Going from 2D to 3D in supply chain 4.0 education: an LSP approach

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Abstract

Purpose – This study aims at investigating the impact of using Lego Serious Play (LSP) on the effectiveness of teaching supply chain (SC) 4.0 in higher education by going from a traditional 2D approach to a 3D one. LSP in this study is explored as a gamification pedagogical approach that taps into the connection between hands and brain to inspire and engage students to build 3D models using metaphors and storytelling.

Design/methodology/approach – An empirical study was conducted among 50 students (over two terms) who were enrolled in a SC 4.0 course and used LSP in their final project that focused on digital SC design. Two questionnaires were designed (one after the standard LSP workshop and the other upon completion of the project) to solicit feedback with respect to how LSP helped students to better understand SC 4.0 topics and fulfill their project. The results were analyzed using Bloom's taxonomy as well as other pedagogical framework to understand the positive impact of LSP at the cognitive, motivation and social levels.

Findings – Results showed that using LSP can enhance the teaching of various SC principles and technologies beyond the abstract point of view (2D) through offering the students an opportunity to apply these principles and technologies in a futuristic project using a hands-on 3D approach. The LSP approach demonstrated its ability to help students navigate through both lower order thinking skills (LOTS) and higher order thinking skills (HOTS) in a meaningful and playful manner. Finally, improving the design skills for students was clear using LSP as it unleashes imagination and taps into internal knowledge together with collective inputs.

Research limitations/implications – The reliance on one case study can be a limitation regarding the generalization of the proposed results. This limitation is attenuated by the representativeness of the case study analyzed. Furthermore, the presented work should encourage future analyses as well as expanding the implementation of LSP to other SC 4.0 teaching contexts and applications.

Originality/value – This paper contributes to the very few literatures regarding using gamification in SC education and specifically how LSP methodology can be adopted in teaching SCM 4.0.

Keywords Supply chain 4.0, Gamification, Lego serious play

Paper type Research paper

1. Introduction

Playing in education had been a successful pedagogical approach to achieve "learn by doing" environment. Gamification is a playing strategy where game design and dynamics are used to pass on knowledge and support different activities and behaviors among students. The implementation of games in education was seamless and expected due to the common psychological and theoretical backgrounds of both disciplines (Landers, 2014). Games offer educators the capability to stimulate and engage students, inspire their creativity and develop their cognitive and social competences.

Today's supply chain (SC) 4.0 is founded on the evolution of digitization and digitalization technologies like Internet of Things (IoT), artificial intelligence (AI), cloud computing and

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blockchain (Cagliano *et al.*, 2021). There are various elements to the modern SC 4.0 that integrate cyber and physical systems from upstream to midstream and downstream, including smart manufacturing, smart logistics and integrated digital twins to name few (Zechnini *et al.*, 2021). These digital technologies together with these smart systems require a critical transformation journey of systematic development of an intelligent, real-time capable, horizontal and vertical networking of human, objects and systems (Kirazli and Hormann, 2015). SC 4.0 offers a new level of integration, transparency, traceability and efficiency that is more advanced from the traditional SC (Simonetto *et al.*, 2022). These new levels are essential for managing the challenges of sustainability (Dossou, 2018), resilience (Ivanov and Dougali, 2021), uncertainty and global dynamic competitiveness faced by today's SC enterprises (Frederico *et al.*, 2020).

Teaching complex systems requires special instructional practices, especially in higher education. Complex systems are those with elements or components that are interconnected, communicate and interact in multiple, nonlinear ways (Yoon, 2011). SCs 4.0 are indeed complex systems, especially in terms of how to design and manage (plan and control) them in today's disruptive and uncertain environment. Thus, teaching SC 4.0 requires special pedagogical resilience and tools that can cope with its continuous emerging patterns. Current research suggests that education sector in the SC 4.0 era still lacks much of these tools in terms of education models (Qu *et al.*, 2022), upskilling and reskilling (Li, 2022a,b) and systems ideas and methodologies (Li, 2022b). Furthermore, most of the few curriculum changes attempts in higher education are focused on teaching Industry 4.0 rather than SC 4.0 (see for example Neaga, 2019; Marzano and Martinovs, 2020). Therefore, in preparing students to be the future SC 4.0 mangers there is a clear need to ensure that the pedagogy and curriculum they go through will be able to take them beyond current linear and deterministic thinking, capture the evolving nature of SC as well as explain the distributive and integrated nature of these systems. Many of the current SC management instructional resources lack the capability to engage with these challenges due to their reliance on mainly passing on a body of knowledge to the students in a classical static manner (Tortorellaa *et al.*, 2022; Vilalta-Perdomo *et al.*, 2022).

In the context of such need, this paper attempts to answer the following questions: (1) Would SC 4.0 curriculum at higher education benefit from adopting a gamification approach in preparing students to engage with the complexity of SC 4.0? (2) Can Lego Serious Play (LSP) with its approach in going from 2D to 3D teaching enhance students' motivation, cognitive and design capabilities to prepare them to manage future SCs? To answer these research questions the author carried out an exploratory, qualitative study in which data from undergraduate students studying SC 4.0 were collected through semi-structured interviews and analyzed. The analysis also aimed at developing insights and recommendation for SC 4.0 educators and researchers.

The remaining of the paper is structured as follows: After this overview, the case for using LSP in supply chain management (SCM) gamification is introduced in section 2. A brief literature review in section 3 is conducted to emphasize the gaps in SC 4.0 education and especially the use of gamification approaches in this discipline. The methodology for the empirical study is then explained in section 4. The results of the study and its analysis are presented in section 5. Section 6 discusses these results and analyses further before the conclusion and recommendations are highlighted in section 7.

2. The case for using LSP in SCM gamification

The power of thinking with your hands is the main entrance to understanding the impact of LSP in gamification (70–80% of our brain cells are connected to our hands). Such power expands our working memory and thus we know more at any given moment if we think with both our minds and hands. Furthermore, LSP underpinning methodology relies on the ideas of constructionism and the use of metaphors to capture and model concepts (McCusker, 2020).

Piaget (1937) discussed constructionism as the idea that learning is developed through the building of knowledge structures and that the personal construction of understanding occurs through engagement with experiences. In addition, metaphor plays an important role in helping us to think about and describe complicated concepts (see for example Schon (1993) research on what he called generative metaphor). Thus, putting these two ideas together, LSP uses the mind and hands to construct metaphorical models of our knowledge and understanding of things. These things can vary from simple to complicated ideas and systems.

In the context of education, the use of LSP is based on the students' ability to imagine and better describe what they retained from the taught knowledge. LSP allows students to give meaning to their perceptions and articulate their depth of understanding through building 3D models. The models use metaphor and storytelling approaches to give the students a far wider field and latitude to express and demonstrate their understanding of concepts beyond the classical 2D assessments approaches (using assignments and exams on a piece of paper as an example). Such an approach will unleash the inspiration and imagination of students (Teply *et al.*, 2022), which are both at the top objectives of today's best pedagogical practices of experiential learning. Furthermore, LSP enhances various social interactions among students through ensuring consensus, teamwork and inclusiveness of all ideas and voices within the team. This will in turn teach students a lot about efficient decision making that is based on shared direction, collective human capital utilization as well as engaging the emotional element during this process.

Teaching SC 4.0 includes different levels of complexities. The first level is obviously the basic knowledge of SC 4.0 fundamentals with its new value propositions and customization objectives as well as its associated digitization and digitalization requirements. The second level has to deal with SCM 4.0 enabling technologies like AI, IoT, cloud computing and blockchains and how these technologies can be integrated and synchronized. The third level deals with envisioning how these technologies can act as a design platform to take existing SCs to the next level, generate new customer experience or at the bare minimum solve critical and chronic operation problems. For students, these levels can be very difficult to understand let alone apply and this is where LSP can act as a great pedagogical tool to help in this regard. The imagination capabilities of LSP can offer students a safe and fun space to explore and imagine how SCM 4.0 technologies can playout in what is possible today and what can change tomorrow. Furthermore, since LSP method focus on the collaborative construction of unforeseen realities, it is an ideal approach to discuss and help students understand the disruptive nature of the SC and how to embed resilience within the design of SCM 4.0. Both the tangibility and unpredictability: the various shapes, sizes, and colors of LEGO® bricks allow for near-infinite combinations of 3D constructs for SCM 4.0 and its applications. Building something concrete forces students to lean-in rather than out, as each construct is unique (Tuomi *et al.*, 2019) and thus offers a fresh look at the different SCM 4.0 elements.

3. Literature review

In this brief review we give examples of the literature that focused on gamification in education generally, and the use of LSP specifically in different education setups. We then explore the existing gaps when it comes to using LSP in teaching SC management.

Gamification in education has received growing attention over the last years. A recent literature review for using games in education can be found in Manzano-Leon *et al.* (2021) and Swacha (2021) and its history in education in Deterding (2014). Another review for gamification in education that focused only on empirical research can be found in Majuri *et al.* (2018). How to use gamification in education was the main line of study in this literature stream. For example, Luo (2022) examined three issues in the literature of gamification including how effective the educational gamification implementations were in previous

empirical studies, how the effectiveness has been measured, and what factors contribute to varied effectiveness results. He pointed to the importance of differentiating between game elements and game mechanisms in designing effective games in education as well as suggested some best practices for game design. The impact of gamification on students' performance was another topic of interest in this literature body. This include the work of Castañeda-Vázquez *et al.* (2019) who stated that in university education, it was observed that when the subject is gamified, the participation and involvement of the students increase exponentially, and consequently their academic performance improves. Earlier work of Chen *et al.* (2015), Martí-Parreño *et al.* (2016) and Deif (2017) confirmed the same enhancement tendency. The use of gamification in STEM was also captured in many works that showed how it helped students' engagement and learning. This was mainly due to how students felt that they were an active protagonist in their learning progress and that the game mechanics allowed them to carry out a continuous practice of the academic curriculum. In addition, the dynamic of continuous feedback allowed them to obtain clues and opportunities for reflection when it comes to problems (Garcia-Cabot *et al.*, 2019; Tsai *et al.*, 2019).

LSP had attracted the attention of many researchers in the field of gamification in education. Literature highlighting the LSP methodology, its basic principles, its core process and its benefits, include Rasmussen (2006), Kristiansen *et al.* (2009) and Schulz and Geithner (2011). LSP in education was used for multiple purposes like articulating the learning autobiographies, enhancing students' creativity and spur innovation, increasing the confidence of students in the ability to apply knowledge and improving collaboration among students (Frick *et al.*, 2013). A clear emphasis on the creative and innovative teaching capabilities that LSP offers for teachers in higher education was apparent in many of the related research work (Barton and James, 2017; Nerantzi and McCusker, 2014; Hayes, 2016). Their work emphasized that LSP is an effective gamification pedagogical tool based on empirical data. Examples of using LSP in higher education and specifically in engineering include the work of Cerezo-Narváez *et al.* (2019) and Kurkovsky (2015).

The use of gamification in SCM education was mainly focused on using computer simulations. For example, Akkartal *et al.* (2019) carried out a comparison between four famous SCM simulation games (Electronic Beer Game, SC Game, The Fresh Connection TFC and SCM Globe Game) and reported on their different strengths and weaknesses as well as their impact on students' engagement. Kandanaarachchi and Perera (2021) illustrated the effectivity of the classical Beer Distribution Game as a self-learning tool for SCM teaching. They also offered new insights on improving the efficacy of the game as a teaching tool to support the low performing students. Similarly, Loaiza-Velez *et al.* (2021) showed that with SCM computer simulator, the students could improve their knowledge acquisition and retention at different levels. The only work found that used Lego bricks (not LSP) in education was by Vanany and Syamil (2016) where they used Bloom's taxonomy assessment testing to compare between students who played a game to reduce SC cost with those who did not. They found the students who played the game reached higher scores of assessment testing than students who did not play the game. Another single work by Sinha (2022) suggested that LSP can be useful in SCM general research.

In this brief review, one can observe how research supports the use of gamification in education generally as it was shown to improve pedagogical effectiveness at multiple levels. In addition, it emphasized how LSP offers a solid foundation for creativity in education setups. However, it was also apparent that researching the use of gamification in SCM education was few and only limited to software-based games. Furthermore, the specific use of LSP in SCM 4.0 education was widely missing. This paper attempts to fill some of this gap by contributing to this limited research on the use of gamification in SC management through answering the proposed research question of exploring the impact of LSP as a gamification approach on teaching SCM 4.0 concepts and engaging students with its new technologies.

4. Methodology and setup

LSP are facilitator-led workshops and can range in duration from 1.5 h to two days. The process of building a model includes four steps: (1) facilitator poses a question/challenge, (2) participants build models using LEGO bricks, (3) participants explain their models by sharing stories and (4) participants reflect on their understanding of the models and their meanings. Each LSP workshop begins with a skill-building exercise aimed at stimulating different types of imagination. This warm-up exercise guides the participants through basic LEGO construction skills, building representations and metaphors, and explaining them through storytelling. Upon completing this exercise, participants should be comfortable enough with LSP approach to begin working on the tasks directly related to the specific objectives of the workshop (Kristiansen and Rasmussen, 2014).

To study the impact of going from classical 2D teaching of SC 4.0 to 3D using LSP, an empirical study was designed and conducted. The overall methodology of the study is shown in Figure 1.

The study involved 50 students (28 males and 22 females) in their 3rd and 4th year who enrolled in two classes of the advanced SCM course at the Industrial Technology program at California Polytechnic State University (one in the winter quarter and the second in the spring

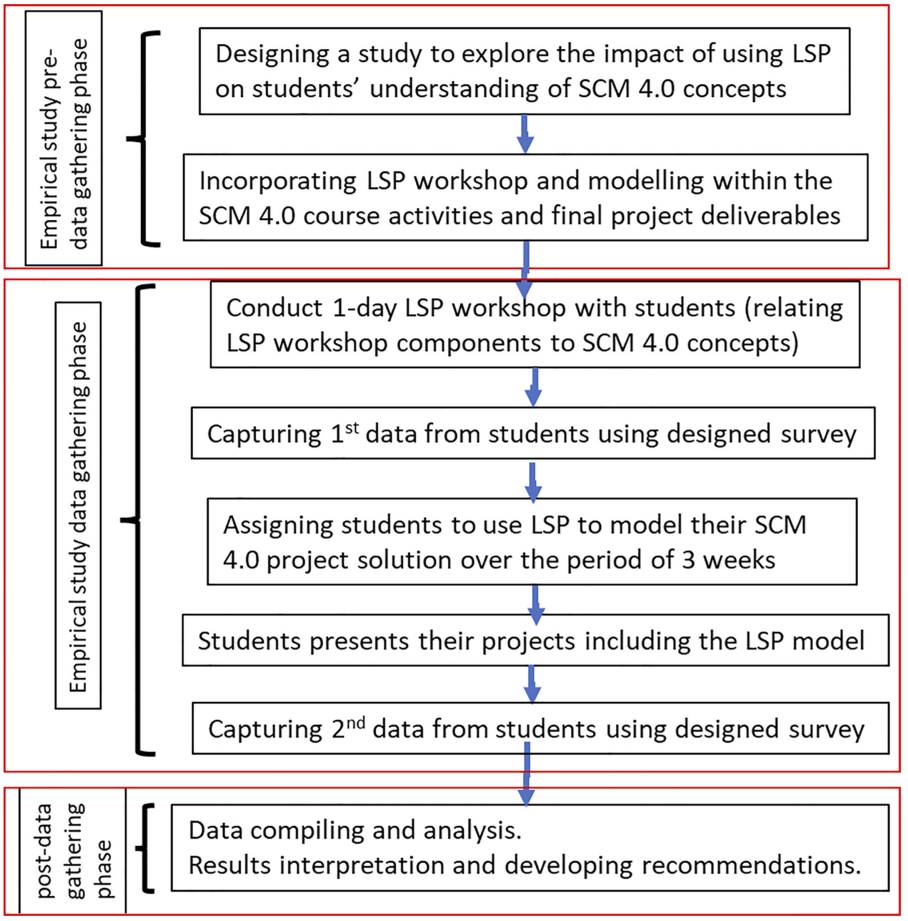


Figure 1.
Flowchart for the conducted empirical study

quarter, both groups finished an introductory SC course as a pre-requisite). The students were asked to use LSP model in their course's final project that culminates the knowledge body involving the use of digital technology (namely blockchain, IoT, cloud computing and AI) in a future resilient SC. They were required to redesign or reconfigure selected SCs to improve the operation, introduce a new customer experience and/or take the performance of the SC to a new level using these technologies. Details of the project are shown in the Appendix.

The data were collected at two different periods using designed surveys to capture the students' experience at different pedagogical levels. The first data collection happened after conducting the one-day standard primary LSP workshop (the author is a certified LSP facilitator). This LSP workshop is based on a step-by-step question that needed to be answered using building LEGO models allowing participants (individually then in groups) to develop their skills, and then face challenges, maintaining the interplay between challenge and boredom. This allows a rapid development of skill, facilitating the modeling of complex ideas and concepts within a relatively short time. The challenges or questions used in this workshop were geared toward the SC 4.0 concepts of efficiency as well as understanding the value chain objective of their intended project.

The second data collection occurred after the students finished their final projects of the course and presented their LSP models in front of the class (pictures for those models are displayed in the appendix). Students were allowed three weeks to incorporate their LSP model in their project. The second survey captured the overall experience of the students using LSP to think about and design their digital solution for the project's SC. It is important to mention that survey questions were designed to capture the success of the required knowledge transfer of SC 4.0 concepts (based on the feedback from students) as this is a common challenge in gamification experiments' assessment (Doucet and Srinivasany, 2010). The results from both data sets were analyzed using descriptive statistics and will be discussed in the following section.

5. Analysis and results

This section will focus on the descriptive statistical analysis of the data collected from the students' surveys as well as their primary observations. More insights will be drawn in the discussion section to follow.

During the course, students were introduced to the principles of value chain and how different operations from upstream to downstream should focus on the customer's expected values while reducing internal wastes (inefficiencies). The first questions during the early standard LSP workshop aimed at capturing how LSP 3D approach improved their understanding of these concepts as well as helped them to express their knowledge about these concepts. The questions used a Likert scale from 1 to 5 where score 1 refers to very unhelpful while score 5 refers to very helpful (full survey shown in Appendix).

Figure 2 displays the answers to the first question; "did the LSP approach help you to better understand the concept of WASTE?" From the results, 84% of the students' scores were either helpful or very helpful in their responses to this question.

Figure 3 displays the answers to the second question; "did the LSP approach help you to better express your knowledge the concept of WASTE?" From the results, 90% of the students' scores were either helpful or very helpful in their responses to this question.

Figure 4 displays the answers to the third question; "did the LSP approach help you to better understand the customer value your project?" This was an important test for how LSP can help students in a collective manner to capture and describe the values that their SC 4.0 project will be designed for. This step in both academia and practice is usually difficult due to the quantitative and qualitative nature of these values which can bring confusion among SC

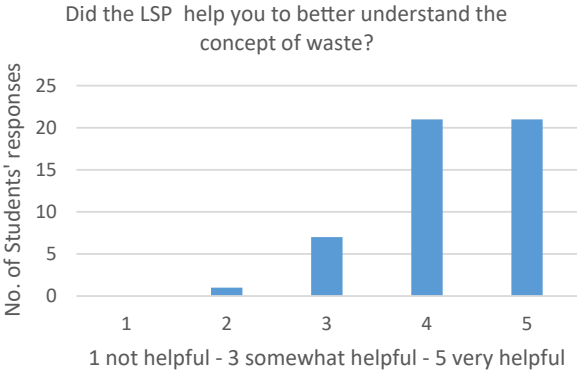


Figure 2.
Students' scores to question 1

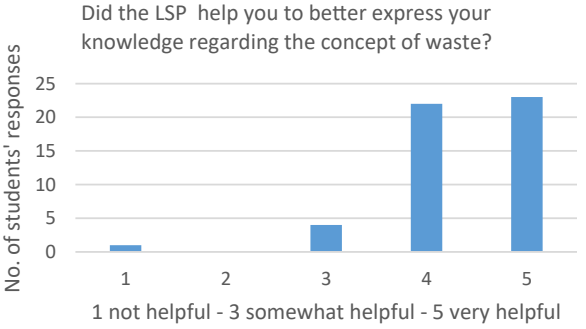


Figure 3.
Students' scores to question 2

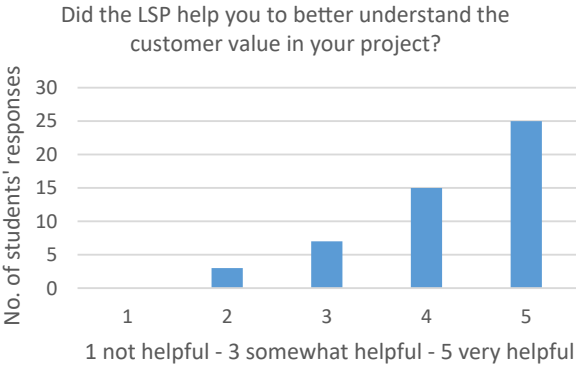


Figure 4.
Students' scores to question 3

managers and designers. From the results, 80% of the students' scores were either helpful or very helpful in their responses to this question.

The next question was aiming at capturing the students' perspective on the different LSP tools and activities and which of these tools and activities were the most impactful. A list was offered to the students in question 4 and they were asked to pick up to three tools or activities that they felt were the most helpful and effective for them. Scores are shown in Figure 5 and point to how using metaphoric models tops the list followed equally by using the story telling approach as well as the group sharing and discussion.

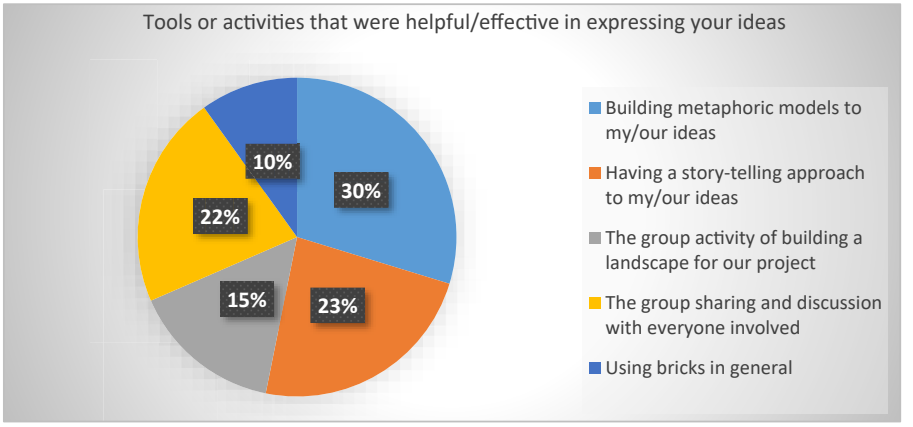


Figure 5.
Most effective LSP tools and activities per students' answers

The next group of figures will show the results of the students' survey upon completing and presenting their final digital SC project. Students were given access to LSP bricks for three weeks to work on their projects as a team and then present their SC 4.0 design to the whole class.

Figure 6 shows the scores for the general evaluation of the LSP 3D approach by the students through answering the question: "after completing your digital SCM project, did LSP help you to better understand and develop your project?" A total of 88% of the students' scores were either helpful or very helpful in their responses to this question.

The next question attempted to explore how helpful the LSP approach was during the different phases of the project. Students were asked on the same Likert scale of 1–5 (1 not helpful, 3 somewhat helpful, 5 very helpful) to score how LSP helped them in designing the digital solution for their SC project. The question had four sub-questions and each one captured an important pedagogical phase which students had to go through to fulfill their project. The phases were: understanding of the problem, ideation of the solution alternatives, motivation and engagement and finally teamwork aspects. Results are shown in Figure 7a–d.

Results from Figure 7 show that LSP was indeed impactful in helping students design their digital SC project with 88% of the students' scores finding LSP either helpful or very helpful in the understanding phase, and similarly with 90, 92 and 94% in the ideation, engagement/motivation and teamwork phases, respectively.

To have a complete picture of the students' LSP experience in this project, students were asked about the most challenging aspects they encountered using LSP. The students were given a list of such challenges to select all what applied for them, and the results are shown in Figure 8.

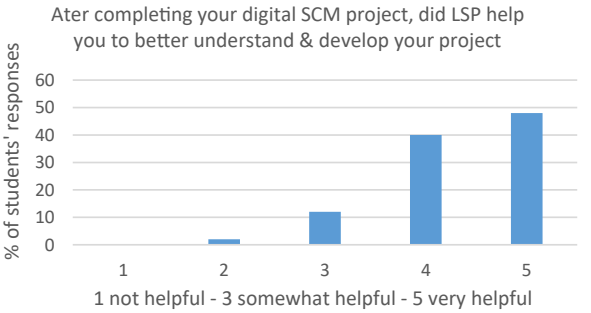


Figure 6.
LSP impact on helping students in their final project

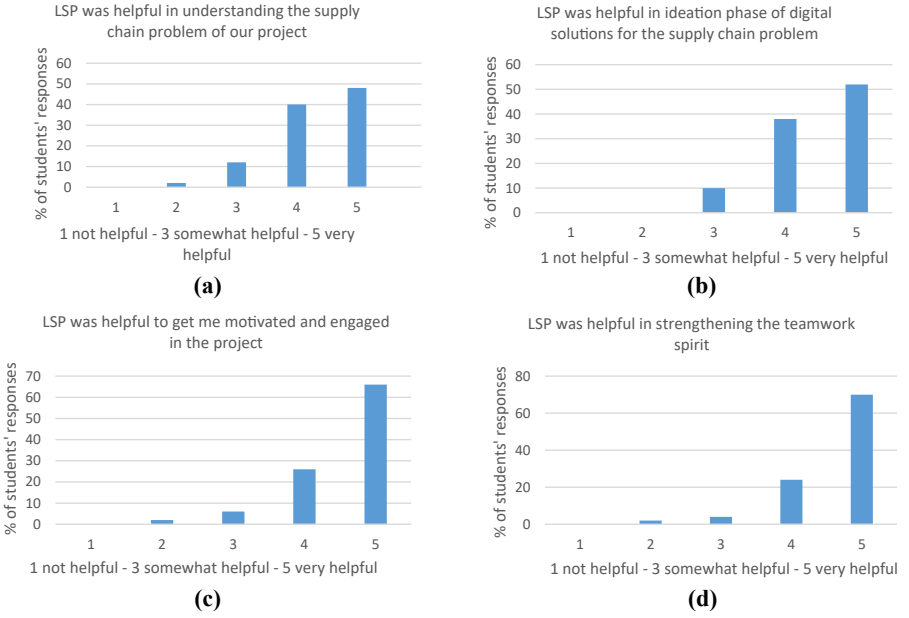


Figure 7.
How LSP helped students in the different phases of designing the digital solution for their SC project, (a) understanding (b) ideation (c) engagement (d) teamwork

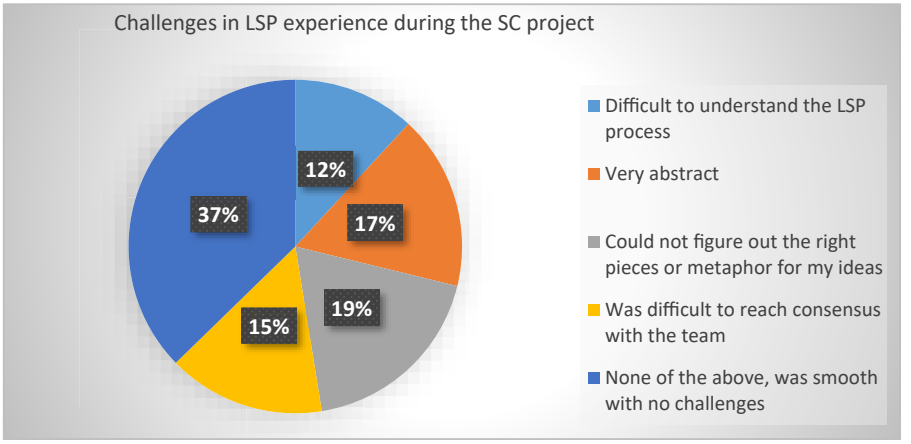


Figure 8.
Challenges encountered by students using LSP

Results in Figure 8 reveals that the highest challenge was the difficulty in finding the right pieces or metaphor to map their ideas (19%), then the abstraction level of the LSP (17%), followed by reaching consensus among the team (15%) and finally the difficulty in understanding the LSP process at the beginning (12%). These challenges are very helpful in determining different areas of improvement for further implementation of LSP in SC education. It is also important to note that more than one third of the class (37% of the responses) faced no challenges during this LSP exercise.

The last couple of results will point to various important aspects of this study. First upon asking the students about whether they would be using their hands to think about their next

project or challenge in coming courses, 94% of the students replied positively with 6% saying no. This is very interesting regarding the possibility of how the LSP approach and going from 2D to 3D can inspire students to carry on with this creative approach. Lastly, in the last open-ended question soliciting students' general reflections overall (there were 12 responses or almost 25% response rate) two-thirds of these reflections were related to the pedagogical impact of LSP while one-third of those comments were pointing toward how LSP unleashed their creativity and innovation talent. These comments (listed in the Appendix) can help SC educators appreciate how the 3D LSP approach is well received by students in this discipline.

6. Discussion

The previous results regarding the pedagogical impact of LSP in going from 2D to 3D in SC education can be better understood using different pedagogical frameworks and concepts. First, we will use the famous Blooms taxonomy framework. This cognitive taxonomy, which was proposed by Bloom *et al.* (1956), is the most used in education to evaluate the impact of pedagogical curriculums and tools on students' education. Krathwohl (2002) states that Bloom believed that the taxonomy could serve as means for determining the congruence of educational objectives, activities and assessments in a unit, course or curriculum and panorama of the range of educational possibilities against which the limited breadth and depth of any particular educational course or curriculum could be contrasted. The six levels within the cognitive domain are divided into two levels of thinking skills: 1) lower-order thinking skills (LOTS): knowledge, comprehension and application and 2) higher-order thinking skills (HOTS): analysis, synthesis and evaluation (Bloom *et al.*, 1956).

The students' feedback suggests that LSP was effective in helping students along these entire six cognitive domains. Particularly the results from the first standard workshop show how LSP aided students along the LOTS cognitive objectives regarding their knowledge, comprehension and application of SC concepts of efficiency and value (Figures 2–4). The results collected at the end of the project clearly suggest that LSP was instrumental in the students' journey along the HOTS cognitive objectives of analysis and synthesis of their digital SC solution (Figures 6 and 7). Furthermore, using the revised Bloom's taxonomy categorization of the notion of knowledge, the surveys outcomes highlight how LSP was particularly significant in conceptual knowledge (Knowledge of principles, theories, models and structures) and metacognitive knowledge (Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge).

The 3D hands on approach of LSP also showed (through students' responses in Figure 7 regarding ideation and design phase feedback) that it can address the challenge of SC 4.0 complexity. Various research indicated that the complexity of both Industry 4.0 and SC 4.0 requires higher education to adopt a learn by doing approach (Hariharasudan and Kot, 2018), through a challenge-based problem (Vilalta-Perdomo *et al.*, 2022) in a didactic environment (González and Calderón, 2018) to be able to teach them to students. LSP as a platform fulfills these requirements and the results presented support such a claim.

The results of this experiment can also be considered to be following a summative assessment approach as the case in many of the serious games application in education (Michael and Chen, 2005; Sebastian *et al.*, 2007). The survey questions were designed to be used as post-test evaluation instruments which is one of the most widely used experimental designs and is particularly popular in educational studies that aim to measure changes in educational outcomes after modifications to the learning process such as testing the effect of a new teaching method (Shute *et al.*, 2009). A similar assessment approach to a serious game in education can be found in Allen *et al.* (2009).

The summative results of this experiment demonstrated the value LSP can bring to the research that explores the applications and implications of game-based pedagogy in teaching future digital SC 4.0. Having a medium that is both tangible and easy to follow such as using

Lego bricks (and often already familiar to participants), yet surprisingly complex and multidimensional, helps students better imagine, envision and articulate where and how a SC 4.0 technologies should best be applied, as well as what impacts they might have on the resiliency and efficiency of these complicated systems. As demonstrated in Figure 5, 30% of students found building metaphorical models using the LEGO bricks to be a helpful tool in this regard.

On the social and emotional assessment level, LSP gives a unique pedagogical opportunity to engage all students in a social and emotional inclusivity where there are no winners or losers. Rather, each student will bring a new insight to complete the picture of the overall concept being taught. This observation aligns with the guidelines of designing online gaming education environment suggested by Simoes *et al.* (2013) who emphasized the importance of promoting competition and collaboration throughout the various stages of the game and ensuring that the game is fun for the player to guarantee that they feel an immersive experience.

In addition, the results of this LSP approach to design SC 4.0 solutions suggested a high level of attention, motivation and input from all students leading to a higher level of engagement (Figure 5 shows many students appreciated having everyone sharing their ideas, Figure 7c points to the high motivation level and Figure 7d stresses the motivation from the teamwork spirit). This is important to note since among the best practices of using gamification in higher education is to ensure that these games cater for motivation and social objectives in addition the cognitive ones (Deif, 2017).

Students' comments and their desire to continue this practice of thinking with both hands and minds, suggest that in general LSP allows higher education students to develop several transversal skills including creativity, motivation, design, resilience, teamwork and effective oral communication. This suggestion is supported by Malone's principles (1981) that the gameplay approach has multiple elements of intrinsic qualitative factors for engaging students including challenge, curiosity and fantasy. In addition, LSP can enable SC students to navigate their integrated intelligence and build 3D models as a response to the various future SC 4.0 challenges.

Finally, it is important to acknowledge the feedback from some students regarding the challenges they faced due to the level of abstraction that sometimes LSP questions can have as well as their difficulty to relate their ideas to models (going from 2D to 3D). This highlights the importance of having SC educators acquainted with the LSP method and its critical balance between boredom and complexity and being ready to keep students within the flow of the gamification and help them along the way as suggested by Csikszentmihalyi (1990).

7. Summary and recommendations

This study aimed at exploring the impact of using LSP on the effectiveness of teaching SC 4.0 in higher education by going from traditional 2D approach to a 3D one. An overview of LSP as a gamification pedagogical approach was first introduced to highlight how LSP uses both mind and hands to inspire and engage students to build 3D models using metaphors and storytelling. The paper next reported on an empirical study that was carried out among 50 students (over two terms) who were studying SC 4.0 course and used LSP in their final project that focused on digital SC 4.0 design. Two questionnaires were designed (one after the standard LSP workshop and the other upon completion of the project) to solicit data in respect to how LSP helped students to better understand SC 4.0 topics and fulfill their project. The results were analyzed using Bloom's taxonomy as well as other pedagogical frameworks to understand the positive impact of LSP at the cognitive, motivation and social levels.

The research questions posed by this work regarding how teaching SC 4.0 in higher education would benefit from adopting a 3D gamification approach especially using LSP were well addressed through the analyses of this study results. The answers for the research questions can be presented in the form of the following general observations and recommendations for using LSP as a gamification approach in teaching SC 4.0:

(1) Learning by doing is fundamental to the concept of teaching SC 4.0. It is a challenge to balance the teaching of various principles and technologies from an abstract point of view (2D), while offering the students an opportunity to apply these principles and technologies in a futuristic project using a hands-on 3D approach. For that, LSP can be used to resolve such challenges.

(2) Teaching SC 4.0 concepts using LSP can be expressed in more detail and better understood. This is due to the ability of LSP to simplify complicated systems (at the cognitive level) and motivate students to engage in learning about these systems (at the motivation level).

(3) Teaching SC 4.0 requires students to demonstrate a wide spectrum of LOTS and HOTS cognitive skills (as described in Bloom's taxonomy). LSP approach demonstrated its ability to help students navigate through both cognitive skills categories in a meaningful and playful manner.

(4) The gameplay approach of LSP will add to the cognitive gain multiple elements of intrinsic qualitative factors for engaging students, including challenge, curiosity and fantasy as suggested by Malone's principles (1981). With both advantages (cognitive skills and intrinsic satisfaction), LSP is set to be a clear effective tool for educators.

(5) Improving the design skills for students was clear using LSP as it unleashes imagination and taps into internal knowledge together with collective inputs. In higher education and especially in advanced SC courses where various designs of digital solutions are core of the taught curriculum, LSP would come very handy to fulfill that difficult task of transferring knowledge and imagination into practical solutions using unique synthesis hands-on approach (descriptive, creative and challenging imagination design approaches).

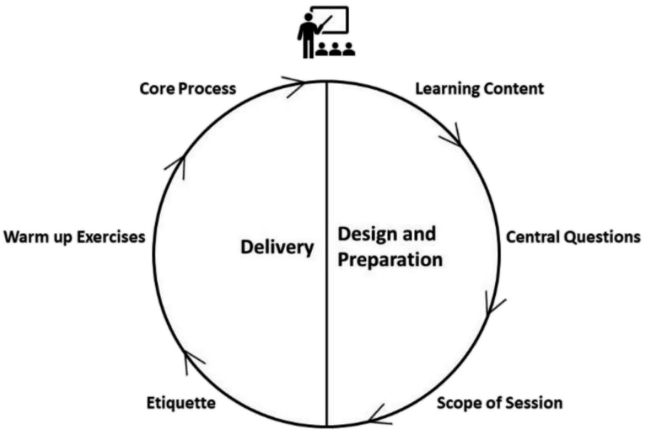
(6) The emerging nature of SC 4.0 offers students at this educational level a great opportunity to explore and investigate its potential applications. LSP is well suited to be a platform for exploratory learning experience. Rick and Lamberty (2005) define exploratory learning environments as educational arrangements and activities that facilitate the learners' ability to construct knowledge connected to the subject matter through student-led reflective exploration. Using LSP to explore SC 4.0 will help students in building deeper understanding of SC 4.0 and connects theory with students' worldview of the future of SC industry.

At the implementation level we offer the following recommendations for educators of SC 4.0 when using LSP:

(1) Educators need to understand that ensuring the success of the LSP experience in SC courses requires thorough planning. Developing a course curriculum with modules that will incorporate exploring SC concepts using LSP sessions as well as designing projects and assignments that include LSP models are examples of such required planning.

(2) The delivery phase of the above planned activities needs a high level of attention. This includes clear definition of the design problem using inspiring questions, balancing the flow of the LSP gamification between boredom and complexity as well as all other LSP logistics parameters like duration, Lego sets and team dynamics.

(3) Both planning and delivery will require educators to get trained on the concepts of gamification in general as well as the specific techniques and mechanics of LSP. Gkogkidis and Dacre (2021) capture these implementation activities in what they called LSP wheel shown in Figure 9.



Source(s): Adopted from Gkogkidis and Dacre (2021)

Figure 9.
LSP wheel

This paper contributes to the very few literature regarding using gamification in SC education and specifically how LSP methodology can be adopted in teaching SCM 4.0. However, its reliance on one case study can be a limitation regarding the generalization of the proposed results. This limitation is attenuated by the representativeness of the case study analyzed. Furthermore, the presented work should encourage future analyses using other assessment approaches including comparing a "treatment" group with normal one using pre- and post-testing mechanisms. In addition, expanding the implementation of LSP to other SC 4.0 teaching contexts and applications can give more insights for SC educators. Finally, future work will include defining some specific SC 4.0 skills that can be measured before and after the implementation of LSP to give this early research a more quantitative dimension.

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Further reading

Hochschule Zürich, *Laboratorium für Lebensmittel-Verfahrenstechnik*, pp. 77-86.

Appendix
Survey 1 (after the standard LSP workshop)

1. On a scale 1-5 (1 not helpful, 3 somewhat helpful, 5 very helpful), how did the LSP approach help you to better ***understand*** the concept of WASTE

   1 2 3 4 5

2. On a scale 1-5 (1 not helpful, 3 somewhat helpful, 5 very helpful), how did the LSP approach help you to better express your ***knowledge*** regarding the concept of WASTE

   1 2 3 4 5

3. On a scale 1-5 (1 not helpful, 3 somewhat helpful, 5 very helpful), how did the LSP approach help you to better ***understand*** the customer value your team is trying to capture in their project

   1 2 3 4 5

4. Based on your experience in this event, which of the following ***tools or activities*** was the most helpful/effective in expressing your ideas (you can choose up to 3)

   A) Building metaphoric models to my/our ideas
   B) Having a story-telling approach to my/our ideas
   C) The group activity of building a landscape for our project
   D) The group sharing and discussion with everyone involved
   E) Using bricks in general

5. Would you be ***using your hands*** to think about your next project or challenge

   A. Yes (how-"optional":)

   B. No

Survey 2 (upon completion of the SCM project)

1- On a scale 1-5 (1 strongly disagree, 3 somewhat agree, 5 strongly agree), after completing your digital SCM project, did LSP help you to better understand develop your project

1 2 3 4 5

2- On a scale 1-5 (1 not helpful, 3 somewhat helpful, 5 very helpful), score how LSP helped you in designing the digital solution for you supply chain project

A- LSP was helpful in **understanding** the supply chain **problem** of our project

1 2 3 4 5

B- LSP was helpful in **ideation** phase of digital **solutions** for the supply chain problem

1 2 3 4 5

C- LSP was helpful to get me **motivated** and **engaged** in the project

1 2 3 4 5

D- LSP was helpful in strengthening the **teamwork** spirit

1 2 3 4 5

3- Which of the following was a **challenge** in your LSP experience during the digital SC project? *Select all that can apply*

A- Difficult to understand the LSP process
B- Very abstract
C- Could not figure out the right pieces or metaphor for my ideas
D- Was difficult to reach consensus with the team
E- None of the above, was smooth with no challenges

Optional:
Any thoughts or comments you would like to share:

Below is the list of the comments for the students who answered this question:

Comments toward innovation and creativity

(1) Anything to get group thinking in a new way is great for innovation

(2) I love being able to actually manipulate space to create a new reality with the bricks

(3) I like how this encourages creativity

(4) Simulate system thinking

Comments toward pedagogical impact and understanding

(1) Way easier to visualize process implementation with hands on approach.

(2) Stayed engaged

(3) This was a great way to understand concepts or problems

(4) I think I will be using these tools to work through other problems for projects in the future

(5) Super fun. Activity did not necessarily teach new learnings but it did reinforce learnings in a very positive way.

(6) Made learning memorable

(7) I will use it for modeling product prototypes and system challenges

(8) This modeling helps the project seem clearer

Final Project Outline used in the Study:
Developing an Integrated Technology Solution for Supply Chain 4.0

Consider the supply chain of any industry. It may be agriculture, manufacturing, healthcare, apparel, retail, entertainment, defense, public sector, logistics, education . . . etc. Research and capture the supply chain activities being performed, from upstream to downstream, the responsibilities of workers, the role of managers and leaders and how people coordinate.

Investigate what aspects work and what do not work? Where is there room for improvement? What is the role of the SCM 4.0 Technology Stack (IoT, blockchain, cloud computing and AI) and what are current forms of these technologies being used and incorporated effectively?

(1) Is there an opportunity(s) to change the supply chain for the better or is there a specific problem(s) that need to be solved? (This may be through improving the customer experience, changing the way products and services are produced, changing the way sourcing/procurement activities work, improving or fixing logistics/distribution issues, enhancing integration and visibility or even introducing new lines of business, for example.)

(2) How could the 4.0 technology stack make this possible?

The team will need to draw a diagram (or "avatar diagram") of your technology stack intervention

Your drawing should adhere to the following specifications:

(1) Before starting your drawing, think about who the stakeholders are who need to understand the story. How does it help them understand?

(2) In your drawing, specify the components making up your trio technology network and their interrelationships, and account for any component types that are not included.

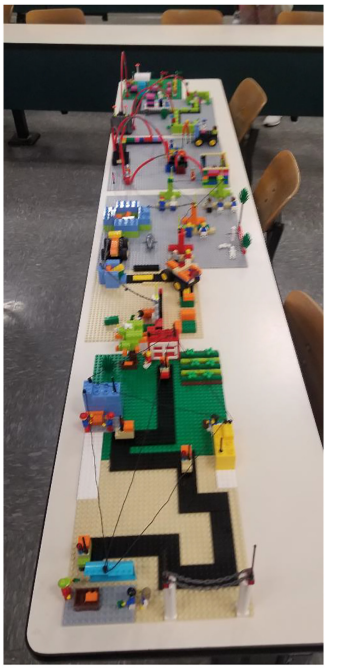
(3) Draw lines between the components to demonstrate how they relate to each other. Avoid having lines cross each other to keep the diagram as clear as possible.

After designing and drawing the avatar, the team will build a mockup of the avatar using the Lego Serious Play (LSP) kits in the PI Lab. The mockup will be used to display the proposed integrated technology solutions to stakeholders. Different and appropriate Lego bricks will represent each component of the avatar and the trio technologies. Furthermore, connections along the supply chain components (flows of material and information) will be modeled using the Lego connection kits.

Finally, provide an analysis of the risks and challenges entailed in the adoption of SCM 4.0 technologies' solution. Suggest an approach to identifying and addressing these risks.

Samples of the students LSP model for their digital supply chain project

Projects for 6 teams in class 1



Projects for 5 teams in class 2

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