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Enhancing Serious Game-Based Teaching and Learning through Learning Analytics

Abstract

In modern business management, the topic of the Internet of Things (IoT) is connected with Supply Chain Management (SCM). To teach the necessary business and personal skills, methods like serious games and simulations are often used. The skills that students can acquire are manifold but difficult to verify. In this article, we show methods and visualizations for supporting educators and students with learning analytics that are specifically designed for collaborative SCM serious games. The results and visualizations of the specific learning objectives of the application were aggregated and presented in a dashboard, which was evaluated in a usability study with guiding questions by six teams of two players and interviews with learning technology experts.

Key Words

Learning Analytics, Lab-based Learning, Supply Chain Management, Serious Game

1 Introduction

Supply Chain Management (SCM), controlling, and logistics are topics in study programs like engineering and management (Johnson & Pyke, 2000). In 2015, Loh et al. defined serious games as “digital games and simulation tools that are created for non-entertainment use, but with the primary purpose to improve skills and performance of play-learners through training and instruction” (Loh et al., 2015). Serious games are one way to teach topics like SCM and its respective related skills (Willems, 2020). There are various serious games dealing with linked topics in different simulation levels (Riedel & Hauge, 2011), (Tobail et al., 2011), (Hauge et al., 2016), (Willems, 2020), and (Galli et al., 2021). Ibarra et al., 2020 conducted a quantitative review which showed that serious games are recent research subjects, and the interest in them is increasing.

The other core topic of this paper is learning analytics, which "is the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (as cited in Siemens et al., 2011, Learning Analytics section, para. 2). The approach to gaining knowledge out of data could be used to create an interesting view on learning with simulation games. But besides the opportunities are some challenges, like data protection. An important step in the learning analytics process is to bring all stakeholders together. Students especially should be part of the process (Ifenthaler & Schumacher, 2016).

In this paper, we will connect learning analytics data with business game teaching SCM. We show visualizations for teachers and students, which were tested in a pandemic compliant study. The visualizations were presented in a dashboard, which was designed to connect the results with the specific learning objectives of the SCM serious game. The results of an evaluation with the players will conclude the contribution. We show insights from the usability study with the players, which was done based on some pre-arranged guiding questions, and from interviews with experts.

2 SCM Serious Game Research Prototype

For this research, we used a special variant of a business game named TransAction, which was developed at the RWTH Aachen University in 2013 and has been continuously improved since then[1]. The web-based business game deals with the supply chain. Students act as managers of a virtual company and increase their game success by applying knowledge obtained in the lecture during the semester. Originally a single-player game, we transferred the game mechanics into a collaborative multiplayer game which works on a simplified set of rules compared to the original game (Schablowsky, 2020). The resulting game mechanics and the basic gameplay are comparable to the games linked in the introduction (for a detailed explanation, see Schablowsky, 2020).

1 https://blog.rwth-aachen.de/lehre/2013/06/25/transaction/ and https://www.medien.rwth-aachen.de/transaction/

3 Learning objectives

A general learning goal at university is to help students to develop good *self-management* skills. Business and serious games are one way to teach students how to learn for themselves (Nissen, 2006).

The main learning objectives of the multiplayer variant of TransAction are reduced in comparison to the variant that accompanies the semester. In contrast to the nuanced learning objectives of the lecture-based variant of the game, they are limited to *understanding the complexity of the supply chain*. This point is interesting because a key limitation of simulations like TransAction is that we need to didactically reduce reality. Games like that are not feasible without the reduction of complexity (Goldmann et al., 2020). Our goal of understanding complexity is therefore confronted with the fact that in simulation games we are forced to reduce the complexity of reality.

Another learning objective is the *development of strategies to deal with uncertainties* and how these change over the course of the game, e.g. through increasing and decreasing demand for virtual products. And here we come to the most serious difference between the game's versions. The component of *collaboration* is an important learning objective and research subject, which is also related to the other learning objectives. The strategy is developed and discussed together with the other players. Two very fundamental learning objectives are that the students should *understand the functionality of the learning game* and be able to *comprehend its possibilities and limitations*.

The subject-specific learning objectives that are not on a basic level (e.g., understanding the function of the serious game) are typical learning objectives for engineers and economists. For example, the Accreditation Board for Engineering and Technology (ABET) lists *problem-solving* as a criterion in the curriculum of engineering technology programs (ABET, 2021), naming *identifying and solving problems* as important skills for graduates. Likewise, the World Economic Forum named *complex problem-solving* and *analytical thinking* as two of the Top 15 skills for 2025 (WEF, 2020). An example of a similar serious game in this context is SHORTFALL (Hauge et al., 2016). Willems, 2020 used the serious game "The Fresh Connection" to research cooperation development.

4 Dashboard

"The Learning Analytics Dashboard (LAD) is an application to show students' online behavior patterns in a virtual learning environment" (Park

& Jo, 2015). The Dashboards display visualizations designed to present the results of learning data collection to teachers and students in a way that is as easy to understand as possible. Specific calculations and associated visualizations are often assigned to the various questions (Dyckhoff et al., 2012). An example of such a question is "Do students who have practiced with the SCM serious game outperform students who do not use it?". The questions used for this research lead back to the different learning objectives described in the section before. The goal was to find indicators of concepts that are hard to operationalize like collaboration and the process of building a strategy. One big challenge is to design such results in an understandable format, because they should be understandable without expert knowledge (Dyckhoff et al., 2012).

As in Alonso-Fernández et al., 2021 data was collected in the xAPI data format and stored in a data warehouse. Preliminary work and decisions on this can be read in Ehlenz, et al., 2020 and Lukarov et al., 2020. For the current version, only logging data from the multi-touch devices was used without an extension to include other sensors. A possible extension for post-pandemic research, which is implemented in the underlying framework but not yet used in the current investigation setting, is eye tracking (Heinemann et al., 2020) and others, like motion tracking (Ehlenz, et al., 2020). Praharaj et al., 2018 were able to show that eye tracking data could be used as an indicator of collaboration quality. One way is to calculate the joint visual attention (looking at the same area), which could predict the quality of collaboration. This sort of data could be integrated into a later version of the experimental setting. We collected data comparable with that of Alonso-Fernández et al., 2021, who used the serious game profile of xAPI vocabulary (Serrano-Laguna et al., 2017). The set of definitions used is openly available (https://xapi.elearn.rwth-aachen.de/). The following set summarizes the types of collected interactions: Started (game or period is started), Finished (game or period is finished), Synchronized (stage is synchronized), Asked (question for next period), Answered (answer to question), Selected (module chosen by player), Stopped (stopped working on module), Changed (value of a slider is changed), Pressed (button was pressed), and the collected activities are Game, Level, Stage, Question, Answer, Draggable, and Button.

The dashboard for the SCM game contains four sections. Schulz, 2021 developed the visualizations shown in this paper in his master's thesis. Each section shows up to nine graphs with increasing complexity. Each of these can be assigned to at least one of the learning objectives, with a focus on the section in which it is displayed. Each visualization and indicator is designed using best practices and guidelines, see Abela, 2013 and Iliinsky & Steele, 2011.

The first section shows general information about the sessions. It is designed in line with other dashboards, especially the ideas of T-Mon, "a monitor of traces for the xAPI-SG standard" (Alonso-Fernández et al., 2021). They implemented a set of visualizations with aggregated data for each player.

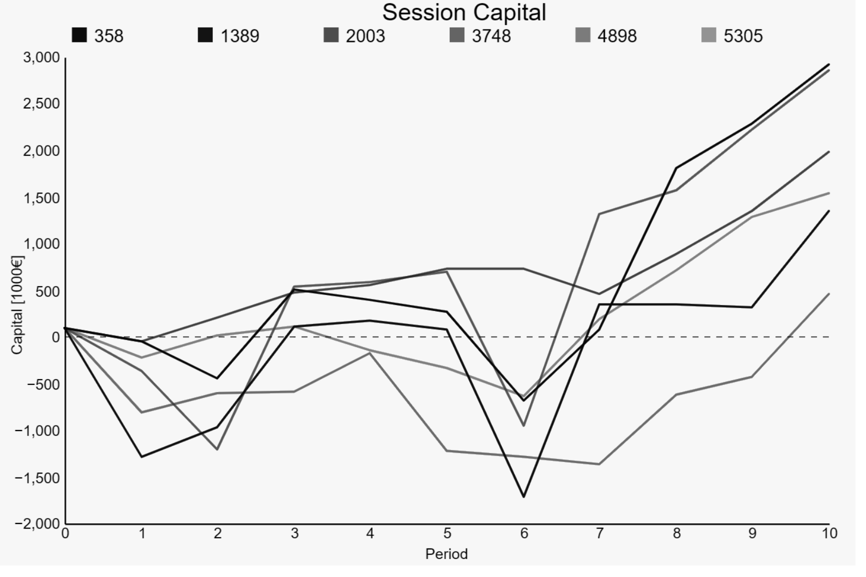

Fig. 1 Example visualization from the general section. The teacher could compare the overall capital of the 6 different groups at first sight.

The second section shows data about the usage of different functionalities of the serious game. Fig. 2 shows two visualizations about the handling of the game. For example, two groups were able to pay back the loan in the middle of the gameplay and took out new loans for the later periods.

Fig. 3 shows a visualization which could be used to compare different groups with regard to the production components used to build cars. With these visualizations, the teacher could learn about the management of materials that was done by each group. On the y axis, the distribution of the different materials is plotted; a solid color-filled period would therefore mean that only one material was present with the group, while no data shows that the players had no materials in the period (as group 2003 in period 5/6). An even distribution shows that the players had the same amount of all materials, like the same group at the beginning of the game.

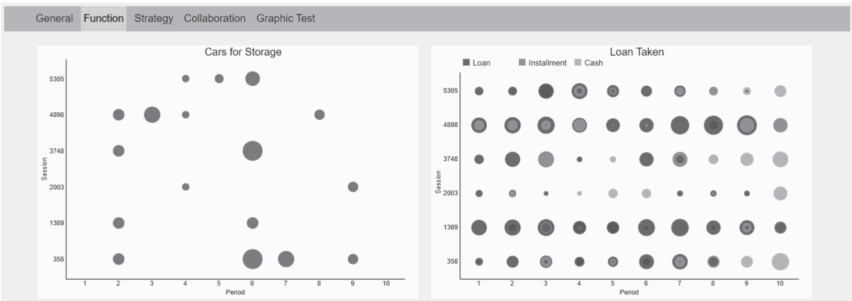

Fig. 2 Example visualizations from the function section. The left graphic answers the question of if the students used the storage function, how and in which game period. The right graphic shows if the learners used loans and how often. This also relates to the first graph shown in this paper.

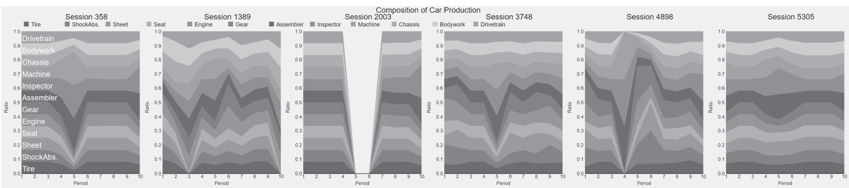

Fig. 3 A more complex visualization from the functions section showing the material management of all groups. The y axis shows the relative distribution of materials; the x axis represents the time periods.

For the third section, indicators were derived which are connected to strategy development. Here it is possible to determine the inherent difference between group strategies. For example, the evaluation showed that there are typical mistakes connected to strategy development, which occur at different stages in the game. Especially in the first cycles (rounds) of the game, it is hard for some players to deal with their uncertainty, which is visible in the data on the dashboard. Fig. 4 shows some results of the dashboard concept for SCM serious games. The upper right graph shows the results of the actual group and the mean from the other groups. Together with the capital allocation, the graphs could be used to analyze the strategy of the learners with regard to the finances of the team.

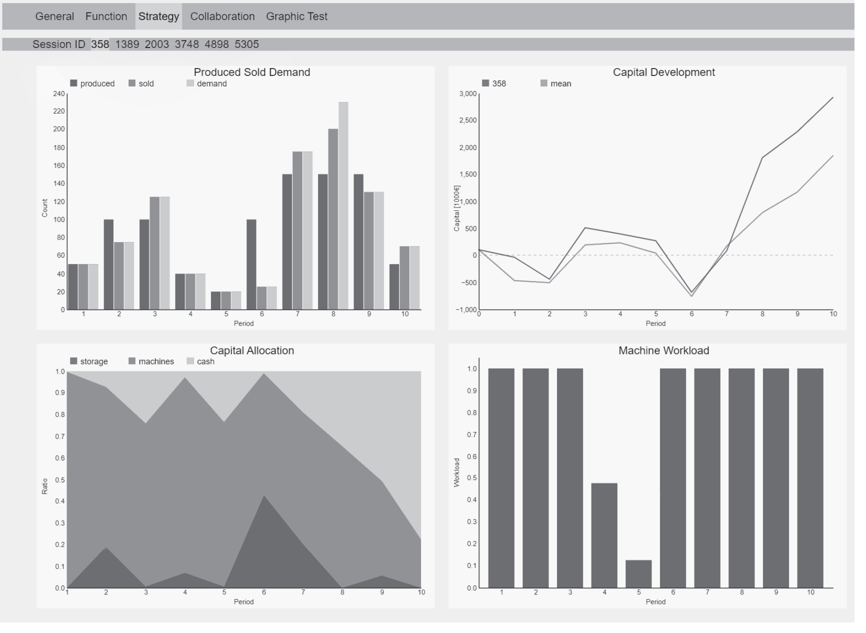

Fig. 4 Example visualizations from the strategy section. The four graphics show the results for group 5305, which can be used individually or jointly.

The fourth section of the dashboard deals with group behavior; this last part of the dashboard gives insights into collaboration: Division of tasks is the most obvious indicator; other more detailed insights like interaction distribution and attribution of period conclusion allow educators to get a deeper look into the behavior of students learning in teams. Fig. 5 shows the basic visualizations, which are accompanied by others. From these very basic visualizations, the teacher can first see how the students have assigned themselves the individual tasks. However, this type of visualization has led to reconsideration of the decision to let the players pass the module selection. This is because unfavorable distributions show that one player has significantly fewer interactions than the other player.

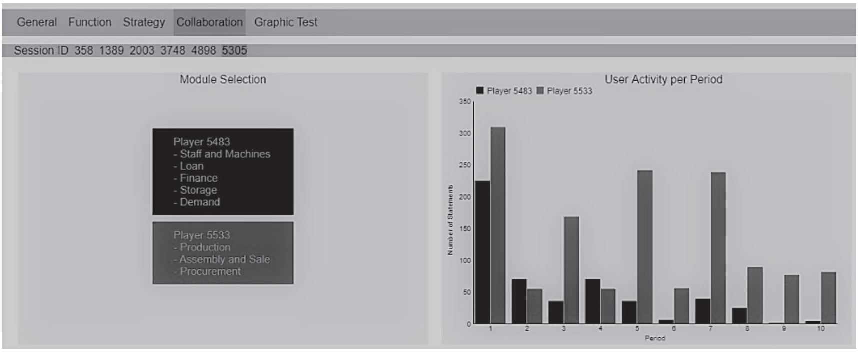

Fig. 5 Example visualizations from the collaboration section. The left graphic shows how the players distributed the modules, which was a decision taken by the groups themselves. The right graphic shows the number of interactions recognized by the system assigned to the players.

5 Evaluation

One obstacle in designing dashboards is the need to evaluate them. Jivet et al., 2018 analyzed how researchers evaluated learning analytics dashboards in a systematic review of 26 papers. We tested their usability and the understanding of them in a small-scale study.

A possible next step regarding dashboard evaluation could be to investigate if and how the dashboard is able to change the behavior of the learners in certain respects. For example, it could have an effect on the balance of the workload, forms of collaboration (i.e. division of labor), or a deviation in the observed communication strategies. For now, data about usability and understanding was collected and has yielded promising results, as the *System Usability Scale* (Brooke, 1995) reaches an average score of 85.25. Though the scores are 0–100 and 85.25 is in the official range of “excellent” results, it still leaves room for improvement.

The evaluation of the specific understanding of the dashboard and the indicators employed is done mostly qualitatively and described in more detail in Schulz, 2021.

6 Conclusion & Outlook

The work presented here is the aggregate of the efforts of multiple groups from different disciplines. It shows the evolution of curricular content to a serious game, then to a collaborative game, and then further on to a powerful instrument for obtaining deep insights into the understanding process of the complex interdependencies in the supply chain.

While the first evaluations had to focus on the usability and understanding of certain aspects due to the pandemic situation, the results look quite promising: The indicators allow instructors and supervisors to understand their students to a higher degree and yield information inaccessible before. Furthermore, they enable students to reflect on their behavior regarding decision-making as well as collaboration, discuss it in group and with their instructor, and have constructive feedback to improve in upcoming iterations.

The next step should be a larger-scale study to evaluate the current prototype with a larger audience, to test if the learning goal of *self-management* could be improved with a dashboard for students and compare the results to different modalities, i.e. single-user or remote collaboration. Provided the results justify further pursuit of this avenue of research, the prototype will be enhanced to reflect the current complexity of the single-user serious game.

Acknowledgements

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