. Secondly, we compare classical classroom teaching methods against the simulation game teaching method to demonstrate the superiority of the latter in explaining the workings of the complex liberalized electricity market. Questionnaire results show that students' knowledge is increased by approximately 94%. Test results exhibit an average success rate of 80% for the game-related questions. The average success rate for subjects taught by classical methods is approximately 70%. The results show that the simulation game proves to be a better teaching method for complex subjects such as the liberalized electricity market.

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1. Introduction

The electricity industry used to be regulated. Network sectors such as electricity began as private entities [1] but later morphed into monopolistic systems [2]. A sector is said to have a natural monopoly when its expensive capital cost and demand can be matched at the cheapest cost by one company [3]. Competition is not pondered as a tool for achieving good pricing and standard of service [4]. With a focus on the national level, governments used to plan to expand capacity as a means of investing in power plants in the monopoly system [5]. The most efficient combination of power plants, the appropriate capacity of the power plant, the best moment to decommission the plants are some of the reasons that necessitate central planning [6].

Even though the regulated or monopoly system ensures certainty in business operations, consumers' electricity demand and fuel prices remain uncertain [5]. The regulated electricity industry only allows electricity generators to decide the price of electricity [5]. These electricity generation companies are owned by the state and are integrated into a top-down fashion [7]. Moreover, monopolies are not usually very effective [8,9].

Researchers studied monopoly regulations [10] and how sectors such as electricity and gas are liberalized [4]. Natural monopoly began to be contended in the 1970s and 1980s citing that some utilities could operate better in a market environment [2]. Subsequently, the competition was introduced in the electricity sector [11]. Chile was the pacesetter [12] and England, Wales, and Norway followed suit [13,14]. This then propagated to other countries prompting the European Union (EU) to support competition in 2000 [15].

The liberalization of the electricity sector is needed to solve the problems in the monopoly system [13]. Even though the aim of deregulating electricity remains common across different jurisdictions, different methods of executing the competitive market system were adopted. In Europe, it was the quest for efficiency, which was believed will lead to cheaper electricity prices, and restricting the state's participation was the case for England [2]. Developing countries deregulated the electricity sector because they were unable to expand the industry due to financial constraints [16]. Deregulating the electricity sector reduced electricity prices and promoted new ideas as a result of competition [17].

Contrary to other deregulated markets that rarely regulate their system, electricity markets mostly require an established regulatory body [18]. This is because of the evolving market dynamics in terms of technology, initial designs, and behavioral changes of participants such as consumers, generators, and policymakers [2]. Several factors including adequate coverage, good capacity, and reasonable prices are considered during regulation [18].
The state of countries that adopted the electricity sector reform before the deregulation varied greatly [2]. For example, in terms of electricity coverage, while most countries in Western Europe had almost full nationwide coverage [2], just about a third of Nigeria was covered [19]; for technology, Norway adopted hydro as its primary technology [20] but Denmark used none [2]. In 1995, Columbia suffered a major electricity crisis before deregulation that resulted in major blackouts [21].

The format of deregulation is different for each country [2]. For example, to allow new entrants at the generation level and initiate competition, the UK liberalized generation while keeping transmission and distribution regulated [22]. It also started a new concept called the price-cap regulation which was intended to promote dependency and regulatory forecasting [23].

Because of the constant changes in the market dynamics, the intended objective, which is to provide reliable power at the lowest price possible across the nation, is not always realized [2]. This is due to the regulatory challenges [21] and solving these problems can be tough, expensive, and time-consuming.

Uncertainty became the major characteristic of the liberalized market as the state of the market depends on the consumer's desires and competition among generators; this makes planning a challenge [24]. Paşaoğlu [5] explained that the inconsistency in the market makes it difficult to use optimization methods to forecast and prescribe actions. Dyner and Larsen [16] complemented this by adding that other approaches such as agent-based modeling are needed to work in tandem with a solid strategy to succeed in the deregulated market.

The internet mostly exists as a tool for communication which most students are excited to use. However, Kiili [25] argues that students who are already conversant with technology no longer acknowledge this. Creating computer games that conform to how students behave will help them learn concepts easily [26]. According to Norman [27], games do not only

provide the necessary environment for learning but also enable the gamer to engage with the environment. The experiential environment games provide is the cause of the success of educational games [25].
In many universities across the world, courses are being introduced to teach the fundamental operations of electricity markets. However, the uncertain nature, basic shift of procedures in the market system, and its incorporation of a vast array of other disciplines complicate the understanding of the deregulated electricity market. Moreover, the newly liberalized electricity market is still under development in some countries [28, 29].
Students traditionally learn through the classical teaching methods but according to Paşaoğlu [5], this method fails to show participants the results of their actions. When Jennings [30] studied the case-based, simulation, and action learning methods to verify the best by evaluating the perceptions of course participants, the simulation method emerged the victor, followed by action learning, and then case learning. Senge [31] points out that people learn better through experience when the results of their exploits are clear and timely.
As such, we set to investigate the simulation game teaching method to justify which would be the most efficient in explaining the electricity market to the students and beginners. To bridge the learning gap, we developed a web-based electricity trading game that uses the simulation teaching method to help students on the deregulated electricity trading and its dynamics. Such simulation software can help students predict the results of the market dynamics before implementation. This paper sets out to achieve two goals. First, we will present a new web-based electricity trading simulation program that simulates the dynamics of the electricity market including investment and trading. Secondly, we compare classical classroom teaching methods against the simulation game teaching method to demonstrate the superiority of the latter in explaining the workings of the complex liberalized electricity market.

The research contributions of this article are as follows:

- Our first contribution is the game itself. While similar liberalized electricity trading simulation games exist, some require the installation of other software packages that might be inconsistent with operating systems or even come with malware, some are specific to a country or a school. Thus, making accessibility difficult and even if accessibility is granted, application to one's need poses unforeseeable challenges. The simulation game presented in this paper solves these difficulties. Also, from the pedagogical perspective, the existing electricity market games we examined have complex interfaces, which make them difficult to comprehend and play without a dedicated guide. Most games require deep expertise in electricity trading including mathematics. However, our system provides a simple and self-explanatory interface almost offering a do-it-yourself approach. We also abstracted all complex calculations from the user. Thus, no specialized knowledge of the electricity market is required. As such students can organize and play the games among themselves without supervision from their professors.
- Although it is not the scope of the paper the game is designed and intended to be used in further research on agent behavior in electricity markets. Analysis of the agents' behavior is not presented in this paper, however, the game offers the opportınity to all interested researchers.
- To the best of our knowledge, there is no other paper that discusses the effects of simulation-based teaching on explaining the electricity market. The main contribution of this paper is to show that the simulation game is superior compared to the traditional teaching methods in learning the electricity markets.

The rest of the article is organized as follows: Section 2 describes the developed electricity market simulation tool, Section 3 presents the results obtained from student questionnaires and examination results, and Section 4 concludes the paper.

2. Material and Method

Electricity is generated by power plants of generation companies, and then it is transmitted via transmission lines before it is distributed to the end-users (Figure 1). The electricity market game is related to the wholesale of electricity at the generation level. Private generation companies (gencos) bid to sell their electricity in an auction. The auction results in determining the market-clearing price (MCP) which is the amount to be paid to all the winning gencos. The MCP is set at the intersection of the supply of gencos and the demand. Each genco needs to consider the demand level and strategies of other gencos. The bid should be low enough to win the auction but the MCP has to be high enough to cover the costs.

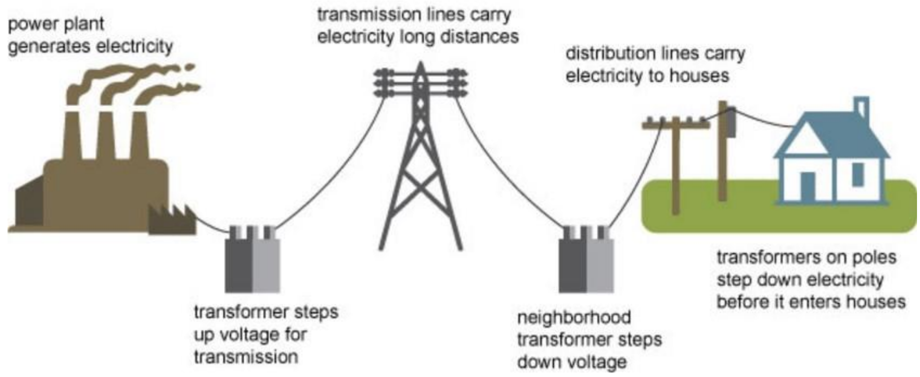

Figure 1 . Simple illustration of the electricity network [33].

2.1 Example Game

Table 1 presents bids of gencos in one period of a simple game to explain how the bidding process works and MCP is determined in a real electricity market (The example game and related table and figure are adapted from [34]). There are five gencos in the game, each of which offers its capacity to the market at a different price. The supply offers are ordered by ascending price which is called the *merit order*. Demand is 55 MW and is represented by a vertical line in Figure 2. The stepped line in the figure is the cumulative supply curve of offers of the gencos. The market is cleared at the intersection of supply and demand lines. In this example, the MCP is set at 55 MW and 40 $/MWh. Dispatch ratios of gencos are determined by the intersection of supply and demand. Supply offers up to the intersection are accepted and the rest is rejected. Gencos A, B, and C are dispatched fully, and D is dispatched with a ratio of 40% so that the accepted supply is equal to the demand. 60% of Genco D's capacity is excess and it is not accepted. Genco E's supply offer is too high to be accepted and it is not dispatched, hence, it will not be paid. Generators A, B, C, and D would each be paid $40 per MWh of their dispatched capacity.

Genco	Capacity (MW)	Bid price ($/MWh)	Dispatch Ratio
A	10	$10	100%
B	15	$15	100%
C	20	$30	100%
D	25	$40	40%
E	10	$70	0%

Table 1. Gencos' bids in the market [34]

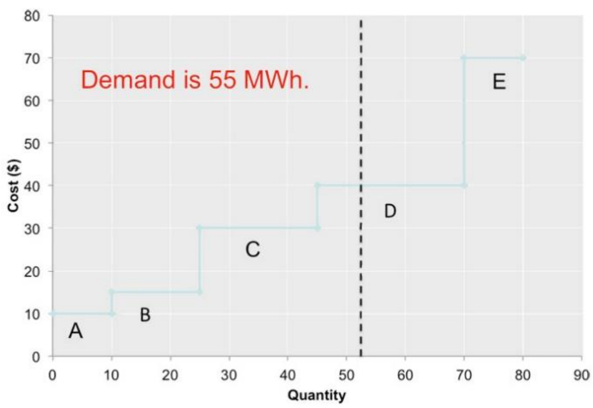

Figure 2. The uniform price auction [34]

In the next period of the game, the gencos, especially D and E, have to reevaluate their strategy to win the auction or get a better dispatch ratio. Genco D would like to get full acceptance and Genco E would like to get paid as well. Therefore, they need to adjust their bid price according to the fuel cost, efficiency, and CO_2 penalty of their technology, the demand increase, and the previous market-clearing price.

Apart from the trading of existing capacity, gencos also need to plan for new investments due to the retirement of existing power plants and/or the desire to earn more money with a higher capacity. For their investment strategy, gencos should evaluate the demand increase rate, possible investment options with their costs, construction and operation times, and investment strategies of other gencos.

2.2 The Electricity Market Game Interface

We present the features of the new electricity market game in this section. It is a web-based game platform that simulates the day-ahead markets of the deregulated electricity trading process. It incorporates the investment, trading (bidding), and power exchange stages of the electricity market. It is a competitive game with an unlimited number of human agents (players). Its web-based characteristic allows user accessibility from anywhere in the world and on any computer with an internet connection. This eradicates the need for software installation. Besides, it is cross-platform and independent of the operating system. These features make the system simple and user-friendly.

The game is played in periods and each period represents a year. A period begins with investment and bidding and ends with the determination of the market price. Figure 3 shows the main investment page and demand. The investment page contains a box with a field to select the power plant that must be purchased. Also, attention must be given to the budget and the demand for that particular period.

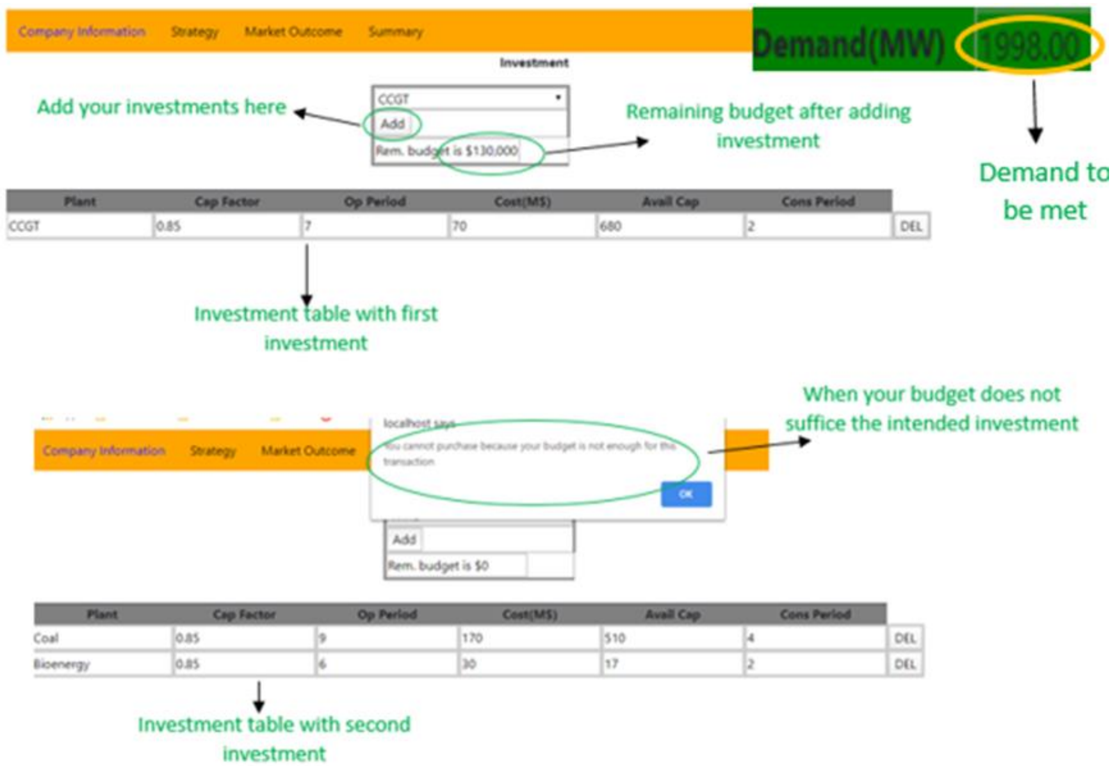

Figure 3. Investment procedures and demand

Each player starts the game with a power plant portfolio and each plant is given a plant number. There are eight alternative technologies to invest in the game and their technical properties are presented in Figure 4. For their investment strategy, players should evaluate the demand increase rate, possible investment options with their costs, construction and operation times, and investment strategies of other players. For example, the nuclear power plant has the greatest capacity and the longest operation period. New players usually choose to invest in it, however, it is the most expensive power plant. Moreover, the construction period for a nuclear plant is the longest. So, even if a player's budget is high enough for a nuclear plant, the player must wait for 5 periods to utilize it. On the other hand, the coal power plant is reasonably priced with relatively good capacity and high efficiency. However, one must consider its high carbon emission as it pollutes the environment and could be charged for each tonne per MWh. The solar plant is one of the cheapest and has the shortest construction period with no carbon emission because it is a renewable energy source. But, it has the lowest efficiency and shortest operation period.

Plant	Nuclear	Coal	CCGT	Hydro	Wind	Solar	Geothermal	Bioenergy
Price(M$)	800	170	70	60	30	40	60	30
Capacity(MW)	900	600	800	120	30	30	50	20
Efficiency/ Cap factors(renewables)(%)	30	40	60	35	30	16	75	85
CO2_Emission(ton/MWh)	0.0	1.0	0.4	0.0	0.0	0.0	0.0	0.2
Con. Period	5	4	2	2	2	1	2	2
Op Period	10	9	7	9	7	6	8	6

Figure 4. Properties of each power plant

To bid in trading, the player selects the plant number in the bidding row. The properties of the selected plant are displayed in the table next to the bidding row. Then, the player inputs the quantity of power that would be offered in MW and the bidding price ($ per MWh). The process continues for all the power plants the player wants to offer. These steps are illustrated in Figures 5 and 6.

Figure 5. Depiction of the bidding segment

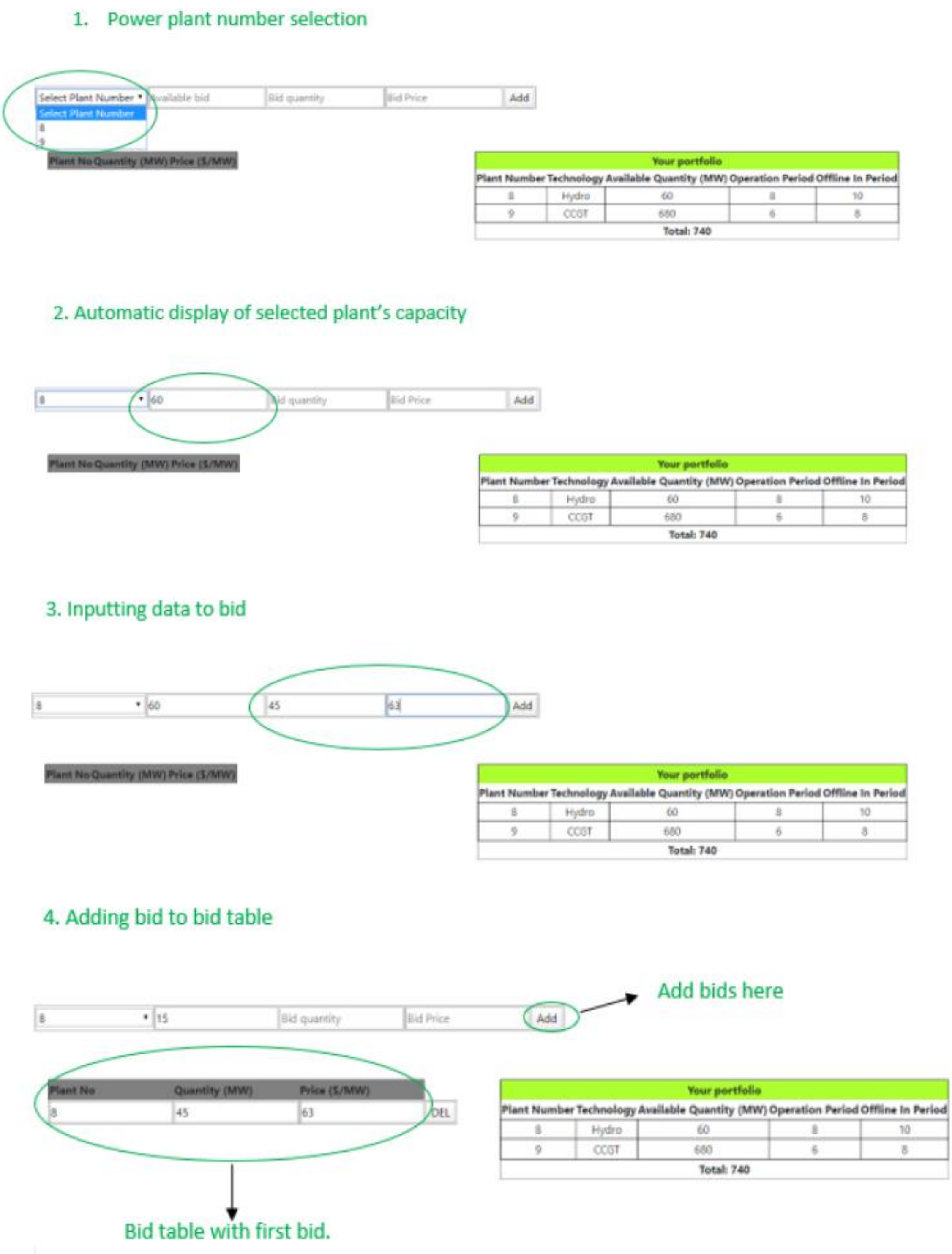

Figure 6. Demonstration of the bidding process

Bidding is done in a quantity-price format as represented in Figure 5. Dispatch ratios in the figure show if a bid is fully accepted, partially accepted, or rejected. For instance, with a total demand of 1998 MW, the supplies (quantity) in Figure 7 are bid to meet the demand. The process of determination of the market-clearing price is simply demonstrated below.

Total demand = 1998 MW (1)

$$\text{Supply} = 60 + 500 + 15 + 45 + 680 + 60 + (680 \times 0.9382) \approx 1998 \text{ MW} \quad (2)$$

Market-clearing price = $ 96 (3)

Quantity(MW)	Price($/MW)	Dispatch_Ratio
60	45	1.0000
500	45	1.0000
15	52	1.0000
45	63	1.0000
680	66	1.0000
60	74	1.0000
680	96	0.9382
180	100	0.0000

Fully accepted bids

partially accepted bids

Unaccepted bids

Market price

.

Figure 7. Accumulated quantity-price bid from players

The market-clearing price is the price at which all the aggregated bids or quantities from generators (players) meet the demand (constant in this case) [32]. This is illustrated in Figure 8. Price per megawatt is represented on the vertical axis while the demand or quantity is on the horizontal axis.

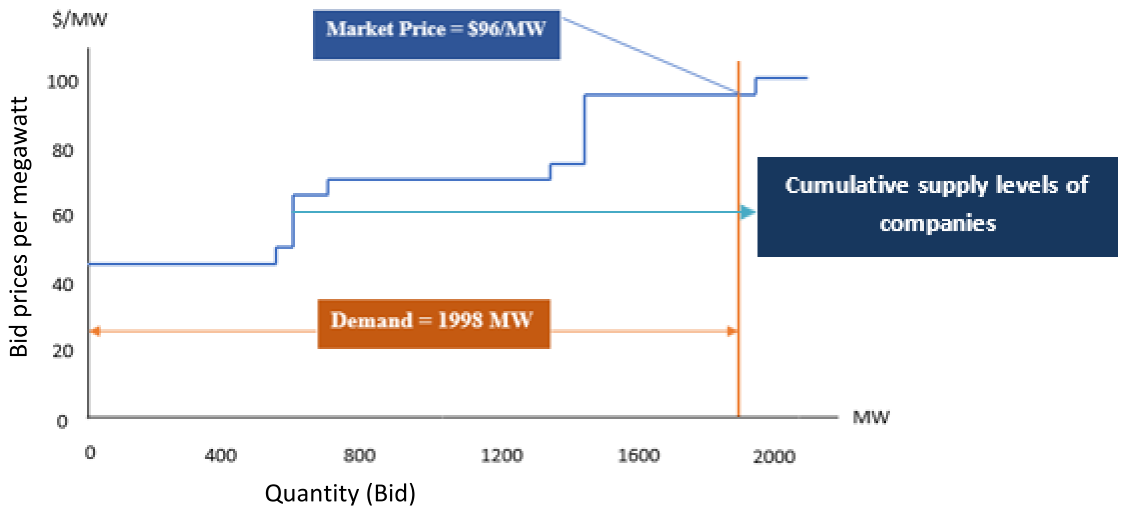

Figure 8. Supply-demand graph

The game continues for the number of periods designated by the manager. The player with the highest budget ranks first. Results are displayed in tables and graphics after each period and when the game is over.

2.3. Architecture of the Electricity Market Game

The general structure of the electricity market game is presented in Figure 9. The system is subdivided into 3 levels, namely, the client, middle, and data.

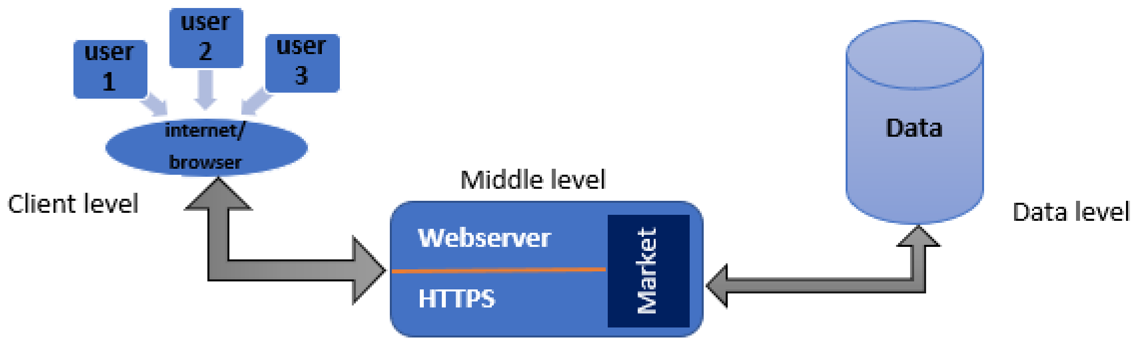

Figure 9. The general architecture of the electricity trading game

JavaScript and PHP are the key web development programming languages used. JavaScript interacts both with the browser and user and PHP performs server-side functions such as executing the algorithm at the power exchange and complementing the Structured Query Language (SQL) to transfer data to and from the database. The client level consists of the users, that is, the players (representing the generation companies) and the manager, and each agent interacts with the system via the web browser. The manager logs into the system, names the game, selects players, set a time limit for each period, and creates the game. The manager can also choose to play. The player logs in to the dashboard, invests in the power plant, submits bids from the power plant portfolio, and views the results of the bids. Each player aims for budget maximization. Figures 10 and 11 illustrate the roles of the manager and players at the client level, respectively.

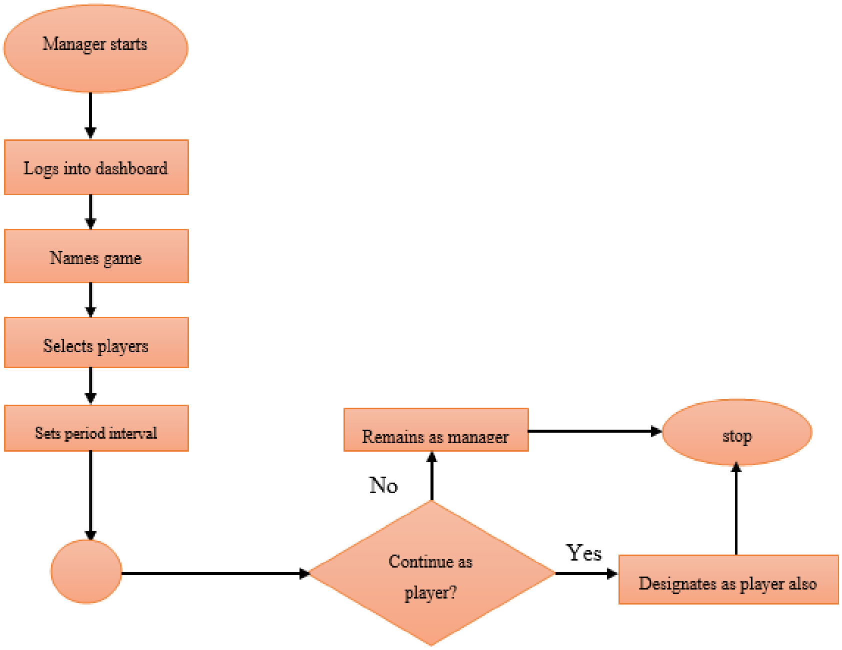

Figure 10. Flowchart displaying the manager’s role

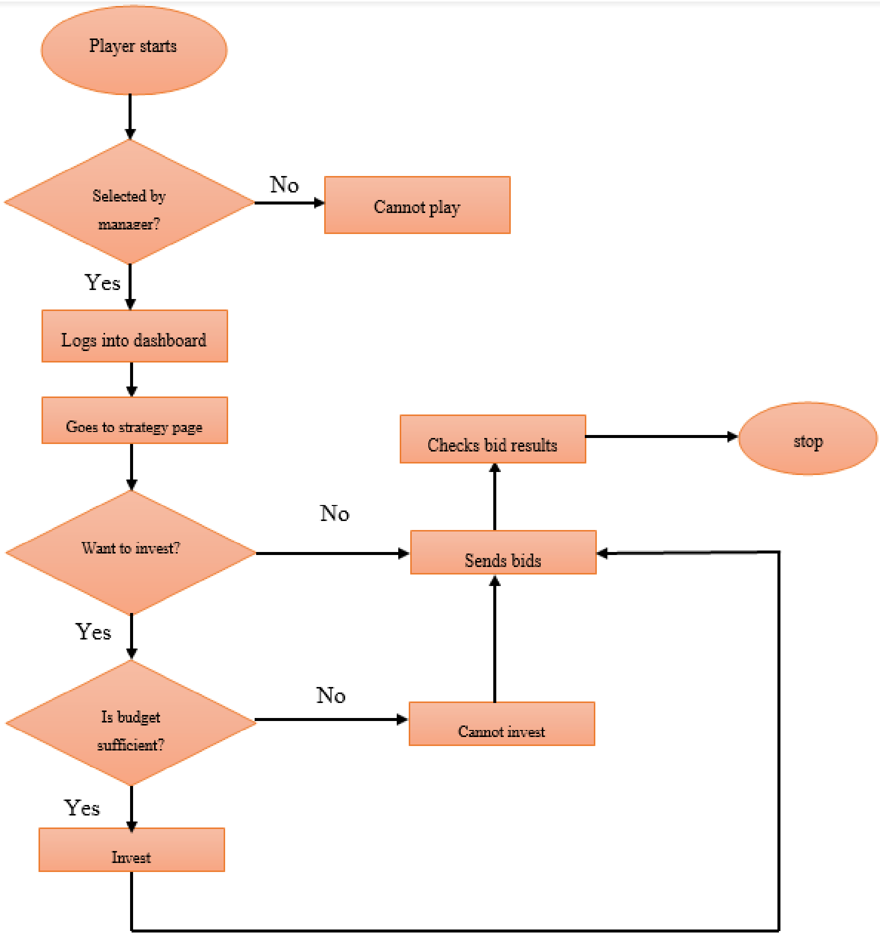

Figure 11. Flowchart displaying player's role

The middle level is made up of two parts, namely the webserver and the power exchange. The web server, with the aid of Hypertext Transfer Protocol (HTTP), creates an environment suitable for responding to clients' requests. The power exchange, created using PHP and JavaScript, hosts all the algorithms that compute the market-clearing price, demand for the next period, profits, and budgets. It also consists of a countdown timer and executes the algorithms continuously at the end of the set time (See Figure 12).

The data level encompasses the database. It stores both temporal and permanent data about the electricity trading system. Some of the temporal data are the market price, the calculated profit, and the budget for each period while the permanent data is the users' data. Figure 13 presents the power exchange.

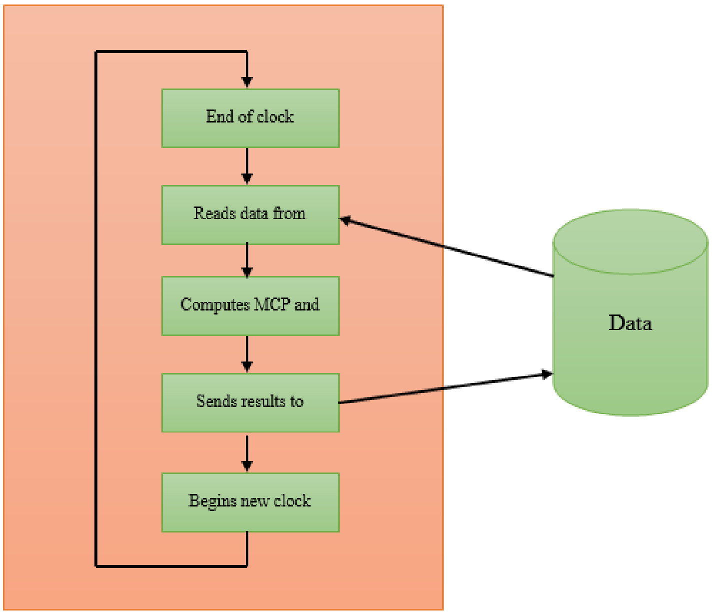

Figure 12. Flowchart showing the steps of the power exchanges (MCP: market-clearing price)

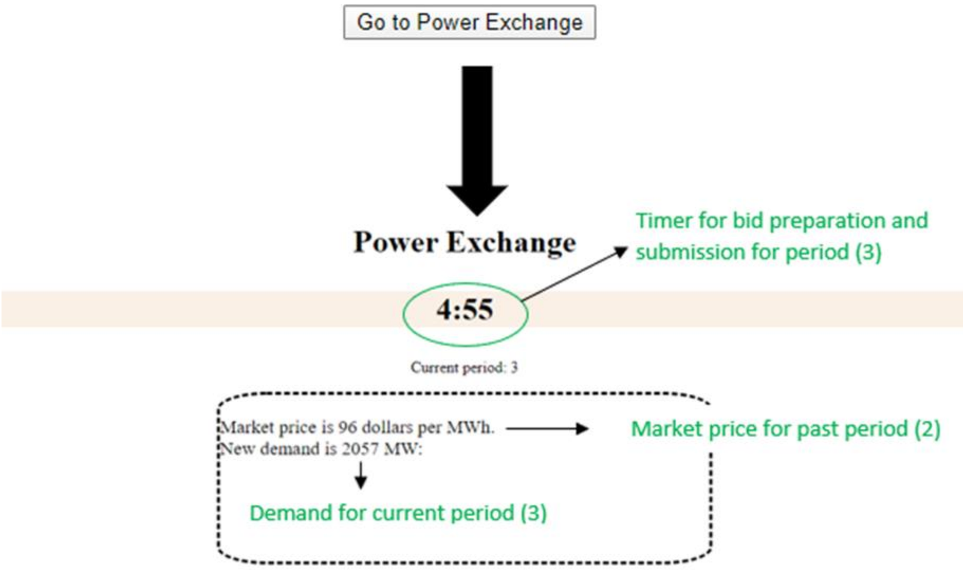

Figure 13. The power exchange

2.4. Application in the classroom

A total of 264 students participated in the game as part of the Energy Economics and Policy and/or Energy Law courses. The last 4 weeks of the semester for both courses are reserved for the game sessions. Students are allocated into groups of approximately 30 players and each group played the game in two sessions. Grouping was necessary due to the server capacity of the website hosting. It also helped to manage the game effectively and answer student questions in detail. Every student joined the game via their personal computer. Later, some experiments show that it is easier to organize the game sessions via online platforms such as Zoom because it is difficult for students to use their PC in the classroom especially due to the limited charging outlets and low wi-fi speed. Online platform teaching is also easier for the instructor to share their screen with students for explanations about the game.

3. Results

One of the main goals of this work is to assess students' understanding of the electricity market. We achieved this by comparing results obtained from questionnaire responses on the simulation game and examination tests of the electricity market lessons taken in class.

3.1 Results from the simulation game

After many rounds of the simulation game, 86 students responded to a questionnaire designed to examine their comprehension of various concepts as pertained to the deregulated electricity trading.

To ascertain the rate of increase in the understanding of the deregulated electricity market, we first checked their knowledge level before the game. We found out that only 3 students, representing 3.4% of the students have a firm understanding of the deregulated electricity market. The details are presented in Figure 14.

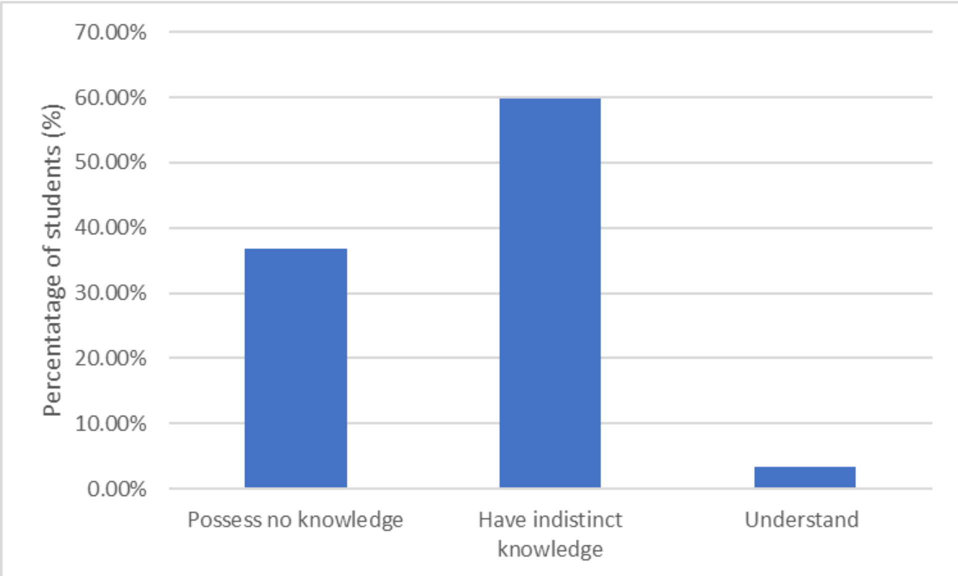

Figure 14. Students' knowledge of the liberalized market before the game

After the game and using a scale of 0 to 5, where 0 means "Have no knowledge" and 5 means "Absolutely understood", we examined the students' comprehension of electricity auctions and determination of bidding price, the investment process, and the determination of market-clearing price. 19 students (22.1%) "absolutely understood" (scale 5) the electricity auctions and determination of bidding price and 44 students (51.2%) chose scale 4, signifying that they "understood".

19 students (22.1%) "absolutely understood" the investment process, 37 (43%) checked scale 4, and scale 3 was marked by 29 students (33.7%). Only 1 student chose 1 and none selected 0.

The trend is similar for the market-clearing price where 33 students (38.4%) marked 5, 37 (43%), and 13 (15.1%) students selected scales 4 and 3, respectively. Figure 15 illustrates these results in detail.

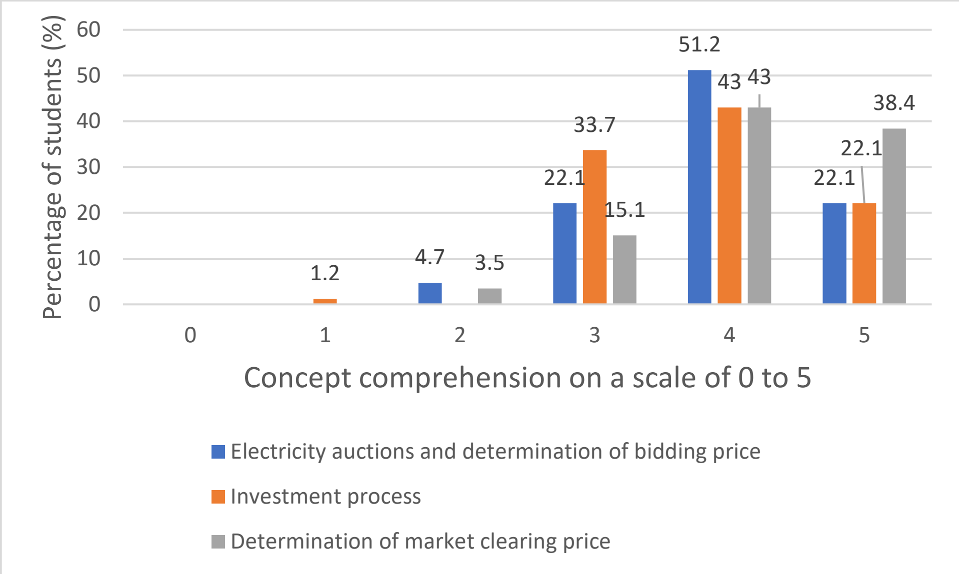

Figure 15. Students' knowledge level after playing the game

We can conclude that 95.4% of students understood the electricity auctions and determination of bidding price, 98.8% understood the investment process, and 97.5% understood the determination of market-clearing price. On average, 97.23% of the students generally understand the liberalized electricity trading through the simulation game. Comparing this with the pregame percentage, there is a 93.83% increase in knowledge which is a convincing improvement on the effectiveness of the simulation game.

Figure 16 presents students' comments on the game. Most of them find the game fun, educative, and informative. Only one student found the game boring. One other student stated that the game was difficult to understand. However, the same student stated that the game was informative. More than 70% of the respondents stated they wish other lessons also use simulation games.

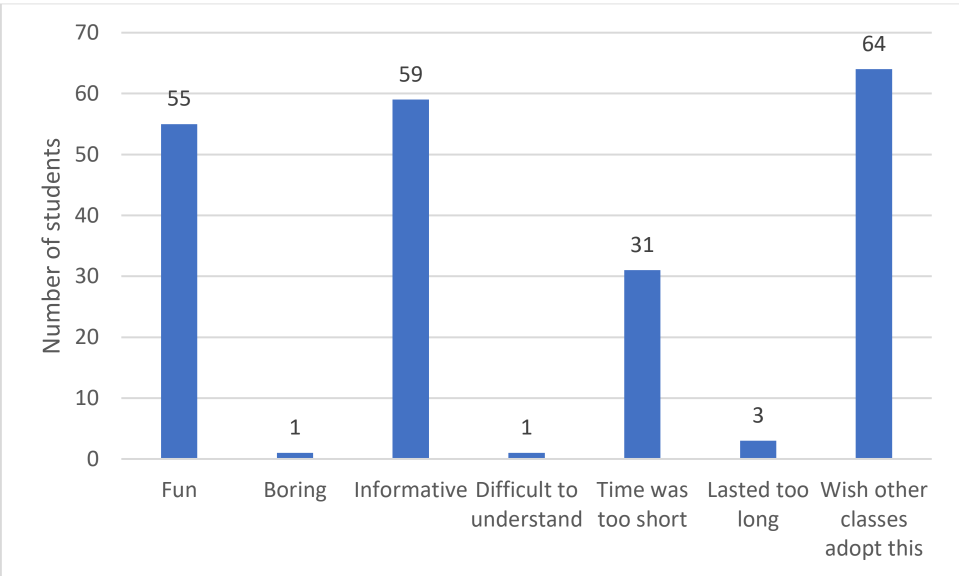

Figure 16. Students perspective of the game

3.2. Results from tests

Students take a final test for the Energy Economics and Policy course conducted in the Department of Energy Systems Engineering at Erciyes University where the game is used for teaching purposes. A total of 264 students participated in a 40-question examination. The questions are categorized as follows: (a) bidding questions related to the simulation game, (b) cost computation problems associated with power plants, (c) profit maximization problems related to power plants, (d) Herfindahl-Hirschman Index (HHI) calculation problems, (e) game theory and analysis questions, and (f) conceptual questions about energy economics and policy.

There are 15 simulation game questions, and they are designed to assess the student's knowledge about the bidding process and market clearing. There are five questions about power plant cost calculation questions and students need to make detailed calculations about plant capacity, efficiency, fuel cost, carbon penalties, and investment costs. There are five questions about profit maximization and these questions require taking derivatives of profit and revenue functions. There are seven HHI calculation and market analysis-related questions, and these are relatively easier than cost calculation and profit maximization problems. Game theory and analysis questions are related to a simple two-OPEC-country problem where countries try to maximize their revenue. There is also one conceptual question, usually related to the definition of a term about energy economics and policy.

The overall success rate of the students is determined to be 76.68%. Recorded as the best success rate is the bidding question as 212 students, representing 80.4%, performed excellently. This makes sense since the questions in this category are tied to the simulation game. A sharp contrast to that and the least success rate at 68.4% (181 students), is the conceptual question. This is pure theory and has no relation to the simulation game. Other success rates include 185 students (70.2%) for the cost computation, 188 students (71.5%) for the profit maximization, 197 students (74.6%) for HHI, and 212 students (80.1%) for the game theory problems. Figure 17 presents these findings. Just as the conceptual question category, cost computation, and profit maximization are also theory lessons entirely covered in class, hence the lower success rates.

The game theory category also had a gaming component besides the bidding question category. Even though they were also covered in class, the supervisor organized a game session that was used to demonstrate the concept. Thus, the success rate is higher. This again demonstrates the advantage of simulation gaming as a tool for explaining complex ideas and theories to students and inexperienced professionals.

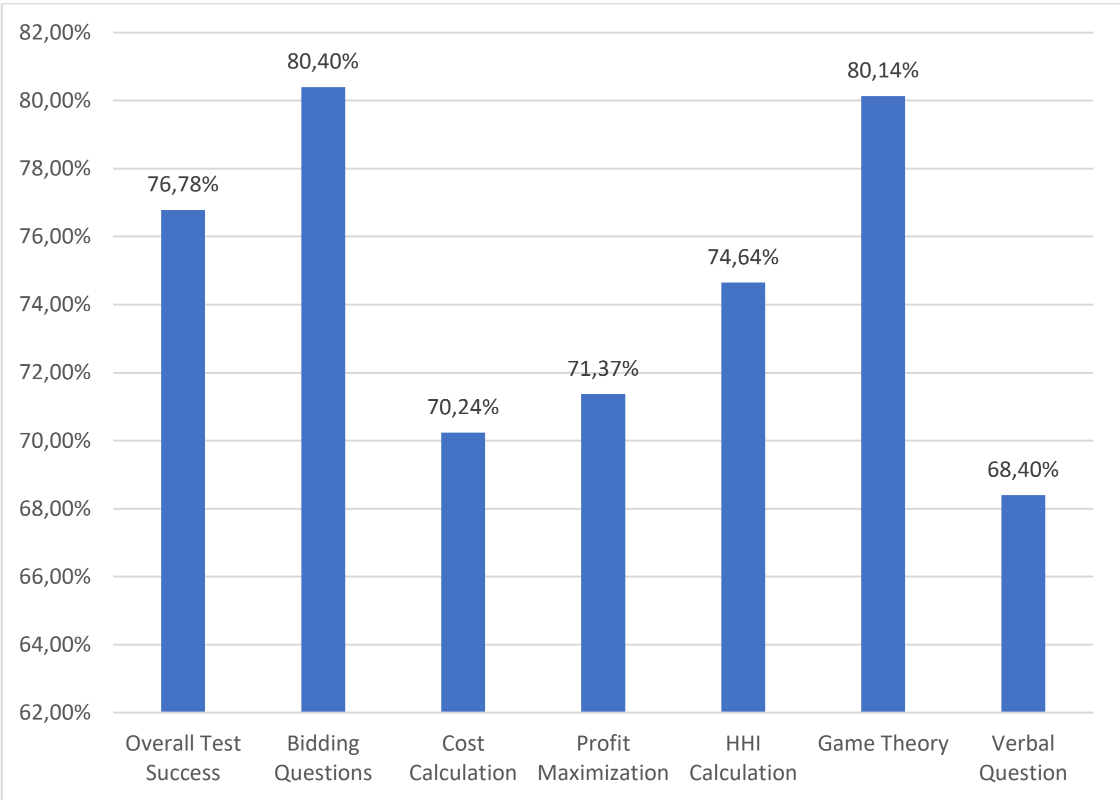

Figure 17. Student success rates after taking classroom lessons

The game is also implemented in the Energy Law course so that students can offer legal regulations to overcome the flaws of the simulation game. Students are asked before the game to observe the game process and potential flaws while playing the game. After the game, the groups are given homework to offer two legal regulations to fix the observed flaws of the market as simulated in the game. The legal regulations are asked to be written in the format of Turkish law. There have been several interesting ideas, however, most students focused on low prices due to the competition and excessive investments. Most groups offered some kind of price floor regulation because they observed that their profits are lost due to the low bid prices. The second most offered regulation type was on investment cap. Students observed that they have invested excessively at the beginning rounds of the game and this caused destructive competition towards the end and most groups suffered serious losses in the market.

The original idea of the Energy Law course was to implement the most voted legal regulation offer to the simulation game and to play one more session with the same groups so that students could observe the changes. However, this idea could not be implemented due to the high number of students and the limited class time.

Another purpose of the game is to observe player behaviors so that artificial intelligent agents can be designed for future research. We are still working on analyzing data for this purpose and the game will be modified accordingly.

4. Discussion and Conclusion

We present a web-based game that simulates the deregulated electricity market. The simulation consists of three levels; client, middle, and data levels. The client is made up of the users and the web browser. The users (players and the manager) use the web browser to interact with the system. The middle level contains the HTTP which helps to receive and respond to users' requests and the power exchange that hosts the algorithms to compute the market results such as the market-clearing price.

Unlike the existing similar games, our application does not require any installation of other software packages, it is much easier to access and more universal in terms of game specifics. Also, from the pedagogical perspective, the existing electricity market games we examined have complex interfaces, which make them difficult to comprehend and play without a dedicated guide. Most games require deep expertise in electricity trading including mathematics. However, our system provides a simple and self-explanatory interface almost offering a do-it-yourself approach. We also abstracted all complex calculations from the user. Thus, no specialized knowledge of the electricity market is required. As such students can organize and play the games among themselves without supervision from their professors.

To the best of our knowledge, there is no other paper that discusses the effects of simulation-based teaching on explaining the electricity market. The main contribution of this paper is to show that the simulation game is superior compared to the traditional teaching methods in learning the electricity markets. Findings show that simulation-based learning has proven to be successful with the complex deregulated electricity market. Results from the simulation game were compared to the students' end-of-semester examinations results. The average questionnaire score for the simulation game was 97.23% and that of the exam result was 80%, proving the superiority of the simulation game teaching over the classical teaching methods.

Although it is not the scope of the paper the game is designed and intended to be used in further research on agent behavior in electricity markets. Analysis of the agents' behavior is not presented in this paper, however, the game offers the opportınity to all interested researchers. In the future, we intend to add artificial intelligence (AI) components such that either only AI-agent will act as players or play together with human agents, implement carbon market, and demand-side bidding. We are now working on an upgraded version of the game which is more flexible and allows changes in a shorter time. It also includes different market mechanisms for comparison. We will present the related results in a future research paper.

Additionally, from the pedagogical perspective, we are working with researchers from the Faculty of Education to develop the classroom or online application for a better learning experience and to better use assessment and evaluation techniques.

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