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COMPUTER SIMULATION GAMES IN TEACHING PRODUCTION MANAGEMENT

A b s t r a c t: The article concerns the analysis of the possibility of using selected computer simulation games in educational processes as part of studies, courses and training in the field of production management and related areas. It discusses selected simulation games available on the market. The characteristics of the analysed programs are given. Their functional features were indicated and their functionality was discussed. The areas in which computer simulation games can be used to teach issues in the discussed area are presented. The possibilities of using these programs in the IT environment supporting the functioning of the organization were also characterized.

K e y w o r d s: production management, simulation game

J E L C o d e: A22, C63, D24

INTRODUCTION

The development of computer systems made it possible to include simulation modelling (quantitative reality models), training games (business simulations) and simulation games in training methods. Simulation games reflect a specific fragment of reality by introducing participants to an interesting and complex virtual reality. Game designers try to reproduce real processes from various areas of social and economic life, taking into account the relations between the participants of these processes. One of the goals of the games is to simulate conditions that will force participants to react to various types of

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real-life situations. Such action, based on conclusions resulting from the conducted game, is to prepare participants to function in real processes.

Game participants should deal with attributes that directly relate to the analysed real processes. Simulation games can be conducted both in real conditions, for example in the field, as well as part of a computer simulation, as faithfully reflecting real conditions as possible. They can be implemented in single sessions, lasting several dozen minutes to several hours, or in multiple sessions, even over many days. Simulation games usually cover a wide range of issues in real processes, which gives participants the opportunity to practice various aspects of these processes extensively. This enables practical experience and preparation for significant problem situations occurring in the present or future professional life of the participants. They allow participants to work out various, often innovative ways to solve the analysed issues, they also develop creativity and flexibility. Basic psychological knowledge is also important in most simulation games.

Most often, simulation games are games involving many participants or many teams of participants. Each of the participants in the game takes a specific position, corresponding to the position in the real process, they have specific tasks to perform, as well as a specific scope of responsibility and assigned resources that he can use. As part of the games, participants develop skills in using various economic models, process management models, people management, and also develop their own "soft skills".

A very important aspect of the games is the role of the coach, responsible for the proper preparation of the game, controlling and influencing its course, as well as helping the participants to draw conclusions from the course and the results of the game. In this context, the trainer should have knowledge, skills and competences both in the area of the actual process that is the subject of the game, as well as functions available in the game (the course of the game scenarios) and pedagogical preparation covering psychological aspects.

Simulation games are used in many substantive areas, including finance, company management, logistics, and production management. They can be used both as part of courses and training for company employees, as well as a part of education at schools and universities.

The latter approach has been implemented for several years at the Faculty of Management of the Warsaw University of Technology. The Modelling and Production Organization Center operating at the Faculty of Management develops and implements simulation modelling subjects (using the Tecnomatix Plant Simulation and FlexSim computer programs) as well as training and simulation games. Currently, as part of the rector's grant for 2020, entitled *The development of a computer simulation game in the field of organization and production management* for the "Manager" Students' Scientific Association, one of such games is to be selected and implemented for use in laboratory classes.

The research methods used in the paper are literature analysis and case studies. The purpose of the research presented in the paper is to analyze and evaluate the possibility of using commercially available computer simulation games to achieve educational objectives in teaching production management. An additional practical aim is the selection of a game to be implemented as part of the ongoing teaching processes.

Due to the limited room of the paper, the stress was put on the preliminary literature review and analysis (in a repetitive form) of selected four production games, which can be purchased and used in the didactic process at the authors' home university. It is planned to publish the full results of the research after the grant is completed.

1. OUTLINE OF LITERATURE ANALYSIS

For many years simulation games have been enjoying increasing popularity in the academic environment. As indicated in [Krokosz-Krynke, 2005], the academic environment simulation of situations as close as possible to the real world is used not only in the case of teaching in the field of management and organization of production processes, but also in specialist areas such as educating future surgeons and pilots.

However, in the general case, it is important to make the distinction between the term simulation (simulation process) and the term simulation game. The term simulation means reproducing the phenomena or behavior of some object using its model, where the simulation participants (if any) search for an optimal (or at least acceptable) solution to some predefined problem. This approach still has an important role in academia, but does not fully support the learning of new skills by undergraduate students. Adding the word "game" to term simulation changes the meaning of the phrase, suggesting the inclusion of a rating system, a script for participants to follow, or generally evoking the level of competitiveness, such as between opposing teams [Siewiorek, 2013]. The sense of being able to win or lose at the end of an exercise may be enough to significantly increase student engagement [Deshpande, 2011]. Therefore, [Keys and Wolfe, 1990] define a simulation game (in this case in the field of management) as a simplified experiential environment in which the situation contains sufficient verifiability, i.e., the illusion of reality, to elicit reality-like responses from those participating in the exercise.

The reason for the aforementioned popularity of simulation games is, among others, the difficulty faced by students, related to the limited possibilities of practical application of knowledge acquired during traditional classes, which is common in academia [Krokosz-Krynke, 2005]; [Czyżewska, 2015]. Young people entering academic studies today have had the opportunity to grow up in an environment filled with interactive, engaging, and non-repetitive sources of informa-

tion, the popularity and availability of which has increased with the growing use of the Internet. The use of simulation games in their case enables them to engage multiple senses, thus supporting their cognitive abilities, which are accustomed to the philosophy of "learning by doing" [Deshpande, 2011].

Depending on the size and level of funding of a given institution, not every university or research institute is able to invest the funds necessary to simulate a realistic environment reflecting the place where graduates will pursue their future profession. Other limitations may include simple unawareness of the potential benefits as well as an inability or lack of interest in learning new ways of teaching among tutors [Deshpande, 2011]. This means [Chlebus, 2010] that students lose the opportunity of first-hand experience, eg. a sense of responsibility resulting from the existence of real effects of their actions, or the whole set of benefits resulting from the possibility of working in a team. Simulation games allow to experience aspects such as role allocation, where the group often has to rely on self-organization. Similarly, based on the simulation of natural mechanisms, it is the added value for the group when a leader is appointed [Stadnicka, 2015]. Other benefits resulting from the adoption of simulation games include but are not limited to:

- Incorporating an element of fun in the process of learning [Jenkins, 2006],[Hainey, 2013].[Herakovic, 2014] allowing the process of gaining proficiency through repetition to be more enjoyable [Philpot, 2003]
- Presenting an opportunity to develop decision-making skills and information processing skills [McFarlane, 2002], [Jenkins, 2006]
- Providing participants with the opportunity to experience consequences of decisions taken [Torres, 2000]
- Presenting an opportunity to increase the difficulty of exercises allowing incremental development of comprehension [Deshpande, 2011]
- Providing feedback that makes the game a learning process rather than an evaluation process [Deshpande, 2011], [Prensky, 2001]

In the literature on the subject, descriptions of simulation games are divided into two categories: games carried out in a physical way and computer games. The first type of games allows participants to experience the real processes that are key to organizing a production line by recreating the full production cycle. The advantage of this solution is, above all, the ease to observe the flow of information between participants, positions, customers and suppliers. This is important, due to the most popular use of this type of game, which is teaching the rules and mechanisms related to the introduction of *Lean Manufacturing* to an organization, which requires a generalized, holistic view of the processes carried out [Blöchl, 2016]; [Stadnicka, 2015]. As part of this type of game, it is very important to involve the teacher in the course of the game. Both in [Chlebus, 2010] and in [Stadnicka, 2015], the authors emphasize the need for continuous

verification of the course of the game. In the case of computer-based games, this role may be limited if the given program has strictly determined rules for the course of the game.

On the other hand, the physical environment makes it possible for the participants to lead to situations that disrupt the integrity of the educational process. The same difference is also relevant at a potentially pivotal point of the exercise – after the game is over. The goal is to learn something new, so the key stage is drawing conclusions from the effects of each participant's actions. The lack of automatically generated reports means that some participants may find it more difficult to spot key metrics that can provide valuable insight when interpreted. Of course, even when such reports are available, it remains difficult to interpret their results.

The case mentioned at the beginning, where a scientific institution does not have the resources or the space required to purchase physical equipment, creates favourable conditions for the purchase of computer simulation games (the second category of analysed games). Until recently, it was a less popular variant in the literature on the subject. It resulted from the difficulty of preparing and executing a sufficiently complex computer game that enabled cooperation or competition between several players [Riis, 1995]. It is caused by the fact that most of the older computer-based games are single-decision maker games. The player makes his own decisions, but all other game parameters are determined by the built-in algorithm.

On the one hand, this means that the user does not have the opportunity to experience real relationships with partners or competitors. On the other hand, the result of eliminating a large number of variables is the ability to immediately analyse the course of the game by the system in order to create a final report for the user. Currently, the problem of connecting many players is no longer a challenge while maintaining the functionality of generating feedback and reports [Stadnicka, 2015]. This is an exceptionally advantageous solution for academic reasons, because despite relatively large class groups (even a dozen or so people, depending on the game), each participant receives individual information that helps to determine the correct conclusions from the game. Currently, the lecturers (teachers - trainers) can choose various game scenarios, influence the course of the game and discuss the evaluation of decisions and conclusions based on information from the program.

2. GAME "PRODUCTION LINE: CAR FACTORY SIMULATION"

Description of the game. According to the supplier, the game aims to test and improve the management and organizational skills of the participants. The task of the players is to build an optimized, smooth car production line, while

beating the competition, while maximizing profits. A modern car factory is to be an example of a combination of efficiency, process management and work flow. The game is to show the complexities of managing production lines and make participants aware of the difficulties in competing with other companies on the car market.

Game mechanics. The player's main task is to build the most efficient production line that will allow him to achieve the maximum profit from selling cars. At the beginning, the player gets a small factory with a production line. The line is not very efficient and the mounted stands do not allow for quick production. Failures and unpredictable random events constitute additional obstacles in the development of production. The player has a full list of workstations and machines that can be used to build the line. There are also diagrams that show what activities must be performed to create a given element, a set of elements, and then a finished vehicle. There is a specific purchase cost for each machine or station. After building their own line, the player can observe how it works, check the work of machines and observe the formation of parts. After the finished vehicle is manufactured, they can name it and determine the margin on sales. Then the car is put in the showroom. The player can also influence the price of the vehicle in the showroom.

Tools for users. During the operation of the production line, a bar is visible on which the player can see the time since the start of the line, the amount of energy used and the balance of his account. There is also a window with statistics on income, costs and loan costs. During the game, charts presenting a breakdown of revenues and costs are available. The player can also control the speed of the simulation. The results of the game are presented on various types of charts that allow you to check how the factory works. Graphs are available that provide detailed information on the production volume and the costs and revenues of different types of car models.

Game scenarios. At the beginning of the game, when building the first production line, the user has a fairly limited selection of available machines and devices. This is due to the limited resources of available financial resources. However, the user has complete freedom in determining how to use these resources and how to configure the production line. The whole game is based on the user's choices, including how they want to develop production lines, what machines to buy, how to arrange devices, etc.

Information for users. In the introduction to the game, the user receives information on how to buy devices, what effects it has, how to set the devices and how to start production. The voiceover also explains to the player how the game works. In the event of an incorrect course of the game, when the player fails to build a functioning production line and the vehicle is missing some elements, information about the missing parts appears after clicking on the vehicle. At any

time during the game, the player can always use the vehicle blueprint. Instructional information about the game is available from online sources, and you can watch videos of other players playing the game on YouTube. The time needed for one game is approx. 4 hours. The price for a license for one user does not exceed several dozen zlotys. A computer with a Windows operating system is required to play. The hardware requirements are specified on the provider's website.

3. GAME „PRICING PLANS"

Description of the game. The subject of the game is to learn the supply chain management and its continuous improvement. The game is a computer version of a similar physics game developed at MIT in 1960. It is very popular all over the world, in various organizations. The players control an object (store, warehouse, factory) that is part of the brewing company's supply chain. Their goal is to deliver the right number of product units throughout the supply chain to satisfy end customers' requirements**.**

Game mechanics. The game simulates the flow of orders and goods between the brewery, distributor, wholesaler and retailer. During the game, participants play the role of managers controlling individual parts of the supply chain. Their goal is to manage deliveries and plan orders in such a way as to minimize costs and at the same time efficiently deliver the ordered products to customers. On subsequent stages they are forced to make quick decisions and act under pressure, which very often occurs in real business ventures. Supply chain actors can only communicate with each other using completed orders. The application allows the teacher or trainer to run a separate session for participants.

Tools for users. As part of the game, the results obtained by the participants are presented in graphs. Costs for stocking goods and costs for non-delivery can be considered and compared. It is possible to present statistics containing information on individual links in the supply chain.

Game scenarios. The game leader primarily decides the size of the deliveries. At the outset, the game can be run for multiple stages (weeks). Next, you can shorten the number of stages (simulation time) and compare the results. The operator can also adjust inventory costs and backorder fulfilment costs, initial conditions (stock status and orders at each stage), order requirements (volatility, inventory target). The game can be performed when the participants only have access to their own data as well as when they can see the data of other players.

Information for users. On the provider's website you can find information about the game, answers to frequently asked questions and a guide that helps you prepare the game step by step. The game is very popular and often used - a lot of information about it is available on the Internet. The time needed for one game is approx. 2 hours. The price for a time-limited license for one user does not exceed

several dozen zlotys. A computer with a Windows operating system is required to play. The hardware requirements are specified on the provider's website.

4. GAME „BIG PHARMA"

Description of the game. The game is supposed to combine an engineering approach and a business approach to problem solving. The subject of the game is the production and sale of medicines. The player starts in a small factory that produces cheap, simple remedies for common diseases. Its goal is to develop the factory to the level enabling the development and production of the latest generation drugs. The player must remember about the constant changes on the market and about the competition that threatens them.

Game mechanics. At the start, the program randomly allocates ingredients for the production of medicines. Missing ingredients must be purchased from the outside. Appropriately qualified personnel must be employed to conduct research on new drugs. The player buys production equipment and machines and organizes the production process. The production of more valuable drugs requires the expansion of the production line. Some machines can be bought, some have to be designed with the support of the personnel hired for this purpose. After obtaining sufficient revenue, the size of the production hall can be increased. The player can invest in researchers looking for new drug ingredients. In this case, over time, its list of available drug ingredients will expand and production costs will decrease. Thanks to the extension of the line, new types of drugs can also be produced from the same ingredients.

Tools for users. The program includes functions that allow them to check the components, technologies and management information for the management. Information is also provided on the balance of funds and the amount of expenses. The system signals the appearance of competition for a given drug. For each drug, you can check its market price, raw material costs, production costs and sales profit. Information on the company's performance is also available - total income, production volume, operating profit, hired employees, loan costs, and capital expenditure.

Game scenarios. After starting the game, the user selects the difficulty level and business goals to achieve. The program automatically allocates useable resources to the player. The game is based on user decisions, including development of the production lines, how to invest in research, how to react to competitors' actions, etc.

Information for users. Each user receives a guide in the form of an e-book. Before starting the game, it is recommended to follow the tutorial explaining how the game works. There are videos posted by other players on the Internet. The time needed for one game is approx. 4 hours. The price for a license for one

user does not exceed several dozen zlotys. A computer with a Windows operating system is required to play. The hardware requirements are specified on the provider's website.

5. GAME „FACTORIO"

Description of the game. The goal of the game is to build and maintain a factory on an alien planet. Players extract raw materials, research new technologies, build infrastructure, automate production and fight local opponents. At the beginning of the game, most building and manufacturing activities are done manually. As the factory develops and additional funds are obtained, production is automated and robotized. During the game, the resources must be protected from being destroyed by the inhabitants of the planet.

Game mechanics. The game is strategic in its nature. The player's tasks include obtaining the necessary funds for the development of the factory and optimization of production lines. The player can optimize production by introducing new technologies, developed in research centres, and constantly improving the methods of delivering goods to the place of their processing. The factory primarily includes transport systems that ensure efficient delivery of raw materials, semi-finished products and finished products. Players have at their disposal conveyor belts of various speeds, trains, as well as hovering robots (drones). To protect the factory from the indigenous inhabitants of the planet, fortifications are built - walls and defence towers. Preemptive attacks are also possible.

Tools for users. As with most strategy games, players can primarily observe and quantify the course of the game. The effects are presented in the form of expanding the territory occupied and the resources available.

Game scenarios. The game can be played in the single player mode or in a multiplayer mode. The basis of the game is the single player mode. It is possible to play in story and author mode. Multiplayer requires the division of tasks between participants. One of the tasks is also to erect a spaceport that will enable the launch of a rocket with which it will be possible to evacuate from an alien planet. Players can choose the difficulty level they want to play. They can also edit the map on which the game takes place.

Information for users. Players can use tutorials and game manuals. There are online forums for gamers. The game is relatively new - there is not much material available on the internet about it. The time needed for one game is approx. 4 hours. The price for a license for one user does not exceed several dozen zlotys. A computer with a Windows operating system is required to play. The hardware requirements are specified on the provider's website.

6. USE OF GAMES IN THE EDUCATIONAL PROCESS

The presented simulation games are only a part of the possibilities available on the market. Diversity in this area allows to choose an appropriate solution for the implementation of specific didactic goals. Due to their attractive form, the games make it possible to present complex issues in an accessible form. The simulation nature of the game enables decision making and observation of their consequences at a level that is practically unavailable using other methods. No other form of classes allows to design and build an entire production line or factory from scratch, and then introduce changes and rearrangements in a few dozen mouse clicks.

Simulation games allow students to experience associated with the knowledge acquired during a course in the most practical way. Every exercise done while learning is a valuable addition to their education [Lojo, 2016]. The best results can be achieved by combining traditional and practical learning. This also helps in deeper understanding of new knowledge and issues. In addition, students greatly appreciate hands-on activities in which they can use computer programs and games [Chang, 2009]. Playing a simulation game is also a good opportunity to summarize knowledge and combine information from several subjects, such as finance, management, production, marketing, etc. It helps them to feel and think like a manager [Ibendahl, 2017].

Virtually each of the above games can be used in classes for students. Depending on the game, it can be helpful in subjects such as production organization, logistics, business management basics or simulation modelling of production processes. The need for a computer for each participant of the classes means that students should have the opportunity to attend classes in a computer lab or expect the participants to have the right equipment, which is practically no longer a limitation. The cost of acquiring (purchase, operation and service) games for a large group of students may be an obstacle. Also the license conditions for making them available (time-limited licenses, licenses used each time the game is launched) can be a difficulty.

It needs to be remembered that games should be an element of the entire educational process and that they require appropriate, prior adaptation of the educational program. Their use at the university also requires properly trained teaching staff. Carrying out a simulation game for a group of students along with its summary and drawing conclusions is relatively time-consuming. Therefore, the use of simulation games should now be treated as a supplement and introduction of variety to the course of classes, making it easier to teach the key elements of the subject, as well as the most difficult ones.

SUMMARY

Computer games are slowly ceasing to be associated only with entertainment and are gaining recognition as an attractive form of classes with the use of modern information technologies. From the perspective of the authors, students of Management Engineering, this is a positive change, but it requires a lot of caution and awareness from those responsible for education to properly select the game and its implementation scenarios to achieve the assumed didactic goals.

The article presents a few sample games to illustrate their diversity and show the multitude of possible applications. Depending on the nature of the classes, various games can be a valuable element that will help the trainers to communicate more difficult issues or encourage students to delve into the subject of a given subject. Their use should also influence the development of creativity among students in the approach to solving practical problems. By participating in the game, it is possible to learn about real issues, encounter situations that require problem analysis, drawing conclusions and making decisions about further actions. Learning to cooperate with other people is also an important aspect.

The article also systematizes information on selected simulation games and points out the benefits of their implementation in the didactic process. The research, due to its initial character, focused on the analysis of issues related to achieving of learning objectives in the didactic process and evaluation of simulation games on the basis of available materials and their demonstration versions.

Subsequent work in this area will concern the selection of a game, the development of instructions for a laboratory exercise, testing the instructions on a group of students and introducing possible corrections to it. The decision to implement the game as part of specific classes will be made by academic staff responsible for the education program. In the future, it is worth consideration to learn about other games that could make the content of education more attractive, also in other areas.

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KOMPUTEROWE GRY SYMULACYJNE W ORGANIZACJI I ZARZĄDZANIU PRODUKCJĄ

Streszczenie: Artykuł dotyczy analizy możliwości wykorzystania wybranych komputerowych gier symulacyjnych w procesach kształcenia w ramach studiów, kursów i szkoleń z zakresu zarządzania produkcją. Omówiono w nim dostępne na rynku, wybrane gry symulacyjne. Podano charakterystykę analizowanych programów. Wskazano ich cechy użytkowe oraz omówiono funkcjonalność. Przedstawiono obszary, w których można wykorzystać komputerowe gry symulacyjne do nauczania zagadnień z obszaru zarządzania produkcją. Scharakteryzowano możliwości wykorzystania tych programów w środowisku informatycznym wspierającym funkcjonowanie organizacji.

Słowa kluczowe: zarządzanie produkcją, gra symulacyjna