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Experiencing the Role of Cooperation and Competition in Operations and Supply Chain Management with a Multiplayer Serious Game

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Abstract. We present an innovative, cooperative, and competitive multiplayer serious game, suited for the educational needs of supply chain and operation management post-graduate students. Hence, the objective is to satisfy the ever-increasing requirement of students to have the ability to experience and practice the theory learned in traditional ways, for active knowledge acquisition. To cope with such needs, we designed and implemented a multiplayer online serious game, that provides players with a realistic industrial experience, and teaches them how to take a whole range of day-to day and medium-term challenging decisions. Learners are divided into teams, each one representing an Original Equipment Manufacturer (OEM), in every team the students will collaborate and will compete in the same market, and sharing a limited set of suppliers. To this aim they have to define a strategy to target the best market segmentation. Teachers have the possibility to investigate the decision patters of the learners, analyze KPIs and learning analytics, to better understand the learning process and guide the learners in their educational journey. By means of a preliminary questionnaire, the interest in using the serious game to study operation management was confirmed. In addition, the game was tested by a small group of students, who acknowledged the effectiveness of the game's dynamics as a tool to complement traditional teaching methods.

Keywords: Serious Game, Supply Chain, Operations Management, Competitive, Cooperative.

1 Introduction

Serious games in the education of both engineering students and professional have been proposed and implemented since a couple of decades, but especially in the first years, they have not been taken very seriously [1]. Nonetheless, with the rise of virtual-labs, distance learning and on-line services for continuous education, a renewed interest for innovative, immersive, and even entertaining ways of learning calls for a reconsideration of such learning tools. Moreover, for many teachers and pedagogues, learning by doing is considered one of the most effective teaching styles to close the

gap between theory and practice, as it gives learners the opportunity to experience, explore and understand the context in which they will be operating, through an effective simulation. Indeed, an intrinsic characteristic of Serious Games is that of being simulations of real-world environments and to reflect everyday practical processes. For these reasons, Serious Games are ideal tools to teach and learn Operations Management [2].

Nowadays is possible to find Serious Games developed either for single or multiplayer usage. The first approach definitely helps the learner to accelerate his or her training path, but it cannot deliver the augmented experience that multiplayer games have [3]. Indeed, many researchers investigated the added benefits of multiplayer serious games, and concluded that multiplayer solutions teach team-working, collaboration and cooperation in a very effective way [4], [5], and they can be successfully implemented for game-based collaborative learning [3]. Multiplayer Serious Games, such as the one represented in this paper, can be conceptually seen as virtual laboratories that enable distance learning through online services, if the multiplayer is accessible remotely through, for example, the Internet. So, they can perfectly fit with the necessity to have distance learning and on-line services [2].

This work belongs to this stream of research and presents a multiplayer serious game that allows learners to experience the day-to-day workings activities and the dynamics of managing a business in a competitive environment, both at the operational and strategic levels, together with the correct coordination with different supply chain actors. The paper also presents the ongoing evaluation of the proposed serious game, which will be firstly targeted to bachelor's degree students of industrial engineering courses.

The rest of the paper is organized as follows: section 2 provides a quick overview of the literature review on the most relevant papers on serious games with a strong focus on studies concerning existing Operation Management/Supply Chain Management serious games. Section 3 presents the design of the serious game, describing the educational features implemented. Finally, section 4 provides the mid-term results, extracted from the questionnaires distributed to students in order to have a feedback on the preliminary design of the Serious Game, as well as on provided didactical support during the game sessions.

2 Literature Review on Operations and Supply Chain Management Serious Games

Nowadays, the studies on Serious Games are numerous. Briefly, Serious Games can be defined as “an application with three components: experience, entertainment, and multimedia” [6]. During their research, [7] discovered that different outcomes of the adoption of Serious Games can be identified by empirical evidence, like the acquisition of knowledge but also the improvement of motivational, social, physiological behaviors. Moreover, Serious Games are mainly focused on the improvement of the learners' performances, the motivational features are usually of secondary interest. Nonetheless, [8] showed that games can promote intrinsic motivation, encouraging

and sustaining learning, of both academic and non-academic skills, motivating learners to collaborate and share information effectively, thus improving soft skills. However, to achieve that, additional mechanisms need to be implemented.

Recently there has been a spike of interest in the popularity of applying gamification to teach supply chain and operations management. Indeed, having powerful and representative simulations help students to experience and apply learned theory, in a timely and cost-effective way. Although engineering education has traditionally focused on the so-called hard or technical skills, modern curricula are changing to expand core engineering competences and to deliver up-to-date knowledge in a fast-changing world, as well as broader professional skills [9]. Moreover, many researchers highlighted the need to enrich engineering curriculum with design-build-test projects, helping scholars to practice soft skills such as collaboration, team building, communication, leadership, through active and experiential learning, and constantly improve [10].

To better contextualize the multiplayer serious game object of this study, the most relevant supply chain and operations management serious games will be briefly discussed. Relatively to the first group, the Beer Game [11], originally designed as a multiplayer card game, is probably the most known and used one. Players represent different tiers of a supply chain and interact with each other to fulfill customer's demand; in doing so, they experience naturally arising dynamics of a supply chain, such as the bullwhip effect. Also, AUSUM [12] is a supply chain serious game, but the focus is on the dynamics of an automobile supply chain and the aim is to investigate the interconnection and dependencies among players' decisions. Finally, the Fresh Connection [13] is about value chain learning. This game gives players the opportunity to experience the importance of cross-functional alignment and inter-company collaboration (i.e., internal, and external coordination), in terms of both strategy and actions. Players, indeed, should avoid maximizing personal objectives, and are driven by the goal of maximizing the Return on Investments (ROI) of the whole supply chain.

Learn2Work [14] is one of the main examples of serious games in the field of operation management. It delivers three main scenarios, each one designed to help the player to embark, from different starting points, in the journey of an entrepreneur trying to bring the company to success. In doing so, the learner has to deal with a variegated set of entrepreneurial challenges, from hiring staff and expanding production capacity, to managing customer relations. Finally, Practice operations [15] is presented as a 3D, single-player, interactive game that allows students to control the operational management of a clothing company. To assure the success of the company, players have to cover different corporate roles, and deal with tasks such as: placing offers for orders, managing physical and human resources, managing the procurement of raw materials, transforming them into finished products and organizing shipment to the customer.

3 Overview of an innovative Multiplayer Serious Game on Operations and Supply Chain Management

The serious game is aimed at bachelor students of supply chain and operation management courses. An extension for master students is planned for the future. The aim is to address different learning habits (i.e. Self-Directed Learning, lectures, etc.) of learners and to motivate them in different ways. To increase the effectiveness of the proposed Serious Game, we followed the ARCS model. The ARCS model [16] is a method to improve the appeal of learning/instructional material, and it is composed of three different features: (i) it details four conceptual categories, which address specific variables and concepts, to try and characterize human motivation; (ii) it suggests a set of strategies to increase the appeal of instructions from the educational point of view; (iii) it suggests an approach called “motivational design” that can be successfully applied to instructional design models [16]. This model is one of the first theory that addresses the question of how to motivate the stimulation to learn, and it is often referred to in Serious Games design (see for example [17]).

Concretely, users will face various real-life and real-time dilemmas that naturally occur during the daily management of a manufacturing company. Also, to improve both hard and soft skills, the game was designed as a multiplayer environment and implemented as a web application. In this regard is worth noting that the only requirement for participants is to have a computer/tablet/smartphone with any common web browser software. In each match, players are grouped into teams (of two or three students at most), and each team represents an Original Equipment Manufacturer (OEM). OEMs are e-bikes manufacturers that compete in the same market niche, sharing suppliers and customers. At the beginning the product portfolio is fixed, but during the gameplay (at precise moments dedicated to strategic decisions) it can be extended or modified, if the players within the same company agree to do so. Each company compete for the satisfaction of a limited number of customer agents, which model the overall market demand dynamics, in terms of quantities, qualities, due dates, and price. To this aim they must define a strategy to target the best market segmentation.

Each player performs a specific role within the company, with a precise scope and a pre-defined set of tasks to be accomplished for an effective and efficient management. Roles are the following ones: purchasing manager (PM), operations manager (OM), and sales manager (SM). PM is in charge of managing the procurement of raw materials, managing raw materials stock levels, and correctly selecting the best suppliers/material combination, planning orders timely, both in terms of quantity, quality, and due date. OM is in charge of effectively and efficiently schedule production orders, to satisfy demand, correctly exploiting the equipment at disposal. SM is in charge of dealing with customers’ requests and managing customer deliveries.

For an effective management, players must cooperate and coordinate their daily activities, and they are also required to make shared and consensual decisions, concerning the supply chain management strategy. Indeed, teamwork, cross-functional understanding and collaboration are key issues to turn the company around, toward success.

In Figure 1 is depicted the simplified flow chart of operation and interconnectedness and dependencies between the different main call to actions of each role. In particular, the flow chart shows one of the main approaches to deal with market demand, namely make to order (MTO). In this strategy, players react to the successful acquisition of a customer request made by the SM. Indeed, as soon as the acquisition is successful, the SM should alert the OM which in turn should check and plan shop floor activities accordingly, in coordination with the PM which is in charge of checking and managing future raw materials availability. Such strategy is one of the many that players can explicitly or implicitly adopt. Many others can be evaluated and chosen. Indeed, by design, not only one specific strategy must be followed in order to successfully play the game. So, in order to successfully apply this strategy, the SM has to learn how to analyze the market demand, and negotiate with each customer, as well as managing the outbound logistics. The OM has to learn and apply classical scheduling methodologies by considering the overall productive capacity. The PM must learn how to handle the inventory, by managing the raw materials supply chain, using well known inventory management policies.

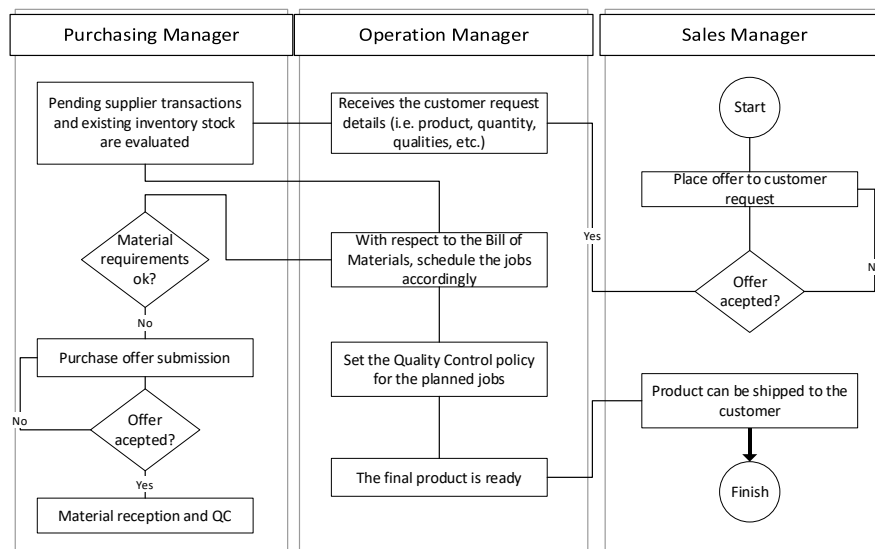


Fig. 1. Make to Order flow chart

One of the most prominent examples is the market segmentation analysis. Indeed, the demand dynamics are modeled in a way that, depending on the selected difficulty level, more than a single market segment could exist. Thus, the players should discover these segments, and tailor their production and distribution strategy to perfectly meet the needs and expectations of the customers they decided to serve. Quality management is another prominent issue that players have to deal with, both at the operational and strategic level. Indeed, anytime a customer's enquiry is received, SM should analyze it not only in terms of quantity, price, and delivery dates, but also in

terms of quality requirements. These parameters, in fact, can be negotiated with the customer, and choosing a right trade-off is crucial for success. These decisions also impact the manufacturing process because, in turn, the OM must schedule production accordingly and decide whether is economical convenient to plan detailed quality controls in one or more points of the production process. Similarly, also the PM must operate accordingly when submitting order requests to potential suppliers and he or she must decide if which, if any, quality controls policies should be applied when goods are received.

Finally, the game is designed to teach the value of communication as a necessary means of coordination among different departments and/or corporate functions. To force an active communication among partners, in fact, the game interface, designed to mimic a simplified ERP, does not allow players to have full visibility of the actions taken by their teammates. Specifically, the interface hides the information at disposal of the other members or, at the most, it offers a partial and very aggregated information about the targets achieved in other processes. So, the players are strongly encouraged to communicate with each other, and must establish effective communication protocols for better coordination.

4 Students' opinions and preliminary evaluation

To confirm the growing interest in serious games, and to assess the quality of our solution, a total of 176 bachelor-degree students (enrolled in industrial engineering courses held at two Italian-speaking universities) were interviewed. The same students will be asked to use the serious game during the next semester, and a second questionnaire will be submitted to register their perceptions and their satisfaction about the game.

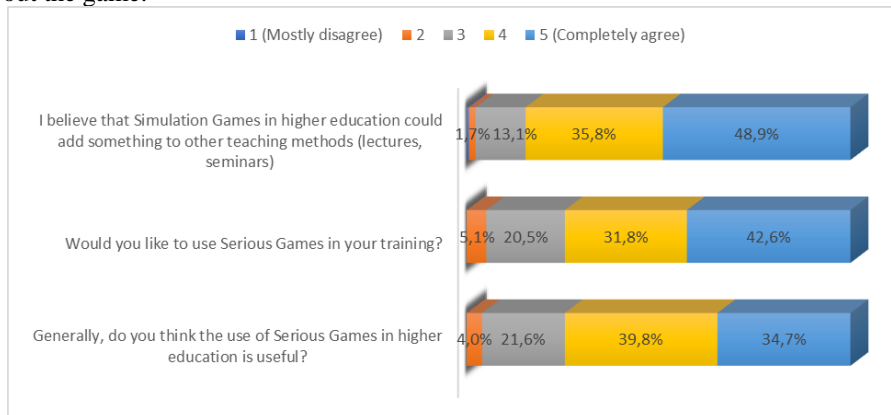


Fig. 2. Questionnaire results about general interest in serious games

Results, concerning the first questionnaire used to measure the general interest in serious games are summarized in Figure 2.

We note that the questionnaire also included questions to measure the students' previous knowledge on the subject. Nonetheless, these results are not included herein, as they will be part of a future work, aimed to compare the learning performance of a group of students who used the game, relatively to a control group who only attended standard theory lessons.

Since the courses are ongoing at the time of writing, we present interim results obtained on a demo session, during which a cohort of nine bachelor students tested the serious game. At the end of the demo session, that lasted around eight hours, a questionnaire was administered. The aim of the questionnaire was to measure different aspects of user engagement and playability, and to collect general comments about the experience of the participants during the serious game, however due to the limited game time, it was not possible to evaluate the learning outcomes. All nine students were at the last semester of their bachelor-degree, and they have already attended and passed the operation management module.

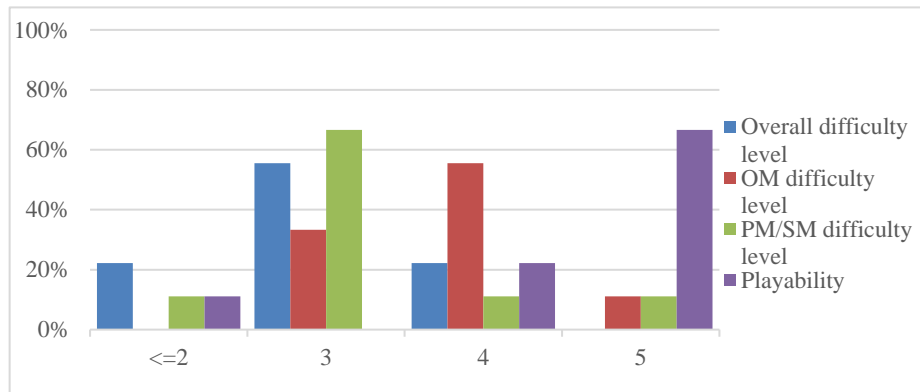


Fig. 3. Results about perceived game difficulty and playability

As it can be seen in Figure 3, in terms of perceived difficulty, most of them (56%) felt the game was properly calibrated (i.e., right level of difficulty or slightly lower), according to their knowledge and limited time to learn the game. However, perceptions of the students who played as Operations Manager were slightly worse. Indeed, 66% reported a difficulty level higher or equal to 4 (on a scale ranging from 1 very easy to 5 very difficult). However, such results were expected, since the role of the OM is more demanding and the player experiences more operational pressure, even more during a short demo session. Vice versa, player engaged either as PM or SM reported a less demanding and less stressful gaming experience and 66% of them quantify in three point (i.e., adequate) the perceived difficulty level. To minimize this unavoidable unbalance (among roles) a full gameplay foresees roles turnover, to equalize the effort of the players and to better balance their experience. This turnover is supposed to lead to a better understanding of a production company's whole environment. Moreover, the learners will better understand how to interact according with the company's function they are representing. Also, as already showed before (Figure

3), the difficulty perceived for the company functions is not equal, so a more balanced learning environment for the trainee to interact with is provided.

Moreover, as shown in Figure 4, all, but one student, reported a very high correlation between the game mechanics and the theory they studied.

This is one of the main results, given that one of goals of such preliminary survey was for the authors to measure how well the game have been designed to make tangible for students the application of theory in the simulated environment. Indeed, such results have been collected from experienced students, which have already successfully studied operation management.

Competition awareness was overall high, with almost 90% of students reporting a level higher of equal to four. All of them agreed that the game is enjoyable, if not exciting, but noted that an integrated chat system could be beneficial, as the communication among players in a company was considered a key issue for a successful business management. Finally, 77% of interviewee found the user interface easy enough, while the remaining 23% reported full satisfaction of the user interface.

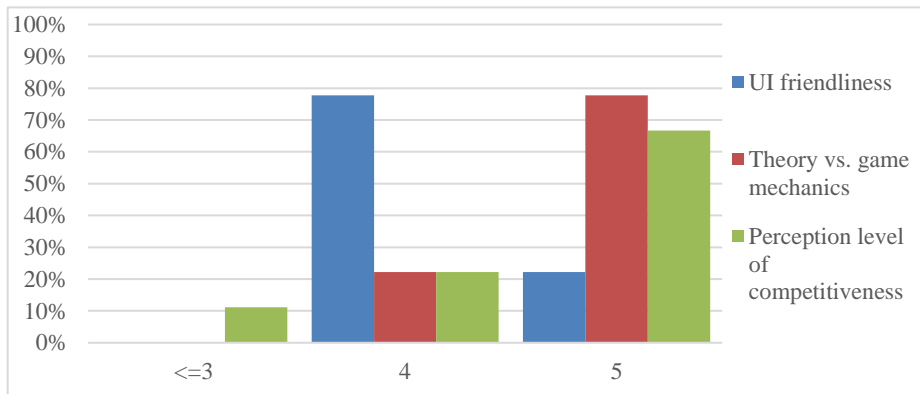


Fig. 4. Results about perception of key game design choices

5 Conclusions and future works

The present work describes an innovative multiplayer serious game aimed at the education of supply chain and operation management learners.

The game is built upon several innovative design choices: first, it is meant to be played by many students at the same time, both cooperating with each other within the same OEM, as well as competing for optimizing the market share. Moreover, within the same company, players have the opportunity to experience different roles, which enable them to better understand both at the operational level as well as the strategic level the implications of several business units' functionalities. These game dynamics enables learners to directly experience and learn the importance of a well-established framework of communication, which, if planned and executed well, should give them a competitive advantage over the competitors.

Early-stage testing have been conducted to confirm the game design and mechanics. Results attest to the correct design of the game, especially in terms of workload balance of the different players, as well as in the general interest of the students in the use of an advanced educational tool within the relevant curriculum with respect to covered topics. While the analysis tested a relatively small cohort of bachelor's degree students, shortly the analysis will be conducted over a bigger sample. Such analysis will be the subject of a future work. Moreover, a questionnaire administered to a cohort of undergraduate students showed notable interest in the use of serious game for operation management which further strength the exploitability of such learning method for teaching operation management and supply chain management courses.

In addition, other future developments could include the ability for players to play roles at different levels of the supply chain, or the creation of computer-managed virtual players to allow one team, or even multiple human teams to compete with computer-managed companies.

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