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Resource Efficiency Learning Game – Electric Scooter Game

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Abstract

Fostering ideas that de-couple the world's growth in population and wealth from the increase of resource consumption must be tackled through the education of engineers. Those have to understand environmental, economic and social effects. Games have the potential to make people reflect their actions and to let them try out new approaches within a safe environment. A game has been developed to make students understand the effects of a resource efficient enterprise. The two-wheeler industry was taken as example because mobility is crucial element of human needs and sustainable development. The participants of this game are leading their own company.

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1. Introduction

In schools and universities frontal teaching is one of the most common forms of instruction. However, cognitive science proved that active participation of students in learning situations is more effective than forms of teaching which are only based on reflective learning [1]. The most effective and efficient learning can be reached if the instruction is organized in a way that it integrates four learning dimensions: active experimentation, reflective observation, concrete experience and abstract conceptualization [2].

Serious games have "an explicit and carefully thought-out educational purpose" [3] that increase the learning effect by connecting knowledge with its application. They are one of the teaching methods, which have the potential to integrate all four learning dimensions into their instruction. Compared to other forms of teaching serious games cover strongly active experimentation, in which traditional forms of teaching like lectures and seminars often lack. Hence the motivation, action and retention of the students should be increased [4] and the gamers are enabled to transfer knowledge and skills more efficiently. Therefore serious games build a powerful approach to enhance learning productivity in the lecture room. Due to that the number of educators using serious gaming rises.

A standardized definition for the term "serious game" has not been asserted yet. While the original definition established by Abt in 1968 [3] is not directly related to the usage of computers in the sense of computer games, more recent science normally associates video games designed for a serious purpose, e.g. Marr (2010) and publications of the conference on Serious Games Development and Applications [5, 6, 7, 8].

Three main criteria are critical to achieve the whole potential of a gamified approach: 1. meaning, 2. mastery and 3. autonomy [9]. Meaning stands for the feeling gamers have through the experience. That is when the activity meets his interests, his passions and his personal goals. Mastery describes the feeling of achieving something, to feel competent and to craft an experience in such a way that the user gets the sense of progressing towards his or her goals. Autonomy is a playground in the sense of freedom, to be left alone to the gamer's own mischief and to curiously explore opportunities without necessarily any functional outcome.

The possibility of trying out and exploring opportunities without creating an impact on real situations makes the

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students eager to focus on the game. Game based learning implies that students can play, try, make mistakes and learn specific contents and skills in a friendly and safe environment without risks [10, 11].

Based on the study of Oliveira et al. the application of blended learning, where the required minimal knowledge is taught before users start to play, is a reasonable way to address relatively complex themes [12]. Furthermore they address the fact that a group setup is more beneficial for the learning success due to individual reflection and discussion between individuals.

Resource efficiency is a crucial aspect of the inextricably weaved economic, environmental and social sustainability dimensions [13]. Resource efficiency can be improved through the optimization of productive use of resources at all stages of the production / consumption cycle. Hence the maximization of the useful utilization of resources and the minimization of waste is aimed [14]. As abstracted assumption, considering resource efficiency as kind of a simplified model of sustainability, this game enables students to understand the basic coherences of the three dimensions. But so far, few games deal with topics surrounding resource efficiency. In this paper a game approach for teaching resource efficiency will be shown. The concept of the "Global Scooter Game" was developed at the Institute of Machine Tools and Factory Management of the Technische Universität Berlin.

2. Games as a teaching method in universities

Based on a literature review the authors identified four games related to the aspects of sustainability, which also have innovative game approaches.

2.1. Business game for total life cycle management

The *business game for total life cycle management* has been developed at TU Braunschweig. Teams of students are represented by competing companies from the automotive industry. In each company four departments exist and at least two gamers are assigned to one company. Company funds are needed in this game to develop new business strategies and personnel are required to implement these strategies. With the help of so called strategy cards the gamers are able to describe their strategies with respect to the expected environmental effects, life cycle costs of the manufacturer and life cycle costs of the customer. The gamers, who are regionally divided according to the company divisions, hold a manager meeting in the beginning and agree on a common strategy. Followed by alternating group work phases and management meetings the game normally can be finished within seven to eight hours based rounds. The success of the company is measured according to the following factors: eco-efficiency, business profit, customer attractiveness and degree of linkage within a company. Success is calculated by using Microsoft Excel for each team. Three test phases have already been conducted with 70 students [15].

2.2. Solar Tycoon

Solar Tycoon is an online simulation and management game about a fictive start-up company in the sustainable energy industry made by University Utrecht and Digital Dreams. It is played in teams who will all take over the role of a sustainable entrepreneur. In the game the entrepreneurs must analyze the market, strategize, carry out plans and handle risks. Students can make decisions about their individual production program and have control over their production and profit margins. They can propose product- and process innovations and have to compete in a continuously changing market [16, 17].

Monetary aspects determine who wins the game. Money can be gained by selling solar panels. The task for the students is to make their virtual company into the most successful one of the industry. A special emphasis lies in the game's user-friendly graphical interface, which allows an interactive gaming experience.

2.3. Material efficiency game

The *material efficiency game* is a four round-based simulation game about a medium-sized company in the automotive supplier industry. The profitable company has several inefficiencies in its production. In order to analyze and suggest methods for improving the production processes, students take over roles - to promote different sometimes conflicting targets - such as chief executive officer, executive producer, controller and environmental protection representative. The focus lies on energy and material flows whose data are provided by a material flow simulation model. This model is not available for the students; they receive a paper. After each round group meetings are conducted during which the groups get feedback for their improvement proposals and the group behavior. At the end all actions of all teams will be presented, so that everyone can learn from the actions of others. The game is executed continuously during a semester when the students spent seven half-days playing and developing strategy [18, 19].

2.4. Keep Cool Online

Keep Cool Online is a strategy game about climate change, based on the board game Keep Cool. It is a round-based game, where three to six players take over the responsibility for a specific region of the world. They have to fulfill an economic goal and one out of two political goals. The economic perspective includes building factories to ensure economic growth. All gamers know about this goal. Contrary to this the political goal is different for each group. To win the game, the players must reach the economic and the political goals. The ability to compromise and negotiate with other teams/gamers is prerequisite to win. The game principle is based on the consequence that greenhouse gas effects of climate-damaging factories have a negative impact on the economic growth due to climate catastrophes. Not necessarily a group/participant has to win; there is the possibility that

everyone loses when the so called climate carbometer reaches the end of the red area [20].

2.5. Discussion

Due to the departmental structure of the *business game for total life cycle management,* the global view is not considered that much. The topic, total life cycle management, includes the development of own resource efficiency strategies, but the main focus lies on the application of preexisting strategies as defined by strategy cards that have to be implemented. Due to this the freedom of the gamer in the sense of the autonomy is neglected.

The graphical user interface provided by the game *Solar Tycoon* has to be highlighted. Nevertheless the game is more a simulation for action strategies for entrepreneurs; sustainability and resource efficiency does not play a primary role. Also the international orientation which is important due to the increasing globalization is missing. The inflexibility of this computer based game poorly enables the penetration of all four learning dimensions.

The role-play in the *material efficiency game* is of importance, as the characteristics of the roles have a direct influence on the game. It is notable that the game does not start from scratch in the initial situation which is a good approach for blended learning. This motivates the participants to analyze their company first and think about possible strategies. Nevertheless the blended learning aspect seems to be disregarded.

The online game *Keep Cool Online* is simply structured and self-explanatory. The game concept is designed to trigger interaction between the gamers; compromises to reach the goals are necessary. The game primarily considers the global perspective without taking into account simple resource efficiency strategies for individual factories. Due to the inflexible structure of the online game it is not guaranteed that all aspects of gamification are considered sufficiently.

The literature review has shown that the presented games, focusing on aspects of sustainability, do not integrate all four learning dimensions in a gamified approach in the context of a blended learning environment.

3. Game concept

The game “Resource efficiency learning game” is about a fictive company producing electric scooters. The game is played by five to six teams of four to five persons each. The organization of the board game is supported by a Microsoft Excel sheet so that all participants can easily access data.

The objective of this game is to build up a resource efficient company. During the course of the game the participants have to work out innovative investment proposals. The game will be played in rounds. Each team represents an independent company. The companies act as individual competitors as they are selling their products in industrialized-, emerging-, or developing countries.

A referee introduces the game to the players and gives advice during the play. He is also responsible for the evaluation of the company’s success and the game requests made by the students. Game requests are used to make students think about ways to improve their factory.

3.1. Learning outcomes

The game focuses on generating awareness of the whole life-cycle and its impacts on the economic, environmental and social perspective. The teams have to propose improvement strategies for their companies based on the value creation factors product, process, organization, human and equipment over all factory levels. Discussion and compromise are crucial for being successful in the game. Within that process of social interaction competences like decision-making, goal orientation, self-confidence, team skills, (intercultural) sensitivity, persuasive skills and assertiveness should be learned by the group. Methodical competences like time management, problem solving, work techniques and moderation skills are acquired by the students through a set of rules. This is especially due to deadlines and outcomes per level/round which are clearly specified and at the end of each round presented.

3.2. Final Product

The first prototype of the game, called *material efficiency learning game,* was implemented by using solar cells as a product. During the testing phase, the product turned out to be not an optimal choice since it is not tangible for the students, and requires a lot of detailed knowledge to enable them to develop ideas for improvements.

The search for a new product included the following criteria. The target group should have a clear understanding of the product and be able to create ideas about how the product could be improved or which materials could be substituted. Mobility is a crucial need of humankind. But today’s mobility habits in the western world cannot be transferred to the rest of the world, without exceeding any reasonable limit of resource consumption. Two-wheelers and especially electric scooters are in many parts of the world an attractive alternative to cars. Because less urban mobility infrastructure is necessary and less energy from non-renewable energy resources, like oil is, needed. In addition, scooters are fascinating for adolescents and students.

Many of the students are familiar with electric engines because many of them drove and maintained scooters during their adolescence. Compared to a bicycle the complexity of the product is higher; this increases the number of possible actions the students can propose. There are a lot of mechanical parts which can be easy changed without influencing the functionality. Moreover the scooter is a product for which the recyclability can be shown by nearly 100%, but nevertheless there are technical developments, like eMotors, which bring new technical requirements and additional knowledge demands into the game. Due to this the electric scooter (E-Scooter) was chosen.

3.3. Game parameters

The manufactured products are characterized not only by price but also by the range of attributes. These include reliability, design, brand image, materials and manufacturing region. Each of those is measured by points between one (low) and ten (high). For example, products manufactured in industrialized regions imply higher technical functionality compared to products produced in developing countries.

To measure the success of the proposed strategies in the categories environment, economy and social issues, credits are given. SO-Credits (social credits) will be given for particularly socially compliant companies. Constructing a factory in developing countries can lead to an improvement of infrastructure and living conditions, as work places are created, in the sense that people can reach a higher standard of living through earning money. The introduction of a new production process, without paying attention on safety measures (e.g. for chemical substances special protective measures have to be provided), will cause negative SO-Credits. ENV-Credits (environmental credits) are given for proposals which affect the environment, e.g. recycling methods or improvements which help to decrease the material input. The economical (ECO-Credits) success is measured by the round based balance sheet of the company which shows its economic success. Based on the operating profit the companies have to build their round based investment strategy.

The sustainability of the companies is calculated by the mean of the companies SO-, ENV- and ECO-Credits.

3.4. Execution of the game

At the beginning of the game, the players have to form teams and choose their starting region. The four regions are one industrialized country, two emerging countries and one developing country. Depending on the first region, the teams will receive different storylines about their companies' situation including information about the financial status, credits, the area, the status of the factory and the machines. The game gets played in rounds, divided in phases. The participants have to choose their sales strategy in the beginning: cost leadership or quality leadership. Students following a cost leadership strategy have to cut down costs, and use rather low quality materials to achieve low production costs; they can transfer these cost savings to the customers.

Phase 1: The phase 'Overview' is the first phase of every round. The referee will provide a presentation for the teams about the sales statistics in each region, and tell them about an occurring event.

Phase 2: In the second phase 'product development' the teams create their products by choosing materials for the electric scooter components. The players will not be informed about the credits they can gain by the selection of the attributes of their materials.

Phase 3: In the third phase 'components and raw materials' to produce E-Scooters will be bought. According to the readjustments made about machines due to the storyline, the raw materials for the in-house manufacturing components and the vendor parts will be purchased and stored in this phase.

Phase 4: In the fourth phase 'recycling' is focused. The used E-Scooters will be returned to the manufacturer three turns after they were sold. Thereby the method 'disposal' is always available; it is cheap, but has negative effects on the environment and therefore the reputation of the company. The method 'dismantling and material separation' will be activated by handing in a dismantling graph. Other recycling methods, such as 'dismantling and reuse', or 'dismantling, reuse and material separation' can be activated by handing in a game request (see phase 8).

Phase 5: The fifth phase is the 'production' phase. Here products can be manufactured out of components and raw materials. Players have to choose the region where they want to produce and which product they want to produce.

Phase 6: In the 'transport' phase, manufactured products are shipped from the region of origin to the sales branches, which might be located in other regions. Transport causes additional transportation costs, and has a negative influence on the environment due to carbon emissions. Used products, which return to the region of sale also have to be transported to the region of the recycling factory.

Phase 7: In the 'sales' phase teams fix prices depending on the region, and decide how many of the final products they want to sell. Unsold E-Scooters will be stored. Each region has one market where every team can sell products. In each region three buying groups are present: 'poor students', 'heavy users' and a group of trendsetting people called 'eco hipsters'. They share the determined market volume in each region, but differ in the emphasis on the product attributes (e.g. the maximum price they are willing to pay for one E-Scooter). Poor Students prefer E-Scooters to be really cheap (cost leadership), whereas the heavy users emphasize the reliability and range, since they need their E-Scooter every day (quality leadership). The eco hipster group prefers a well-designed E-Scooter from a brand with good reputation, since they identify themselves with their scooter (quality leadership).

Phase 8: The 'research' is characterized by a written request. This document is considered as a basis for discussion between the teams to make decisions about what upgrades could be good for their company. The game requests have to be handed in before the next turn starts. In each research phase, two game requests can be handed in. The requests contain information about what the group wants to research, a reasonable explanation, money they want to spend and which game parameters they intend to influence with their investment decision.

3.5. Referee's view

The referee is responsible for the introduction of the game to the students and helping the teams with instructions. He decides whether the teams will get, for example, credits and cost reductions that they requested for their researched proposal. He influences the direction of the game in three phases:

Phase 1: During the 'overview' phase, the referee shows a presentation to the teams including the sales statistics of the former turn and the news item for the new turn. The news item indicates an event which can be positive or negative and can be occurring for only the active turn or be valid for the whole game. One of the single-round-news items will appear each round, and the news items that last for the course of the game are only applied every third round.

Phase 2: During the player's phase 7 the referee's 'sales' phase is carried out. The referee is calculating the sales figures. For this calculation the sales advantages of all offered products on the market have to be calculated. To calculate the sales advantage, the attribute values for the reliability, range and design are needed. They are directly connected with the produced electric scooter, and the sustainability value. The sustainability value is calculated as an arithmetic mean of the SO-, ENV- and ECO-credits:

$$SV_j = \bar{x}_{arithm} = \frac{1}{n}\sum_{i=1}^{n}(x_i) = \frac{(ReV_j + RaV_j + DgV_j)}{n} \quad (1)$$

with
x = $\{RV_j, RaV_j, DgV_j\}$
n = 3

Due to the fact that the buying groups have different requirements for each region, the weighting factor for the attributes can differ between the regions. The sales advantage is then calculated for each buying group and for each region:

$$Sales\ advantage_{i,r} = \delta_{i,r} * ReV_j + \delta_{i,r} * RaV_j + \delta_{i,r} * DgV_j + \delta_{i,r} * SV_j \quad (2)$$

with

ReV…reliability value; RaV…range value;
DgV…design value; SV…sustainability value;
i…specific buying group; δ…weighting factor;
j…specific product; r…region;

Hereafter the data is sorted in descending order. Then the buying groups will buy in each region according to their requirements, starting with the highest sales advantage.

Phase 3: During the students' phase 8 the 'research' phase of the referee begins. After the teams have developed ideas to improve their production processes and products, they will present their game requests in plenum. Then the referee will make a discussion about the individual game requests to let other participants share their ideas and gives feedback. The investment sum is deducted from the company's accounts.

4. Game equipment

The game has been implemented in Microsoft Excel to make the game accessible to everyone as no software has to be installed. Another big advantage, aside from access, is the knowledge of Office products most people already have. However, the game is not only played by using Excel, but also by thinking and developing ideas totally independent of the original playground. During the research phase the teams have to develop improvements about their factory concerning buildings, production processes, logistics, recycling, machines, new materials or any other division in a company. Liberating this phase out of Excel gives the students the opportunity to develop own ideas, do research and to concentrate on the topic. The other phases are embedded in the Excel environment to give a frame and make it easy for students to understand and follow the game.

The Excel environment is the main part of the game, but to make it more visual, there is also a playing field and playing pieces. Figure 1 shows in the front the game field. Initially, and whenever they build a new building, they have to place additional playing pieces like factories, recycling stations and sales points in different colors for each team on the field. With this infrastructure the teams can produce and recycle their goods and sell to the respective region as well as analyze the competitors and their global and regional strategies.

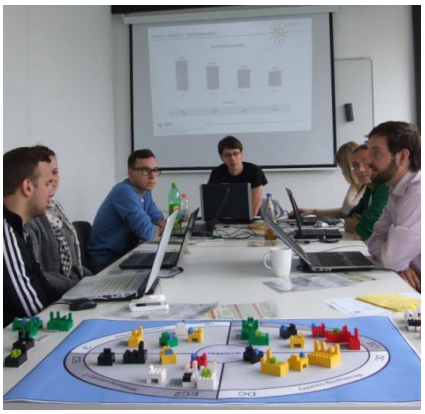

Fig. 1. Playing field and playing pieces

5. Grading and feedback

5.1. Grading

The teaching module consists of 40% lectures, in which the teams should get in touch with ideas for their companies strategy. Here a lecture related test has to be written. Another 30% of the time is reserved for a seminar in which the students present their findings about resource efficiency strategies. The round based investment strategies are also presented within this time and discussed with the other teams. The grading here is based on an assessment. The remaining 30% are reserved for the round playing and game decision making in the way of a group based blended learning environment [12]. Investment plans and a final report build the foundation for the student's grade here.

The grading for the game is not based on the monetary result of the game, but rather on the creativity and participation of the students. All teams will hand in their fully formulated game requests including the topic, an explanation, the amount of money to invest and the expected outcome. In plenum the teams will then present their game requests and face the other teams' questions. Then the referee will evaluate the game request and the following discussions with the other teams and make a decision about the specific game parameters in the Excel environment.

5.2. Feedback

After playing the game, the students were given a questionnaire to evaluate the game. According to the feedback of past executions, the students are able to apply knowledge from other subjects such as production engineering or material science. They also mentioned that they could increase their knowledge in the field of resource efficiency significantly.

Recommendations were also made to improve the game, e.g. to change the gaming platform from Excel to a browser-based version or to liberate more parts of the game to play them without the use of the Excel environment. All students indicated that they had fun playing the game and liked it as an interruption of all-day university life. The team-work was mostly graded as successful since the participants were helping each other with questions or problems.

4. Conclusion and future development

The students of today will be the engineers of the future and they will take part in the continuation of resource depletion or the development of resource conservation. To learn about resource efficiency and total life cycle management, a game has been designed which simulates a company that manufactures electric scooters. During the execution of this game, the students have to create their own proposals for how to improve the quality of their products and reduce costs. In addition, they can upgrade their factory, e.g. by improving the production processes. The recycling of the products is also an integral part of the game, where students can choose between basic methods, and have to develop their own recycling strategies to recover most of their products.

This game helps the students to rethink the educational contents and develop own ideas of how to improve their fictive company. Also students can become more self-confident and will be motivated to deal with particular topics.

On one hand the execution of the game has shown that the time effort for the referee is higher compared to other games like video based ones. On the other hand the first practical implementation indicated that the number of possible improvements which can be suggested by the students is due to the huge flexibility higher, than it could be in a deterministic game. Based on the individual written game-requests an equitable grading of the students is possible.

There is a plan to further develop the game. Therefore a web based user interface is going to be created. This will enable the students to get portable real-time information about the current state of the game. Furthermore it is planned to directly encourage students to improve the game in consultation with the referee. This idea is based on the study from Garneli et al. where the motivation of students who directly programmed a computer based learning game is indicated as higher compared to those students who enjoyed traditional teaching [21].

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