Game-based Learning: Acquiring Supply Chain Management Skills Through Playing Computer Games

Michael Ganske[1], Katherina Meißner[1], Julia Rieck[1]

Abstract: Computer games can support university teaching by promoting strategic, planning, and networked thinking. Especially in supply chain management, many processes require coordination, effects of actions need to be predicted, and decisions are made under time pressure. A structured and analytical approach is therefore of great importance, which is particularly promoted by playing computer games. We demonstrate the use of Rise of Industry to deepen students' understanding of supply chain management, covering logistics and production control as well as interactions and interdependencies between the components of supply chains. Using Constructive Alignment, we define intended learning outcomes and activities of a computer game-based learning course and derive requirements for selecting and adapting a computer game. Evaluating a three-day seminar, we find that students were able to apply prior knowledge to the game world and improve their decision making while experiencing the immediate economic and ecological impacts of their actions through the game.

Keywords: Game-based Learning; Computer Games; Supply Chain Management; Constructive Alignment; Design Science Research; Sustainability

1 Problem Identification and Motivation

Sustainable supply chain management (SCM) is a diverse subject area with many interconnections. Thus, decision-making is complex and challenging. In particular, interdependencies such as the trade-off between economic success and ecological sustainability are difficult to grasp at first glance. Yet it is precisely this interplay that is of great importance in today's society [TGRW15]. Students learn this, e. g., through lectures and discussions, but also in seminars, where *business simulation games* are used.

Game-based learning (GBL) as an educational approach has become very popular in recent years. Using games, students are encouraged to think critically and solve problems themselves [HKS14]. Furthermore, games have a positive impact on developing leadership skills [SR19] and enable a deep understanding of relationships and interactions in corporate processes [PGPCC16]. Many SCM-oriented business games focus on the management of a fictitious company. Students play in groups, taking on the role of different actors in a company and make decisions. These decisions are then entered into a system that simulates their effects for a given time interval. This process is repeated until the game ends after a predefined time [MAA17], e. g., three years. However, how the decisions ultimately affect

[1] University of Hildesheim, Institute for Business Administration and Information Systems, Universitätsplatz 1, 31141 Hildesheim, Germany, {ganske,meissner,rieckj}@uni-hildesheim.de

the environment during the simulation is not apparent. Therefore, students cannot reflect on their decisions and consequences in detail, but only on a strategical level.
Since business simulations often lack visual elements, i. e., only offer text and tables, complex subjects within SCM, e. g., environmental impacts of production and logistics, are difficult to represent. Complementary, more visual, and interactive approaches are considered promising to make interrelationships and sustainable actions in supply chains tangible and thus easier to grasp. *Computer games* are designed to offer a fun, visual, and interactive experience. This leads to players remaining engaged and immersed in the game world. The increased intrinsic motivation can be used to improve the learning transfer of complex topics, as the players learn through the game without being aware of it [MDM08]. As the effects of the player's actions are directly perceptible within the game world, computer games enable experiential learning [Zu19]. This real-time feedback sets computer games apart from business simulations and makes it easier to see and react to decisions' effects. In this way, dependencies and interactions are better learned and understood [Li17, So19], which is especially relevant in teaching SCM skills.
This paper presents the design and implementation of a GBL course using computer games, as opposed to digital or analog business simulations currently found in educational practice, e. g., MIT beer game (`https://beergame.org/`). To promote sustainability-oriented behavior in SCM decisions, we look at computer games that were "not intentionally developed for educational purposes, but which nonetheless have a positive effect on students' learning or development" [CC06]. In order to adequately address the educational need for implementation, the learning objectives as well as the teaching and learning activities of the course are formulated using Biggs' Constructive Alignment (CA) [Bi96]. Since the new course has to be integrated into the existing curriculum, design and development processes are necessary, which we realize in a structured way within the framework of Design Science Research (DSR) [Pe07]. In Sec. 2, we define the educational objectives for the course before we go into the details of the design and development in Sec. 3. Section 4 contains the demonstration of a game-based SCM course in a university setting. The evaluation is presented in Sec. 5 before concluding the paper with a discussion and an outlook on future research in Sec. 6. The graphical abstract in Fig. 1 presents the phases of the development process of a course based on CA and DSR.

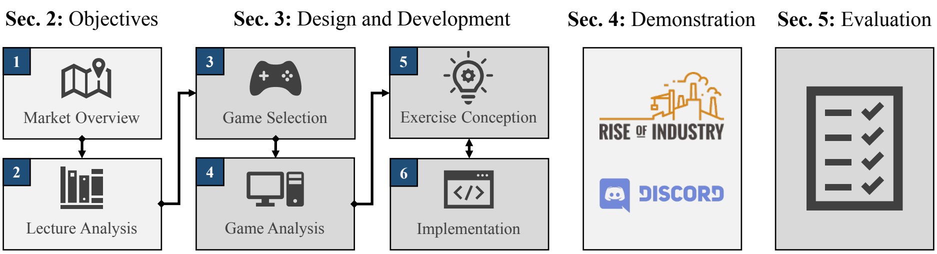


Fig. 1: Graphical Abstract

2 Definition of Educational Objectives

In order to define the objectives for the design of the university course from a competence-based perspective, we apply the theory of Constructive Alignment. The objectives, or rather the targeted learning outcomes, are used to guide the development of teaching and learning activities as well as the assessment of the course, but also to derive specific requirements for the computer game (cf. Sec 3.1) to be implemented in the course. The Structure of Observed Learning Outcomes (SOLO) taxonomy [Bi96] divides students' cognitive processes into five levels (SOLO 1, . . . , SOLO 5) with an increasing order of complexity. These range from missing the point of an exercise entirely to being able to generalize a structure beyond what is given. We structure our Intended Learning Outcomes (ILO) according to these levels (cf. [Br08]), assuming that the students can already make obvious connections and look at individual aspects (SOLO 1 and 2 can be omitted).
After the course, students are expected to be able to . . .

(a) *create* and maintain an economic and sustainable supply chain for a given product by *applying* the theories from former lectures (SOLO 4);
(b) *act* as supply chain managers under timely pressure, *relate* external events to their supply chain, and *apply* sensible solutions for them (SOLO 5);
(c) *formulate* aims and strategies for a company or supply chain department (SOLO 5);
(d) *discuss* their strategy and actions with a team partner (SOLO 3);
(e) *present*, evaluate, and defend their business decisions in front of the class (SOLO 3);
(f) *reflect* their strategy, decisions, and actions (SOLO 5).

In the first phase of the course development process (cf. Fig. 1), we prepared a *market overview* of business simulation games focusing on supply chains. From the overview, we captured the typical implementation of a business simulation game, which is reflected in the teaching and learning activities (TLAs) listed below. The TLAs, incorporating adaptions for computer games, are designed to promote achievement of the ILOs.

(1) **Founding of a virtual company** including the *formulation* of aims and strategies to engage students in the computer game and activate their creativity.
(2) **Playing the computer game** in teams of two to enhance *peer*-activities (learning partnerships) in multiple (short) exercises with given focus on certain aspects of SCM. Here, instructors are responsible for game-related and technical assistance.
(3) **In-class discussions** of decisions to consolidate learning outcomes and to provide space for presentation and discussion skills.
(4) **Writing a group report** based on activating questions in a (longer) reflection phase to assess the learning outcome.

In a *lecture analysis* (phase 2, Fig. 1), we examined the content of students' previous lectures (e.g., business administration) to identify prior knowledge that should be referenced and extended in the course. This analysis also identified appropriate content for the exercises in TLA (2). Structurally, the course iterates through TLAs (1) and (2) multiple times. This gives students space to repeat the process of *creating* and *maintaining* a supply chain at various occasions and allows for insights and feedback from previous assignments to be considered. The course grade is then *assessed* based on performance in the presentations TLA (3) and the group report TLA (4). Gaming skills were not graded. Since the learning activities reflect the time spent in the game, they inherently align with all specified ILOs.

3 Design and Development

In this section, we aim to provide a preliminary framework for how a computer game can be purposefully integrated into a university learning environment. Therefore, the phases 3 to 6, numbered in boxes in Fig. 1, are described.

3.1 Game Selection and Analysis

The intended learning outcomes from Sec. 2 are used as a basis for the computer *game selection* (phase 3, Fig. 1). We deduct the following requirements from ILOs (a) and (b) for the selection process. A suitable game must represent an economy, include sustainability aspects, provide for the establishment and monitoring of supply chains, allow for the production and sale of various products, and provide the necessary data to enable the application of theories from the lectures (e. g., amortization calculation). In order to support the requirements derived from ILO (a), a game must offer a sufficiently interactive visualization of the game world and thus a systemic perspective of the supply chains (i. e., coordination of procurement, production, distribution, and retail). Furthermore, it should be possible to depict various events that influence the supply chain (ILO (b)), so that the players can deal with them, i. e., demand fluctuation. In order for students to achieve the competencies from ILOs (a) and (b), the game should depict a continuous, i. e., close-to-reality, time progression. Therefore, fast-forwarding must be prevented. External timing of the game, i. e., definition of exercise start and end, would also facilitate instructors' management of the course.
For the selection of a suitable game, we suggest an approach similar to a literature search. In a first stage, computer game repositories, e. g., Steam (`https://store.steampowered.com`), were browsed with appropriate genres (e. g., construction and management simulations with a strategy focus) and keywords (e. g., production, logistics, management and business simulation). Exclusion criteria were specified in a second stage (e. g., the presence of competitors and an economy system), to decide whether a game is suitable for the intended purpose. Unsuitable games were sorted out by reading the games' description and by reviewing screenshots, trailers, and gameplay videos. In a third stage, the final game was selected through play-testing.

During testing, particular attention was paid to a balanced coverage of all areas of the supply chain within the games and that players could interact with all processes in the game in order to encourage strategical, analytical, and interconnected thinking. Due to its variety of available products, the realistic representation of supply chains, and the possibility to create customized scenarios, we identified "Rise of Industry" (RoI) (`https://riseofindustry.com`) as the most suitable game for the course. In particular, the need to make strategic decisions, the ability to build a complex manufacturing environment in which production times can be optimized, and the presence of realistic demands made RoI stand out from other games (i. e., especially the Anno Series, Cities: Skylines, Factorio, Industry Giant 2, and Transport Fever). In RoI, players take on the role of an entrepreneur within the manufacturing industry being in full control over the supply chain and all inherent manufacturing steps, from the procurement of raw materials to the sale of finished goods.

Once a computer game is selected, it must be thoroughly tested in a *game analysis* (phase 4, Fig. 1). In order to best align the course to the game, we identified how the achievement of the ILOs can be supported through RoI. This included taking a closer look at the player's perspective on the supply chain, and the way that real-time feedback on participants' decisions and actions manifested in the game world. To better guide reflection and application of knowledge in the course, we reviewed, among other things, how the conflict of interest between economic success and environmental sustainability is addressed and visualized in RoI, e. g., a factory's pollution impact on its immediate environment.

In the game, environmental impacts become evident through visual indicators. In the case of increased air or water pollution, the landscape turns gray, trees wither, and land for farming and livestock becomes unusable. If pollution is not dealt with, buildings are abandoned and the settlement's population decreases, which in turn negatively affects the demand for products. By researching, building, and continuously maintaining filtration systems, these effects can be contained by the player.

3.2 Exercise Conception, Scenario Creation, and Game Modification

Playing computer games leads to learning. However, "the question remains what is learned, why is it learned, and which parts of this knowledge are transferred from the game to the real world" [MDM08]. In order to avoid solely relying on the knowledge imparted by simply playing the game, TLA (2) can be implemented through *creating exercises* (Fig. 1, phase 5) that allow addressing individual learning outcomes in the game world, in particular ILOs (a) and (b). Splitting up content over multiple exercises can also reduce overstimulation and confusion resulting from playing an unfamiliar game. The time between exercises can be used to integrate pauses for discussion, presentation, and reflection (ILOs (d) – (f)). To separate exercises, predefined game states, hereafter referred to as *scenarios*, can be created and then distributed to the students. Scenarios can be used to incorporate game elements into a course that would otherwise only be accessible at an advanced stage of the game. This approach is particularly useful to counteract the limited time available in a course. To achieve a certain part of the game in free play, potentially much more time is needed.

The strategic perspective of gameplay can be enhanced through additional exercises that let students utilize in-game data. This way, competencies from previous lectures can be applied to the game, e. g., corporate strategy definition and amortization calculation. In addition to the exercise conception and scenario creation, exercises should be linked to tell a coherent story, i. e., through task formulation. This story allows for a deeper immersion in the game world, which helps students to stay focused during an exercise [MDM08]. Considering the characteristics of RoI and the ILOs, exercises had to be designed and associated scenarios had to be created. Section 4.2 depicts a sample exercise from the course.
From the observations made in the game analysis (Fig. 1, phase 4), games need to be tailored to the intended learning outcomes. If the computer game does not natively align with all ILOs, *implementation of changes* (Fig. 1, phase 6) through modifications of the games' source code and with so-called *mods* can be considered. Since RoI did not support external timing of the game (cf. Sec. 3.1), the game developers adjusted the source code to allow the speed of the game to be affected via a mod. This change is available through the build (a so-called *beta*) named 'university' in the Steam library. To further align the game-based course with the ILOs outlined in Sec. 2, a mod was created that extracted in-game metrics, e. g., profit and pollution. With this data, students receive information beyond that provided by the game which can be used for decision-making. The data also supports compliance with ILOs (d) – (f).

3.3 Company Score Calculation and Web Interface Development

The data extracted from the mod was displayed on a web interface (i. e., a dashboard) to give students a better overview of the impact of their decisions in the game world. From this data, a *company score* was calculated to allow comparison of the teams' performance against each other and to foster competition among the teams. The considered key figures were weighted in such a way that the interaction between economic success indicators and ecological effects could be read from the company score. Equation (1) shows the calculation of the company score together with the weightings used.

$$\text{Company Score} = \frac{3}{1{,}000{,}000} \cdot \text{CV} + \frac{1}{100{,}000} \cdot \text{PRO} - 100 \cdot \text{MD} - 2{,}500 \cdot \text{POL} \qquad (1)$$

The *company value* (CV) includes the value of the regions owned by a player and the investment costs of factories built by the player. The *machine downtime* (MD) is determined based on the machine running time of all owned factories in the previous month. Sustainability aspects are considered through the inclusion of the players' regions average *pollution* (POL). The *profit* (PRO) is composed of product sales in the respective shops, operating expenses, and other costs. Machine downtime and pollution are entered as percentage values and have a negative effect on the company score. Players started with a company score of 100.
Through the extracted and calculated data, aspects such as waste of resources, utilization of production capacities and effects of production on the environment can be observed. This helps to make statements about the economic and environmental sustainability of the players' actions taken in RoI.

3.4 Communication Server Setup and Virtual Machine Configuration

As the course was designed for an online setting, communication between course participants and teachers had to be ensured. Therefore, a server with multiple text and voice channels was set up using Discord (`https://discord.com/`). Text channels were used to distribute assignments and additional information. Voice channels allowed for easy communication during and between exercises. Additionally, application programs (e. g., computer games) could be screen-shared through the program. We set up virtual machines with Paperspace (`https://paperspace.com/`) using the Parsec Template which is made for cloud gaming to ensure accessibility of the game for all participants.

4 Demonstration of a Computer Game-based University Course

We integrated a modified version of Rise of Industry into a seminar course at the University of Hildesheim in the summer semester of 2020. With the objectives stated in Sec. 2 in mind, we created exercises that are adapted to the game and learning outcomes. In a three-day course, 24 students from various IT degree programs completed five exercises in RoI. During the course, the players and instructors communicated via Discord. It was decided to play in teams of two, a team size that has proven appropriate during internal play-testing to promote communication and teamwork. In the course, the measures defined in Sec. 3.3 represent an operationalization of ILOs (c) – (f); thus the experience of sustainability with all its facets is possible in the context of SCM. The company score (cf. Eq. (1)) can be seen as the enabler for reflection on the part of the players. The players' behavior, i. e., the decisions made during the game, show whether sustainable reflective action was taken in relation to the computer game. During the exercises, the company score was displayed on the web-based dashboard to evoke a sense of competition which strengthens learning effects and increasingly provides for a reflection of one's own decisions [Bl15]. Teams without adequate hardware played the game in the cloud (cf. Sec. 3.4). For more information on the implementation of the course, which is beyond the scope of this article, please visit `https://github.com/joscha999/PlanspielWeb/`. We now describe the used course structure, the exercise structure and example, and the observed results (cf. Sec. 4.1 – 4.3).

4.1 Course Structure

In the online course, we first explained the relevant functionalities as well as important overviews, e. g., a factory's GUI, and essential tools in RoI to the students. This was done since it cannot be assumed that students know a computer game in advance and to avoid that a lack of computer game affinity might affect the attendance of the course. Following the *game tutorial*, students performed a simple exercise in the game world to create an initial, shared understanding. Afterwards, the teams were tasked with founding a fictitious company and make up a name, logo, slogan, and strategy (TLA (1)).

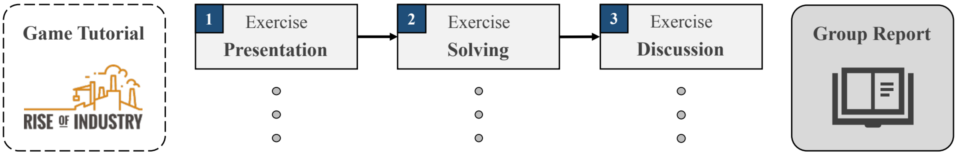
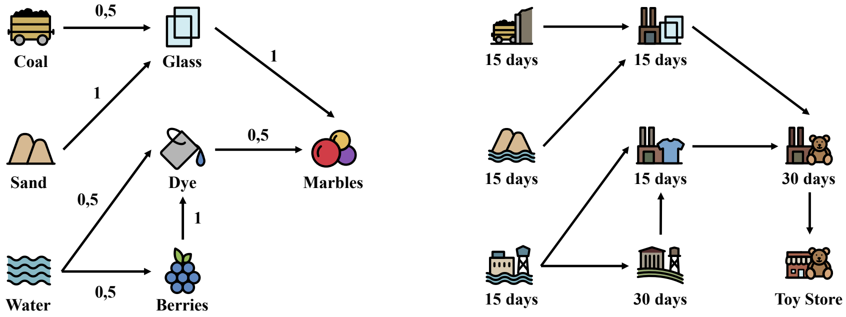


Fig. 2: Structure of the course

As seen in Fig. 2, three steps were repeated for each exercise. The exercises were presented by the instructors (step 1), then solved by the students in pairs (step 2, TLA (2)), and finally the results were discussed and reflected in class (step 3, TLA (3)). The in-class discussion was also intended for students to learn from the experiences of the other teams for following exercises. Each exercise had to be solved within a given time limit. Depending on the complexity, this was either one or two in-game years, i. e., 45 or 90 minutes. Once a scenario was loaded, the time within RoI unpaused and automatically stopped at the predefined end in-game date through the mod. During the exercise, team members communicated in their individual voice channels. The game was played by one person at a time, but the player role could be switched between exercises. While one student played the game, the teammate watched the live stream and helped with decisions and calculations. Upon completion of the course, students wrote a group report on the decisions made in the game and their implications to further reflect on what they had learned (TLA (4)).

4.2 Exercise Structure and Example

In the seminar, students performed five exercises, aimed at building, managing, and expanding their company's supply chain. The introductory exercise focused on a product with low vertical manufacturing depth. In subsequent exercises, the supply chain was extended to include products with a more complex bill of materials (BOM).
At the beginning of each exercise, the BOM of the demanded products must be determined so that the depth of the supply chain can be estimated (vertical dimension). To build the required number of factories at each level of the supply chain (horizontal dimension), the product demand can be referred to. From the demand it can be determined which and how many raw materials are needed for production and whether they are available in the players' region. Unavailable materials must be imported or extracted in another region. Once resources are available, factories and associated transportation infrastructure can be built and configured. The supply chain should be designed from the 'bottom up' to avoid production downtime and idle costs. Besides the construction and maintenance of supply chains, students had to calculate production times and quantities, time-to-market (TTM), and amortization times for various products. Furthermore, suitable production locations and sustainability aspects in the supply chain had to be identified and taken into account.
In what follows, an exercise from the course is presented that covers topics such as TTM, investment cost analysis, and the assessment of the BOM. After setting up a production for wooden toys, the students had to produce marbles and deliver them to the toy store.



(a) Bill of materials (b) Flow chart for units

Fig. 3: BOM and flow chart for marbles production

In RoI, marbles are made of various raw materials (coal, sand, and water) and intermediate products (glass, dye, and berries). The BOM is shown in Fig. 3a. Initially, six units of marbles were demanded monthly at the local toy shop (primary demand $x_{Marbles} = 6$). The total demand r of raw materials and (intermediate) products can be calculated as follows:

$$
\begin{aligned}
r_{Coal} &= 0.5 \cdot r_{Glass} + x_{Coal} && = 0.5 \cdot 6 + 0 && = 3\\
r_{Sand} &= 1 \cdot r_{Glass} + x_{Sand} && = 1 \cdot 6 + 0 && = 6\\
r_{Glass} &= 1 \cdot r_{Marbles} + x_{Glass} && = 1 \cdot 6 + 0 && = 6\\
r_{Water} &= 0.5 \cdot r_{Dye} + 0.5 \cdot r_{Berries} + x_{Water} && = 0.5 \cdot 3 + 0.5 \cdot 3 + 2 && = 5\\
r_{Berries} &= 1 \cdot r_{Dye} + x_{Berries} && = 1 \cdot 3 + 0 && = 3\\
r_{Dye} &= 0.5 \cdot r_{Marbles} + x_{Dye} && = 0.5 \cdot 6 + 0 && = 3\\
r_{Marbles} &= x_{Marbles} && && = 6.
\end{aligned}
$$

Tables 1 and 2 show the determination of investment costs for two types of factories, those without and those with harvesters (e. g., mines, pumps, and orchards). By default, factories can have a maximum of three harvesters each with a monthly production capacity of two units. Demand fluctuations can be responded to by adjusting the factory efficiency (e. g., 75% or 125%). In the game, an efficiency adjustment leads to a shortened production time with a simultaneous increase in air pollution. Since sustainability aspects are considered in our course, air purifiers that combat air pollution should be built by the students. For each cleaner, costs of $125,000 and a monthly demand of two units of water ($x_{Water} = 2$) are to be considered. Summing up the building costs including a purifier, results in an investment cost of $5,175,000.

Tab. 1: Investment costs of factories without harvesters

Product	Demand	Building Costs ($)	Capacity	Buildings needed	Total ($)
Glass	6	600,000	4 / month	1.5(2)	1,200,000
Dye	3	450,000	4 / month	0.75(1)	450,000
Marbles	6	600,000	2 / month	3	1,800,000

Tab. 2: Investment costs of factories

Product	Demand	Building Costs ($)		Buildings needed		Total ($)
		Harvester	Factory	Harvester	Factory	
Coal	3	175,000	225,000	1.5(2)	1	575,000
Sand	6	75,000	125,000	3	1	350,000
Water	5	75,000	150,000	2.5(3)	1	375,000
Berries	3	125,000	175,000	1.5(2)	1	425,000

The TTM of the marble production can be derived from the longest path in the flow chart in Fig. 3b. At least 90 days pass before the first marbles are delivered. The time starts with the collection of water for the berry plantation. Besides the production time, transportation times must also be considered. These are not included in the figure, because they depend on the road and vehicle type as well as the positioning of the factories in RoI.

4.3 Observed Results

During the exercises, student decisions and their subsequent impact, represented by performance metrics, e. g., company score, were collected in Rise of Industry on a monthly basis for all teams (cf. Sec. 3.3). Figure 4 presents the data weighted according to Eq. (1) over the course of the exercises played. The x-axis shows the months played by students. Vertical lines mark the beginning of the exercises, i. e., at months 0, 12, 30, 54, and 78, where jumps in the data are observable due to loading new scenarios. The remaining demand plot describes the absolute deviation of the products sold by the player and the demand for these products. This value is not included in Eq. (1), but helps to evaluate how well the exercises were solved by the teams. In the last exercise, the winning team, visualized with the green line, almost completely covered all demands, which indirectly had a positive effect on the profit and thus on the company value.

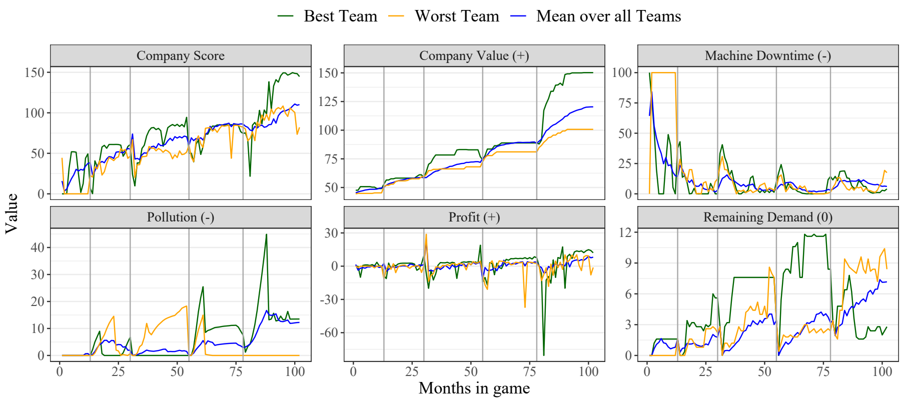
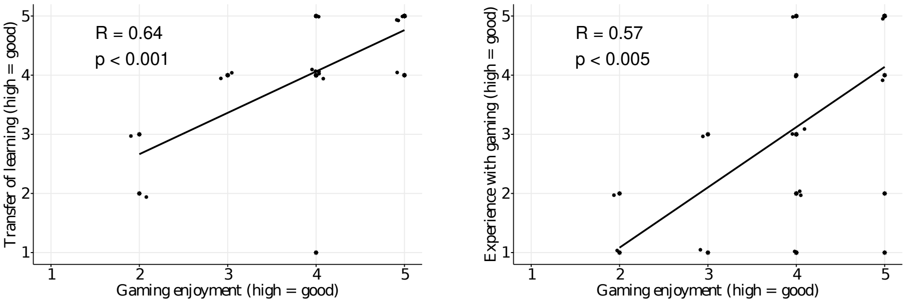


Fig. 4: Progression of Company Score

In Fig. 4, the local extrema of the plots indicate various student actions within the game world. Between months 75 and 85, the profit of the best team decreases due to the purchase of new factories and the expansion into a new region. At the same time, the company value increases. A subsequent delayed start of production due to late raw material deliveries temporarily increases machine downtime. After the start of production, pollution increases significantly, because an air purifier has not yet been set up. Therefore, there is a short-term drop in the company score, which stabilizes after the construction of the air purifier.
At the end of the seminar, student feedback was gathered through a follow-up group discussion and an anonymous online form that included questions about the game-based and online nature of the course. The feedback showed that the students enjoyed participating in the course. In addition to the achievement of educational objectives (cf. Sec. 2), we evaluated whether the fun of playing the game in the course led to increased perceived learning transfer.



(a) Transfer of learning

(b) Gaming experience

Fig. 5: Correlations of gaming enjoyment

Figure 5a shows that there is a strong correlation between the enjoyment of playing and the learning transfer. The more fun the students had in the game, the higher they rated their learning transfer ($R = 0.64$). It should be noted that in our target group the fun of playing the game depended on the previous experience with games (cf. Fig. 5b). The correlation is slightly weaker here ($R = 0.57$). However, students with very little experience also indicated that they sensed a high level of enjoyment and thus a high level of learning transfer. The p-values show that in both cases a significant correlation can be assumed ($p < 0.05$).

5 Descriptive Evaluation

In this section, we descriptively evaluate the first iteration of the computer game-based university course using Rise of Industry. The goal is to use the feedback to draw conclusions to further improve the quality of the course design and contents for future semesters. In particular, the evaluation investigates how well the TLAs supported the achievement of the educational objectives and thus the growth in competency among students.

In our study's game selection, RoI proved to be the most appropriate computer game for supporting ILOs (a) and (b). The remaining ILOs were corroborated through the course design. Through playing the game (TLA (2)) and observing the dashboard, students received direct feedback (in-game real time) on the consequences of their actions in the game world, were able to integrate different points of view, and thus better prepare and think through decisions. During the course, the exercises served as a frame of reference to ensure compliance with the given objectives. Although the exercises allowed us to specifically address individual aspects of the SCM, the compulsory loading of predefined scenarios prevented the students from experiencing the influence of their long-term strategic decisions. This meant that additional efforts of the students, e. g., the investment in an additional production line, were neglected by the new scenario. Moreover, with a new exercise the students received an optimal supply chain solution for prior exercises and were therefore not challenged to sufficiently maintain their own supply chain.
In order to be able to investigate students' competence development, students were observed during gameplay (TLA (2)). To solve the exercises, students applied prior knowledge and competencies received from lectures. In the online evaluation, students assessed their individual perceived learning transfer through playing RoI. It was noticed that the student assessment corresponded with the observations during the game, the discussions between the exercises (TLA (3)), and the reflective group reports (TLA (4)). From Fig. 4, it can be seen that students applied sensible solutions to external events in the game world (ILO (b)). In doing so, they made informed and sustainable decisions such as building an air filter or adjusting production in response to a demand fluctuation.
Application and reflection of knowledge (ILOs (a) and (f)) was achieved by combining the game with exercises on business calculations. From the group reports, it could be seen that students thought strategically, analytically, and in a networked manner. The reports also provided insight into how students thought about the impact of their decisions on the game. Overall, the seminar was characterized by teamwork among the participants, but also by the exchange between the teams during in-class discussions (TLA (3), ILOs (c) – (e)). As the course progressed, students' strategies and decisions improved as they worked in teams and utilized the data provided. By making the students aware of the consequences of their decisions in the game world, they worked in a feedback-oriented way. Whether the increase in competence experienced in the course can be applied in real-life situations remains to be seen. To this end, further iterations and research are necessary.

6 Conclusion and Outlook

In this work, drawing on Constructive Alignment, we defined intended learning outcomes and activities of a GBL course and derived requirements for the selection and adaption of a computer game. To guide the course design and development, we used DSR as an underpinning framework. In the university course, the computer game Rise of Industry was used to empower students to acquire and consolidate SCM-competencies.
Our results indicate that complex learning objectives can be covered not only in traditional

lectures-based, but in computer game-based formats as well. We found that visualizing the supply chain through the computer game and incorporating in-game metrics for decision-making worked well in the presented course. The modified version of RoI along with the exercises and the dashboard provided students with a concrete reflection tool for sustainable SCM-decisions. In the game, students experienced both the economic and ecological impacts of their actions. Although no generalizations are possible based on one iteration, our approach and results indicate that the embedding of a computer game in the university context is a promising approach in the area of SCM. According to our observation, it seems useful to conduct a learning status survey of the students before the seminar and (longer) time after the seminar in order to verify the knowledge growth as well as knowledge constancy and persistency.
Further iterations will follow to improve the combination of RoI and the dashboard and to provide a quantitative examination of the achievement of the goals. In order to raise the students' awareness of the long-term effects of their decisions and strategies, a structural change of the exercises is necessary. Students should play on a single game state for the entire duration of the seminar. Additionally, we plan to adjust the dashboard and the calculation of the company score to further encourage reflection and more sustainable decision-making, e. g., through the use of nudging elements. A graphical representation of the data through charts could help students in making more informed decisions as well. Moreover, it can be investigated how a higher temporal resolution of the submitted data, i. e., weekly or daily in-game, affects student decisions.

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