Teaching supply chain management concepts through simulations and games

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Abstract

Simulations present a different way of engaging students in their learning journey. Within this study, a sample of published simulations and games are analysed based on their learning objectives, simulation design aspects and suitability for online synchronous or asynchronous delivery. Based on characteristics identified following this review, two alternative simulations are being developed, detailed, and discussed in this material. Each of these simulations have the scope to capture characteristics of developing and implementing simulations in teaching and learning supply chain management concepts. This study concludes with a framework for developing simulation models for teaching and learning supply chain management concepts.

Keywords: supply chain, simulation, teaching and learning

Introduction

Simulations and games have been used in business education for some time and they play a significant role in teaching and learning challenging concepts (Goi, 2019) in the area of operations and supply chain management (Webb et al., 2014). Simulations and games can be constructed and embedded into the curriculum not only to help learners understand concepts but also to experience activities and events as they may happen in practice. Andreas Liu et al. (2009, p. 398) comment that simulation games have become a “key factor in management teaching”. They are present in many areas of management teaching, from marketing (Vos, 2014), to operations management (Pasin and Giroux (2011), to lean manufacturing (Badurdeen et al, 2010), to service oriented supply chain (Anderson and Morrice, 2000), to information systems development (Martin, 2000) and to many others.

Goi (2019) has captured several reasons as to why business simulation games are important in teaching and learning, some of these referring to the engagement of learners in critical thinking; promotion of positive participation, perceptions and motivation through interactive games; allowing learners to process and explore information in a nonlinear fashion; engages their imagination, creativity, problem-solving and decision-making ability and many others. Vos (2014) adds that simulations allows learners to see how business functions integrate, experience an environment close to the real world that is competitive and uncertain, allows the integration of theory and for this to be presented in different contexts, develops relevant employability skills from decision-making, numerical, analytical, problem solving skills to team working, time management, communication, entrepreneurship and negotiation skills. In Badurdeen et al, (2010) it is added that simulation games promote more knowledge transfer and accommodate for more learning styles. In their study, Riley et al., (2017) have debated that the mode of delivery has affected student comprehension when teaching operations management concepts using simulations. Therefore, this enquiry sets to understand how some of the benefits of incorporating business simulation games as identified by Goi (2019), Vos (2014), Badurdeen et al., (2010) and others can be embedded when developing computer-based simulations for online delivery and how do they compare with simulation games developed for in-class face-to-face (*ic-f2f*) delivery.

To further clarify the terminology used within this paper, at this point it is relevant to indicate that there will be reference to the in-class face-to-face (*ic-f2f*) delivery of content for traditional teaching setting where the teacher delivers a lecture or seminar in a classroom setting. This, however, does not refer to having this session recorded and made available to students afterwards online via a virtual learning environment (VLE) platform. There is also the mode of delivery that refers to online face-to-face (*ol-f2f*), where teaching takes a form of a synchronous approach where a tutor delivers a session to a group of students who are participating online. For both types of delivery (*ic-f2f*, *ol-f2f*), there is the opportunity for real-time interaction with the tutor as well as peers. There is also the aspect of teaching content that is being prepared and made available online, however the interaction with this content is asynchronous, where students still have the opportunity to engage and ask questions, however these questions are via emails, discussion boards, online set forums, or organised chats. Still, this approach is not necessarily designed for real-time interaction with the tutors. The reference to this approach is noted in this material as on-line asynchronous (*ol-a*) approach.

Various aspects of operations and supply chain management have been tackled using computer-based simulations that have been created and implemented in practice by organisations to respond to challenges linked to supply chain operations, as well as they have been developed for training and learning. Computer-based simulations have also been incorporated in the curriculum material for *ic-f2f* delivery together with experimental exercises (Tipi, 2009) as well as various type of computer-based simulations have been developed for online delivery (Weltman and Tokar, 2019). A range of games including board games and other forms of non-computer-based simulations are also present in the literature for teaching operations and supply chain content (Summers, 2004). When computer-based simulations are being used, it is envisaged that there may be technical challenges and that only particular aspects of simulation design characteristics can be incorporated in online teaching material. However, it is also recognised that supply chains are complex systems and they are best represented using computer-based simulations due to their ability of capturing the complexity of such systems (Chilmon and Tipi, 2020).

This research aims to contribute by identifying a framework for developing simulations and simulation games for teaching and learning supply chain management concepts. By following this framework, the scope is to assist teaching and research staff in constructing and incorporating variations of simulations to be incorporated in their teaching material. This is concluded from analysing supply chain simulation models, however there are a set of general aspects that are valid for simulation models development that refer to other operations management concepts. The proposed framework will be highlighted from the point of view of an online synchronous and asynchronous approach for delivery end engagement with teaching and learning content.

There are differences in developing, delivering and engaging with simulation games in teaching and learning, therefore, this research contributes to the body of theory by assessing and categorising key aspects that need to be considered when developing these simulations.

A review of simulations and games used in teaching operations and supply chain management

Authors have found, that using simulation games enhances student learning (Vogel et al., 2006; Badurdeen et al., 2010; Webb et al., 2014; Loon et al., 2015; Weltman and Tokar, 2019) and there is increasing empirical evidence that they are effective in reaching the desired learning outcomes.

For the purpose of this discussion, simulations will be split into simulations developed that do not require the use of computers and those that require these. It is relevant to note at this point that, non-computer-based simulations are only envisaged for *ic-f2f* delivery. Computer based simulations refer to simulations and games that are designed for ether *ic-f2f*, *ol-f2f* or *ol-a* approach and they can be saved directly under a VLE system where students have access to.

Non-computer-based simulations

Badurdeen et al, (2010) have reviewed over 40 games used in teaching lean manufacturing that used some form of prefabricated modular components such as building blocks, LEGO or K'Nex parts. The review has captured some of the themes relevant to developing a framework for designing simulation games. They first identify the theory covered, followed by the number of iterations required to play the game, and captured if an application has the potential to be reflected in practice. An interesting set of pitfalls are being identified as a result of this review. Some of these are: "students feeling left out or in competition", "facilitator not being able to create a learning environment", "difficulty in relating simulation activities with real-world scenario" and "instructor giving incorrect or unclear advice".

One other interesting example is a simulation presented by Webb et al., (2014) where they are describing a classroom simulation game with the scope to teach the complexities of operating in a challenging supply chain environment by introducing the supply chain reference (SCOR) model (developed by the Supply Chain Council in 1996). The objectives of the game were to introduce the SCOR model and identify the nodes, processes and challenges of managing a supply chain and brings understand to the interdependences of supply chain relations. The game can be delivered in a 45 min class as well as extended to allow for a longer period of time and can be played with smaller student groups from 15-20 to larger groups of up to 150 students. There is a competing element within this game where students need to effectively and efficiently produce and sell two different products. A post-exercise discussion is considered where students discuss concepts around SCOR processes, supply chain relationships, information flow, demand, quality, reverse logistics, competing supply chain incentives and supply chain disruptions.

It can be noted that non-computer-based simulation games appear to be very popular, where students have made a number of positive remarks having participated into a simulation game, however they tend to meet the needs of a particular learning style. There is an elements of competitiveness and group work, where some students prefer to work and learn on their own without the involvement of others, as well as they prefer to have the time to review an idea as many times they require, without the "judgement" of other members in the team.

Computer-based simulations

A range of computer base simulations have been developed and many are presented in the literature as simulation games. Anderson and Morrice (2000) have developed the *Mortgage Service Game* with the scope to teach service-oriented supply chain management principles in a make-to-order environment. They use concepts of system dynamics and tackle a number of supply chain management aspects. The model developed here is implemented in the Vensim© and iThink simulation packages. This game is used in teaching as well as research and assessment. Weltman and Tokar (2019) report on the use of a simulation for the classical direct transportation model, that not only deals with the transportation planning, but also has an addition of exploring customer demand using Monte Carlo simulation. This has been developed using the liner programming model in Excel, the optimiser as Solver, and the Monte Caro simulation was used using Oracle Crystal Ball. This simulation, however, is designed to be used in a classroom environment using dedicated computers and it requires the availability of an additional software package students need access to. It is also relevant to note that running this game requires additional teaching time (as indicated 1 hour and 20 min) and it is important to have an instructor present during the time of running the simulation. Students can work in teams for this exercise and students have reported a positive experience from getting engaged with this simulation. They have also provided positive comments on the use of analytical techniques and effectiveness of learning environment.

Many other simulation games have been developed for teaching and reported in the literature, some of which discussing the use of a simulation for an ERP system using the SAP software (Angolia and Pagliari, 2018); or simulations using spreadsheets (Pasin and Giroux, 2011).

Simulations models development

Analysing the simulation games used in teaching gives an indication of how to develop and design simulation games. The game's design characteristics as identified in previous work (Vos, 2014) focus on: scope of the simulation game (knowledge, interaction, skills to be learned); level at which this is to be delivered (Undergraduates, Masters); mode of delivery (*ic-f2f*, *ol-f2f*, *ol-a*); resource constraints such as time required for delivery, teaching material available; minimum/maximum number of students in class; link to practical application; student reflection and feedback.

For this reason, two simulation games are being developed, one being a non-computer-based simulation with the use of building blocks and the other being a computer-based simulation game using a dedicated simulation software package such as ARENA® discrete event simulation (Rockwell Automation). Both of these simulation games are detailed in the section below.

Furniture supply chain simulation game - a non-computer-based simulation game using building blocks (see Figure 1).

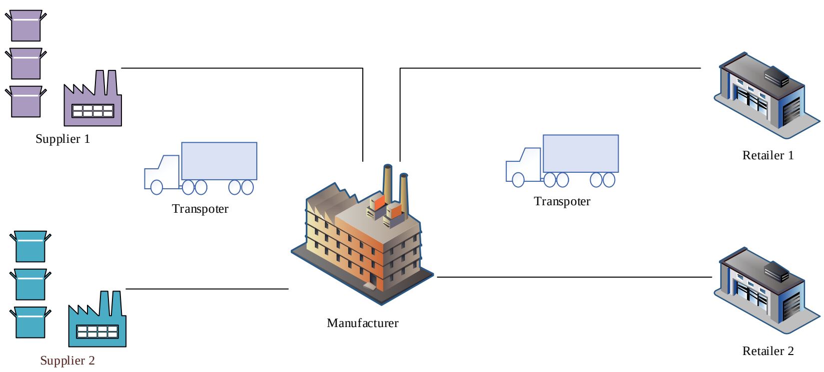

Figure 1 - An overview of the furniture supply chain

Characteristics of the simulation game: to simulate a supply chain environment, characteristics of the key supply chain companies have been taken into consideration, and these comprises of suppliers, manufacturer(s), transport organisations and retailers as customers (see Figure 1). Suppliers are providing raw materials in the form of various building block pieces of various size and colour. The manufacturer places the order for raw materials with the transport company, who are then communicating this order to suppliers. Based on the number of students in class, two suppliers can be selected to form the team of players, each with one or two players. The manufacturer would benefit from a minimum of four players. This is to allocate different roles within the team, such as carry out the manufacturing operations (building the final products), coordinate the internal activities and place new orders, facilitate the communication with the transport company, receive new raw materials when these have been delivered and carry out quality checks. An optimum number of players within the manufacturing team would be of six players. To allow for a more dynamic supply chain environment, two manufacturing teams can be allocated to play the game. The transport organisation can be formed of a team of a minimum two players, to facilitate the communication between suppliers and manufacturers, as well as between retailers and manufacturers, and to carry the raw materials and finished products between the different locations set. Based on the total number of players, two teams can be allocated and up to four players can form part of the transportation team. The retailers receive products from the manufacturer, check these products for quality, engage into marketing activities, and place new orders for products. The minimum of two players are required as retailers.

Scope: *knowledge*: supply chain management concepts, gain understanding of how links between different players in the supply chain are formed, gain understanding of supply chain flows (material, order and cash flow) in the chain, highlight the potential for bottlenecks and the bullwhip effect, make reference to the position of inventory in the supply chain and highlight internal organisational decision; *interaction*: allows for *ic-f2f* interaction with peers, however this is only for the duration of the class time; *skills*: basic inventory calculations, order placing, time management, communication, negotiation;

Level: this simulation game is not restricted by the level of delivery, as it can be considered at Undergraduate as well as Masters, MBA and Executive education.

Mode: this game can be incorporated in teaching content for *ic-f2f* delivery. It is relevant to note that the game design in this format, is not directly transferable to an online environment. However, this can be changed into an online simulation game that may allow the engagement of a similar number of team members. It is envisaged, however, that the experience of playing a similar game using a computer-based format may not provide the same student interaction and visibility as the non-computer-based format.

Participants: can be played with a minimum as 9 players and an average of 20 players for a single supply chain. For larger classes two supply chains can be formed where they can consider the same or different products to manufacture. At this point there are competing supply chains, therefore a new element is added to the discussion.

Time considerations for delivery: It is best to consider one simulation cycle (one day) as 15 minutes. This is when manufacturers start their operation with some material already in stock; transporters are already receiving orders which they must coordinate; suppliers receive orders for which they need a system in place to deliver their orders. The game is best observed when an introduction of the supply chain concepts as well as the rules of the game are explained by a facilitator/tutor. Following this presentation, players will require a 15 minutes time allocated before the simulation starts. This is to allow for all players in teams to discuss their strategy of operating. It is best to allow for the game to run 3 to 4 cycles minimum, so 45 to 60 minutes in total. Within this time, players can start making strategic decisions to eliminate some of the bottlenecks already observed in the first cycle of running of the game. A feedback session is expected at the end of running the game to discuss learnings and provide feedback. Therefore, it is envisaged that the best overall time to be allocated for a session like this is 3 hours, with short breaks incorporated in the design.

Teaching resources: a *room* needs to be booked to accommodate the number of students registered for this session. The room needs to have *desks* as stations organised for group work, with the number of stations equal with the number of organisations forming part of the supply chain. An additional desk may be set up in case students arrive late to their class, however the activity for this additional desk needs to be pre-planned. *Building blocks* are organised per colour and size. From these, each station needs to include the pieces required before starting the game known as starting inventory position. The first *customer order* is required. For a controlled approach, the tutor may prepare all customer orders in advance, however they can also be allocated as a form of decision-making process by students.

Feedback: at the end of the session students are given the opportunity to provide feedback where a feedback form needs to be prepared and distributed ether in printed or online format. Still, it is relevant to note here that permission to collect this type of data needs to be incorporated into the process.

Discussion: Engaging into this type of simulation, students not only have the opportunity to experience the concepts and the links that form a supply chain, but also engage into a team building activity, have the experience of what happens if issues arise up or down the supply chain and at the same time engage into a fun activity. As detailed in earlier studies, this type of setting is not conducive for a one-hour class setting as continuous time is essential to have the desired experience from running the game and gain the learnings set. This particular simulation game is not designed to declare a winner, but more to observe teams responding to performances set such as *deliver on time and in full, satisfied customers, order fulfilment, effective communication*, implications of *returned products* due to quality checks. Therefore, the real benefit of the game is observed in the discussion part, where various supply chain management concepts are being evaluated as a result of being involved in playing the game. This is the space where students have the opportunity to reflect on the operations that took place during the running of the game. In general, this simulation game will be set to run at a scheduled time, and it is expected that all learners aiming to take part in playing the game need to attend the organised session.

Due to the complex nature of the supply chain operations that need to take place at the same time, each learner involved in the game will have the opportunity to take an active role in completing their assigned operations and avoid the risk of generating unnecessary bottlenecks. However, only at the end of the game and through discussions they will gain the awareness of what has happened in other parts of the supply chain.

End-to-end simulation – a computer-based simulation using discrete event simulation software ARENA (see Figure 2).

Characteristics of the simulation: The simulation developed and presented in Figure 2 considers 2 suppliers, one manufacturer, two distribution centre and four retailers. The end product can be designed as general, or it can be defined as being a furniture type product, or food, or textile, or a particular construction product and so on. There is therefore a lot of flexibility in selecting the supply chain, the type of products considered within this chain, as well as, based on the selected product type, there is also room to discuss about the industry this product belongs to.

Scope: *knowledge*: all supply chain management concepts captured in the furniture supply chain game detailed above as well as supply chain modelling concepts using discrete event simulations; *interaction*: allows for *ic-f2f* interaction with the tutor and is primarily designed that students work with the model on their own. However, this example can be considered as group work where decisions on input data can come from different learners as well as different teams; the model can be accessed outside class time. There is also the opportunity to consider this type of simulation for assessment; *skills*: inventory management, order management, performance measurement evaluation, working with data using statistical distributions, gaining a holistic view of operating in a supply chain, understanding system complexity, working with a discrete event simulation tool.

Level: can be developed and incorporated to any level of delivery.

Mode: suitable for *ic-f2f, ol-f2f* and *ol-a* mode of delivery as well as suitable for assessment.

Time considerations for delivery: can be included as part of a one-hour class; simulation can be repeated outside class set time and can be incorporated in following sessions as more system components are being introduced.

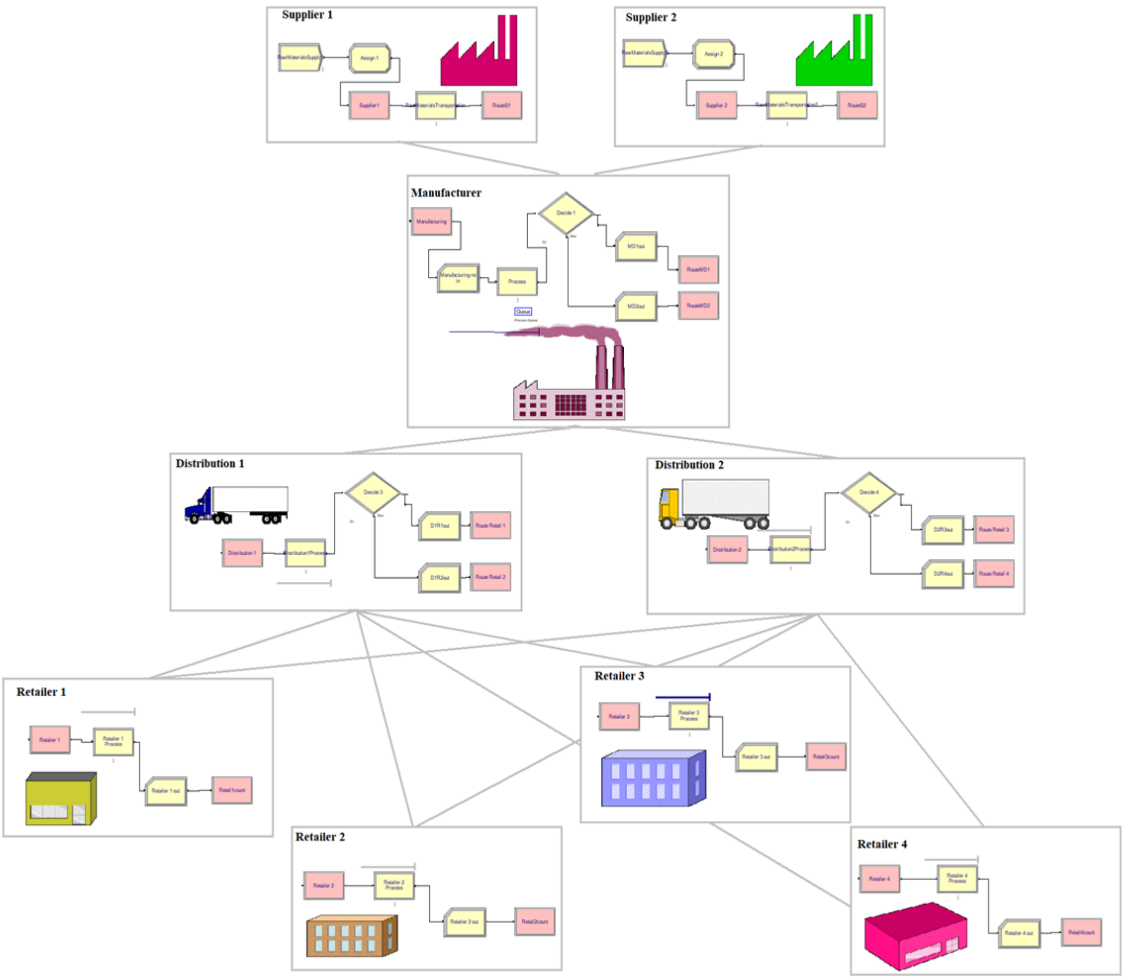

Figure 2- Computer based end to end supply chain simulation

Teaching resources: it is assumed that students taking the class will have access to the simulation software and this can be accessed online from any location using via a VLE system. No other resources are required. However, there may be simulation errors during the running of the game and the tutor presenting this simulation is expected to have the knowledge to answer this type of questions or have access to a specialist who can answer technical questions.

Feedback: as in the furniture simulation game, students have the opportunity to provide feedback to tutor based on their experience of using the simulation.

Discussion: Setting this simulation allows for various levels of flexibility over a non-computer-based simulation. Some of these flexibilities are: the simulation allows for an increased or decreased level of system complexity, engagement with statistical concepts, overview of the entire simulation at any one time, repetitions of simulation, analysis of simulation results after a very short period of time. This type of simulation allows for monitoring system performance over an extended operations time (for example 10 years) in a very short simulation time (simulation run time can take up to 1-2 minutes). It is also possible to stop the simulation at any one time and make changes and re-run the simulation or stop and just take time to reflect.

However, it is relevant to note that if the simulation has been developed using a particular software package (for example ARENA discrete event simulation) the tutor is expected to have knowledge on using and solving simulation errors as required. There is an additional cost regarding the software package and this software will only be accessible to students taking a particular class.

Developing a methodology for simulation models used in teaching

Following from methodologies on developing simulation models for business as discussed in Oliveira (2016), Chilmon and Tipi (2020), and Tipi (2021), the proposed methodology aims to capture some of these principles, as well as to adapt these to developing simulations models for teaching and learning. Tipi (2021, p.40-41) introduces the following modelling stages in the context of supply chain: (1) understanding reality and identifying the problem; (2) conceptualisation stage; (3) modelling stage; (4) analysis stage; (5) implementation stage and (6) post-implementation stage. These stages need to be adapted when considered for developing simulation models for teaching and learning. Engaging with the supply chain simulation developed fulfils the starting point of Kolb's learning cycle where learners engage into a concreate experience (Honey and Mumford 1992). Then the learner reflects upon this experience in a self-conscious way during and at the end of the simulation process. This gives them the option to draw on abstract concepts and link the observations from running the simulation to supply chain management concepts. Following this step, learners have a better picture on evaluating complex operations in a supply chain system and are better equipped to test these concepts out in practice.

For a simulation model development considered for teaching and learning, the following steps can be considered when developing a simulation: (1) evaluation of current learning needs. This will address the first stage in Kolb's learning cycle on bringing a situation close to reality and allowing the learners to have this experience; (2) simulation model development. This needs to be considered with the learner in mind who will engage in particular activities and have the opportunity to reflect on these; (3) analyse the simulation model. This will ensure there are no simulation errors and the model reflects the reality intended for simulation; (4) implement the simulation. The implemented model needs to allow the opportunity for trying our different ideas and requires a degree of flexibility; (5) post-implementation. At this stage students have the opportunity to give feedback on their experience and tutor will be able to make modifications to the model developed. Therefore, the simulation model development is set up in five stages as displayed in Figure 3 and represents the modelling framework for developing simulations for teaching and learning.

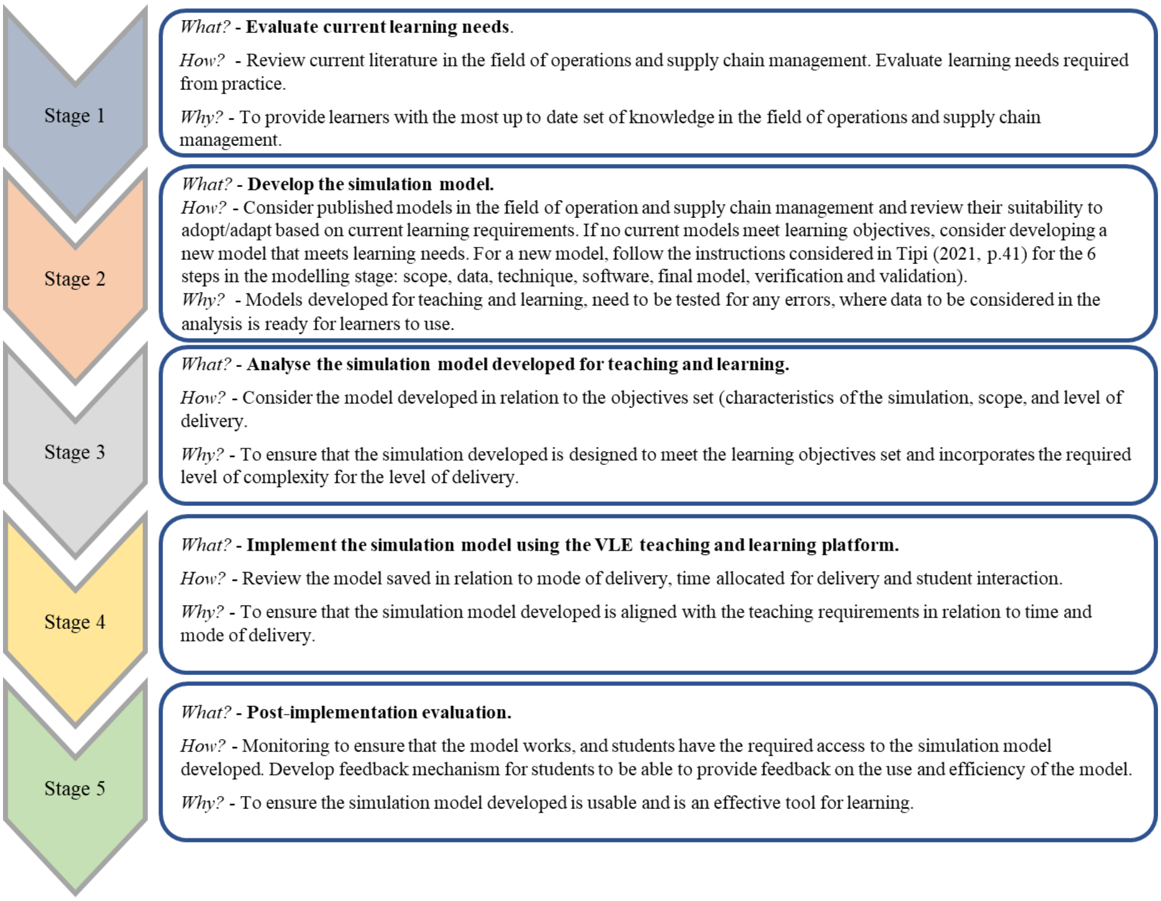

Figure 3- Modelling framework for developing a simulation for teaching and learning for a computer-based approach

Conclusion

This paper has set to develop a framework for designing simulation games to be used in teaching and learning supply chain management concepts within an online environment. Following a review of the literature as well as the development of two simulation games, this work concludes with a framework that considers five stages for simulation development. These stages consist of an evaluation of current learning needs in the context of other topics presented in the course, module material; the development of the simulation model that gives consideration to Kolb's learning cycle; the analysis and implementation of the model developed; and considerations to the post-implementation stage that needs to be taken into consideration.

Following this approach, a number of benefits as captured in the literature can be achieved when developing, implementing and using simulations for teaching and learning. The comparison between the two simulation models developed here highlights similarities and differences based on aspects such as modelling characteristics, scope, level, time, mode, teaching resources and opportunity for feedback. There are limitations within each of the models developed from time allocated to delivery to availability of the software required for simulation and others, however the computer-based approach brings added benefits.

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