Virtual Reality as a Socio-Technical Innovation to Enhance Supply Chain Management Education

AbstractPurpose – We study the potential opportunities and challenges of virtual reality (VR) as a new socio-technological innovation to enhance teaching and improve student learning outcomes for supply chain management (SCM) education.

Design/methodology/approach – We use a mix of secondary research from literature reviews and a case study of a large VR implementation at universities in the United States (U.S.) that includes primary data collection along with in-depth interviews of end users of VR technologies for SCM education synthesized and grounded in the experiential learning cycle model.

Findings – Our findings suggest that VR-assisted education can contribute to SCM experiential learning objectives and improve student learning outcomes for procedural learning and soft-skills. Research propositions are provided to guide future research on the correct fit between VR technical capabilities and SCM pedagogy.

Originality – We are in the early stages of development and adoption of VR use in SCM education. Making this research one of the first investigations into this use case.

Research limitations/implications: – We contribute to the understanding of the affordances and barriers to the adoption and implementation of VR technologies in SCM but are limited by the availability of use case examples, literature and data on adoption and implementation.

Keywords: virtual reality, supply chain competences, logistics competences, literature review, survey, case study, education, pedagogy, experiential learning, metaverse, gamification

1. Introduction

While learning in virtual and digital environments has been used for a significant amount of time in education, the onset of the COVID-19 pandemic accelerated the adoption of virtual technologies. Due to the need to replicate specific experiences in the learning process, technologies that were able to bring real-world interactions into the digital world were highly sought after. Due to this extended period of distance learning and the need to replicate experiences during the COVID-19 pandemic, educators at all levels of the educational continuum explored the use of synthetic environments for educational purposes. Chief among these technologies were extended reality (XR) technologies, including augmented reality (AR), virtual reality (VR), and mixed reality (MR). Virtual reality is defined as a computer-generated fully digital three-dimensional environment with seemingly real physical interactions. In contrast, augmented reality is defined as computer-generated environments and objects which are superimposed over items and environments in the real world. Mixed reality is defined as a blend of both VR and AR. The focus of this study is on understanding how VR-based experiences can facilitate supply chain management (SCM) education.

Digital technologies and specifically VR offer a number of advantages or more broadly affordances for learning by simulating real environments. Thus, VR is one component of the metaverse, which fuses the digital and physical worlds allowing users to have real-time interactions including across space and time (Dwivedi *et al*., 2022; Dolgui and Ivanov, 2023). For example, Dolgui and Ivanov (2023) propose a supply chain framework for the metaverse based on the seven-element digital twin framework proposed by Ivanov (2024),[1] which focuses on metaverse applications to enhance supply chain operations management. However, the focus of our research is on the application of VR for SCM education.

As the technology has progressed, there has been greater emphasis on the development of VR technologies that are realistic, immersive, interactive, safe, and allow soft failure to occur (Lamb *et al*., 2020a, 2014). Building upon this, Dwivedi *et al*. (2022) discuss how synthetic environments can be used for SCM education. The successes of VR across multiple domains in education have driven the adoption of VR technologies for use in business and SCM education. However, there is not currently a coherent strategy for this implementation. Thus, in this article we propose a road map for the effective use of VR as a socio-technical innovation, to enhance SCM education, which is the primary purpose of this paper. Therefore, the concomitant objectives are:

1. Provide an overview of VR technologies by introducing key literature that provides an understanding of VR-based technology and its use in educational settings.
2. Present evidence of the affordances of VR-based technologies that enhance learning in a VR-assisted teaching model.
3. Propose areas for research grounded in theory and the literature on how VR-assisted pedagogy can enhance SCM education.

In this research we review the current state of VR-assisted educational environments and development of VR technologies, to facilitate teaching and learning ultimately with the intent of applying this work to SCM teaching and learning. To do this, we synthesize the extant literature to understand the current state of the adoption and implementation of VR technologies for educational purposes to inform the benefits of VR learning opportunities for SCM education. We use evidence of the implementation of a VR higher educational platform across 19 U.S. universities to support some of the affordances and barriers that emerge from the extant literature on VR-assisted education. Our synthesis of the SCM and VR-assisted education literature leads us to use the experiential learning cycle model proposed by Kolb (2014) to propose a research road map by way of six research propositions for developing a framework for VR-assisted SCM pedagogy.

2. Review of the Literature

In completing our literature review we conducted an exhaustive and systematic search to identify articles published in the Medline, Web of Science and Scopus databases from January 1, 2011, through June 30, 2024. Our intention is to cover a wide range of scholarly articles from multiple disciplines including education, engineering, business, supply chain management and psychology. Note due to the paucity of SCM pedagogical literature we extended the search window back to January 1, 2000.

To ensure a comprehensive review, we expanded our search beyond these databases using Google Scholar. Google Scholar is a widely used web search engine that indexes the full text and metadata of scholarly literature across a number of publishing formats and disciplines. In an effort to provide greater topical coverage, we examined the reference lists of the identified studies and reviews that were included in our initial search. This method, known as backward and forward snowball searching, allowed us to uncover additional publications that may have been missed in the initial database search.

Our search strategy was methodical and thorough using several key words. We used a combination of specific keywords to maximize the relevancy of the articles we found. These keywords included “virtual reality,” “VR,” “education,” “business,” “engineering,” and variations of these terms, singularly and in combination.

We included studies that satisfied the following criteria: (1) VR was used in a formal educational program; (2) VR consisted of head mounted displays (HMDs) or 2D screens e.g. phone, tablet or computer, where the user can drag and explore a 3D environment using a point and click device, e.g. trackpad; (3) the research was reported in

English in a peer-reviewed journal; and (4) studies specifically included estimation of learning outcomes related to skills or content. Studies were excluded if they were: (1) did not specifically identify which learning outcomes were examined; or (2) studies which were conducted within informal learning environments.

Data extraction from each article was conducted focusing on two primary areas of review: (1) the results obtained from the study; and (2) the methodology employed to derive these results. The author team also gathered additional information to provide a more comprehensive understanding of each study. This included the perspective of the study, the time frame within which the study was conducted, the sample size, the target group, the learning outcomes, and the key findings. Furthermore, the authors collected additional data on the types of other modalities besides VR included in the studies, providing a broader context to our review. This approach ensured a thorough and comprehensive systematic review. The reviewed literature is displayed in Table I.

< Table I >

We begin by sorting through the cumulative knowledge from the reviewed literature and report on the affordances, barriers, and most effective ways VR-assisted education can enhance learning. The intention is to synthesize the cumulative knowledge from the VR-assisted education literature, the SCM education literature, and relevant theory, to develop the research propositions that will form our research road map to develop effective VR-assisted SCM education.

2.1. VR Affordances

Classifying undergraduate college majors by their learning style inventory scores Kolb (2014) shows that business majors are *Accommodators* or active and concrete learners. This learning style emphasizes a practical hands-on approach. VR-based pedagogy, by nature is a more active learning style with practical applications (Zhao *et al*., 2023; Conrad *et al*., 2024), which benefits business majors' active and concrete styles of learning (Kolb, 2014).

McGovern *et al*. (2020) report on the improvements in business students' presentation skills using VR. Students improved their attention distribution across the audience, reduced audience stare, and reduced the number of filler words, just by using the purpose-built Ovation® VR software. Cheng and Wang (2011) employed a 3D interactive simulation of a single customer in a supermarket for students to test their understanding of marketing mix theory. They found that students assigned to the 3D simulation treatment showed significant improvement in the application of theory compared to students assigned to the traditional classroom learning treatment. An added benefit of VR is that it facilitates a virtual extension of the classroom for interactive experiential learning activities when physical classroom space is limited (Chen *et al*., 2011). As such, VR has been successfully used to teach entrepreneurship (Giron *et al*., 2023; Ronaghi and Forouharfar, 2024), process model design (Harman *et al*., 2015, 2016), negotiation strategy in international business (Hernandez-Pozas and Carreon-Flores, 2019), accounting (Ratmono *et al*., 2024), business ethics (Sari *et al*., 2023; Sholihin *et al*., 2020) and hospitality (Shi *et al*., 2024).

Even before the availability of fully immersive VR, 3D games were found to increase the level of success in learning (Lamb, 2016). In their systematic literature review, Conrad *et al*. (2024) find that immersive VR for education has a positive impact on learning compared to other types of media. The literature review conducted by Oje *et al*. (2023) similarly reveals that VR has the power to enhance the education of complex concepts (in engineering) by providing immersive and interactive learning experiences. For example, Alhalabi (2016) finds that the use of VR dramatically increases student learning of complex engineering tasks. In an experiment conducted with children engaged in a problem-solving game grouped in three modalities (immersive VR, tablet computer, and board game), Araiza-Alba *et al*. (2021a) find that the children in the VR modality had the highest success rate in solving the problem and transferring their learning to real-life. In addition, the VR group of children was more engaged and motivated.

VR-assisted pedagogy is suited for a diversity of learning task designs (Won *et al*., 2023). Morélot *et al*. (2021) find that when using VR for fire safety training the interaction between the degree of immersion and sense of presence promotes procedural learning, which is the acquisition of motor skills and habits and certain types of cognitive skills e.g., tying a shoelace, cooking without a recipe. Petersen *et al*. (2022) also found that immersive VR improved procedural learning.

Experiments conducted by Petersen *et al*. (2022) find that high degrees of VR immersion e.g., using a HMD, lead to greater learner situational interest, which leads to greater learning. They also find that higher levels of interactivity reduce distractions or extraneous cognitive load. Kuvar *et al*. (2024) studied the reduction of distraction using the frequency of users' task-unrelated thoughts (TUT) during learning. In their experimental design, one group viewed a 2D monitor video, and another viewed a 360° video in VR. They measure TUT using pseudo-random thought probes and recording eye-gaze. They found that users in the VR condition are less likely to experience TUT and consistent with prior research TUT is negatively related to post-test performance.

These characteristics also benefit neurodiverse learners with sensory processing disorders where VR facilitates indirect social engagement, digitally mediated avatar-based communication, and sensory sensitivity (Hutson and McGinley, 2023; Trivedi, 2024). Hence, learners can use VR to control the pace of their learning, manipulate sensory loads, and practice skills they can apply to real-life (Acharya and Mohbey, 2024). The diverse personalization possible through procedural content generation using deep reinforcement learning can benefit how VR is customized for neurodiverse learners (Cunningham *et al*., 2020; Lopez *et al*., 2019).

Particularly pertinent to SCM education, VR is best used to experience hazardous and harmful environments and can reduce the human and economic cost of training in the real world (Dwivedi *et al*., 2022; Jimeno- Morenilla *et al*., 2016; Tiwari *et al*., 2023). Ebnali *et al*. (2021) investigate VR used for training drivers on highly semi-automated self-driving cars on the *transition* task related to transitioning from manual to automated driving and back again and *takeover quality* related to the speed and fluidity of taking over manual mode from auto during a potential emergency. Driver trust in the automated system was also measured. An experiment with three treatment groups was designed using 2D video, low-fidelity VR, and high-fidelity VR. The study found that VR improves the intuitive presentation of information as well as knowledge acquisition. , while knowledge scores and trust increased from 2D video to low-fidelity VR, they did not increase for high-fidelity VR. However, takeover quality did increase for users trained with high-fidelity VR leading authors to claim this as the superior modality for autonomous vehicle training.

VR has been widely identified as a pedagogical tool for experiential learning that transcends time, space, and form (Zhao *et al*., 2023; Dwivedi ., 2022). This characteristic of VR motivates one of its most common applications employing 360° video with immersive VR to transport learners to distant lands and dangerous locations on virtual field trips (VFTs)(Araiza- Alba *et al*., 2021b; Earle and Leyva-de la Hiz, 2021; Fink *et al*., 2023; Kuvar *et al*., 2024; Tiwari *et al*., 2023; Won *et al*., 2023; Zhao *et al*., 2023). Especially when class sizes are large and/or it is either cost prohibitive to travel or too dangerous to access real-world sites, VFTs extend learning opportunities that would otherwise not be possible (Dwivedi *et al*., 2022).

VR has been used to increase interaction among learners (Hsiao, 2021), and foster collaboration that transcends physical space (Liu and Shirley, 2021). Hence, VR has seen widespread adoption for remote learning particularly during the COVID-19 pandemic (Giron *et al*., 2023; Liu and Shirley, 2021; Lopez *et al*., 2021).

2.2. VR Barriers

Paradoxically, while there are several examples of the befits of 360° video (e.g. Kuvar *et al*. (2024) and Araiza-Alba *et al*. (2021b)), Boffi *et al*. (2023) found that the 360° video while more engaging was not more effective for learning. Similarly, Lee *et al*. (2017) found that while 360° video enhanced learners' enjoyment and interest, it did not improve scores for content novelty, reliability, or understandability relative to 2D video. Strojny and Dużmańska- Misiarczyk (2023) find that while the number of published studies on the benefits of VR use in higher education increased significantly from 2010 to 2020, they identify several shortcomings in many of the reviewed studies' research designs. At this nascent stage of VR adoption for higher education paradoxical results of VR efficacy will be prevalent until guidelines ensuring rigor and replication are followed (Strojny and Dużmańska-Misiarczyk, 2023).

Besides research rigor we may need to develop new metrics and measurement instruments to identify efficacy of VR for each unique context, if it is present. Lamb and Etopio (2020) find that despite the realism of the training, due to the complexity and unpredictability of the real-life scenarios, VR was not an effective tool for clinical training of pre-service science teachers. Similarly, while all treatment conditions differed from the control lecture content delivery method, Lamb *et al*. (2018b) find no difference between VR, an educational game, and hands-on learning. Similarly, Lopez *et al*. (2020) did not find an improvement in engineering students' learning probability and statistics compared to conventional lectures even though it did improve their motivation. Radianti *et al*. (2020) provide a potential explanation for these inconsistent findings in the efficacy of VR-assisted pedagogy. In their systematic review of VR applications for higher education, they critique the lack of consideration for learning theories used in VR application development. Skulmowski (2023) echoes the concern with fit and presents three additional areas of concern encompassing the ethics of using VR in education:

1. VR is unsuitable for all learning contexts.
2. Realism can cause cyber-sickness and be detrimental to learners with low spatial ability.
3. VR technology is used to collect detailed data and construct precise learner profiles.
4. VR realism can be used to manipulate learners.

Low fidelity of virtual avatars in reproducing users' expressions and motion can make VR less useful in social and interpersonal interactions and for fine motor-skill tasks with haptic and other sensory feedback. Technological capabilities for sensory, including haptic feedback, are nascent and infeasible for classroom use. Often network bandwidth and computing power of HMDs are limiting factors as well. Potentially for reasons such as these Petersen *et al*. (2022) found that learners were distracted by their embodied avatars' movement in VR, which had a negative effect on learning. Reeves *et al*. (2021) and Lamb *et al*. (2020b) tested a chemistry lab experience for an undergraduate course where users were frustrated due to potential limitations in movement fidelity and sensory feedback, and reported the VR lab as hindering their ability to learn. Low fidelity can also lead to cyber- or motion-sickness

(Wuttke *et al*., 2022; Skulmowski, 2023).

From the authors' own experience of maintaining a large virtual reality lab at a university, there are numerous challenges to consider in the operation and maintenance of VR equipment including HMDs. Many commercial HMDs such as the Quest currently available in the market are optimized for home use. Enterprise-level networks that have several security requirements make it cumbersome to maintain wireless network connectivity. With larger class sizes of over 20 students, there can be instability in the network with refresh rates and high latency especially during streaming of high definition 360° videos for immersive VR. Furthermore, university enterprise IT security protocols close access to network ports required by the HMDs, and have to setup hidden wireless networks with MAC address filtering or other similar capabilities that make maintenance of HMDs, especially with the numerous software updates and security patches very cumbersome (Giron *et al*., 2023). Hence, in addition to equipment cost, there is the cost of employing skilled IT professionals to maintain a functioning VR lab, lab assistants to ensure charging devices, and/or technical infrastructure such as class management software to maintain the devices (Giron *et al*., 2023). In addition, faculty and students need to continuously be trained as the interfaces for HMD use and access to programs keep changing. Some programs employ teaching assistants to manage these tasks (Giron *et al*., 2023), while others, such as the authors' labs, create online training videos to keep up with ongoing training.

2.3. Effective VR Use

Nevertheless, the nascent VR education literature has begun to provide some opportunities to surmount these barriers as well as match learning contexts with the most appropriate VR-assisted educational approaches. Often obvious yet overlooked steps such as the duration and number of training sessions can very often increase the efficacy of VR-based training (Strojny and Dużmańska-Misiarczyk, 2023). Other seemingly simple albeit less obvious steps such as the order in which VR is introduced to a learning scheme can have dramatic results. Lamb *et al*. (2020a) and Lamb and Etopio (2019) found that students exposed to VR first and then assigned the textbook reading versus vice-versa or just the textbook or just VR, demonstrated significantly enhanced learning. The learning was measured by proxy using hemodynamic response in the subject's prefrontal cortex.

The literature investigating VR-assisted pedagogy has developed several insights into effective VR use for learning. VR can be adapted to a variety of learning styles (Kurilovas, 2016; Zhao *et al*., 2023). Learners with higher self-efficacy or belief in their capacity to execute behaviors to produce specific performance attainment, experience enhanced motivation with VR experiential learning outcomes (Hsiao, 2021). Makransky and Petersen (2019) find that efficacious VR features and emphasizing a high level of VR usability are correlated with higher learning motivation and self-efficacy, and higher amounts of learning. Enhancing this effect is the ability to use deep reinforcement learning for procedural content generation to generate diverse virtual contexts that enhance personalization and learner immersion (Cunningham *et al*., 2020; Lopez *et al*., 2019).

The findings of the experiments conducted by Petersen *et al*. (2022) indicate that when learners experience greater physical presence in VR through greater immersion and interactivity they experience greater levels of situational interest that positively predict learning. Furthermore, distractions can be minimized by greater interactivity. In addition, Barrett *et al*. (2021) find that immersion also enhances interaction and imagination.

Lowell and Tagare (2023) investigate whether the collaborative nature, authentic design of learning experience and tasks, and social environment impact the learner's perception of their learning experience and learning transfer, which is the use of acquired knowledge and skills in new learning or problem-solving situations. The results find that while the learners perceived the realism of tasks, environments and collaborative learning activities helpful, the authentic learning environment did not result in learning transfer. However, it did prompt learners' reflection on the value of learning and practice, which changed their self-efficacy. Relatedly, Chen *et al*. (2011) find that learners preferred more realistic versus abstract VR environments.

The 360° video when used in VR[2] for virtual field visits transcends time and space. Therefore, they are increasingly popular and replacing field trips (Fink *et al*., 2023; Won *et al*., 2023). They have been used for study abroad programs during COVID-19 (Liu and Shirley, 2021), to increase higher motivation and engagement (Boffi *et al*., 2023; Zhao *et al*., 2023). Engaging content mitigates the problem of short attention spans, aids learning and knowledge retention, and helps with understanding complex material (Zhao *et al*., 2023). Furthermore, 360° video in immersive VR eliminates distractions and increases learning (Kuvar *et al*., 2024).

In an immersive VR lesson for elementary school children Li *et al*. (2023) found that textual cues in the VR lesson significantly enhanced learning while both textual cues and scaffolding (formal pre-defined instructional assistance e.g. fill-in-the-blank questions) increased learners' mental models. In another study Albus *et al*. (2021) find that textual annotations in VR improved learners' recall performance and germane cognitive load, which is new information that must be linked to current information. Araiza-Alba *et al*. (2021b) find that combining 360° videos watched on a Google Cardboard® device with textual annotations are an engaging and motivational way to train children in water safety.

Kasapakis *et al*. (2023) find that non-verbal cues helped increase users' sense of immersion and presence, and significantly enhanced the learning experience. Non-verbal cues include finger motion, gaze direction and facial expressions in VR. However, in order to achieve this, users' expressions and motions were captured and transmitted to the HMDs using a platform that supports full-body motion tracking (Kasapakis *et al*., 2023). Until this type of technology becomes more accessible and universal, as pointed out in Section 2.2 conveying non-verbal cues to increase immersion and presence for enhanced learning will be out of the reach of most classrooms.

2.4. Emergent Themes

Kolb (2014) defines experiential learning as, "[T]he process whereby knowledge is created through the transformation of experience" (p. 49). As business students, including SCM students, are active and concrete learners we see VR technologies as most advantageous in facilitating experiential learning. In particular, the immersion and interactivity of VR-assisted education can help build problem-solving skills, reduce distractions keep students engaged and motivated, and increase the learning of complex tasks. As pointed out in Section 2.1 these characteristics of VR are particularly helpful to expand pedagogical efficacy to include neurodiverse learners. VFTs with 360° immersive textually annotated videos delivered through HMDs are a popular approach to delivering an engaging and positive learning experience that motivates students and promotes learning. VFTs could be particularly beneficial for SCM education especially for virtually transporting an entire class to experience dangerous and hazardous environments in transportation and manufacturing facilities.

However, despite the widespread use of 360° video Boffi *et al*. (2023) found that these videos are not effective for learning. Similarly, other studies have found that VR lowers learning performance due to unnecessary cognitive processing, which can distract learners (Makransky *et al*., 2019). This raises a prevailing concern regarding the fit between VR and the learning context. Hence, In order to optimize the effectiveness of VR-assisted education, VR application development should be informed by learning and instruction theories, and incorporate multimedia design and pedagogical principles (Oje *et al*., 2023; Radianti *et al*., 2020). In addition, we must consider the many technological barriers that inhibit real-world interactions such as real-time transmission of users' non-verbal cues. Consequently, the development of an effective VR-assisted SCM pedagogy must take account of current VR technological capabilities and affordances to find the right fit with a lesson's or activity's learning objectives.

3. Mini Case Study

We present some of the lessons from the large-scale implementation of a VR platform across several U.S. universities where we also find evidence of some of the affordances and barriers that emerged from the literature review. Our partner vendor, we anonymize for this submission as *TechInc*, contracted with a consulting firm, we anonymize for this submission as *ABConsult* (*ABC*), to study how TechInc's VR platform deployment in the U.S. facilitated instructors' delivery of immersive content to enable student's learning.

In Spring 2023, ABC conducted a pilot study with three participating universities. In the summer of 2023, ABC conducted information for TechInc's partner-university faculty following which intake forms were distributed by email to faculty to solicit participation. ABC conducted a mixed methods approach through the Fall 2023 semester. At the beginning of the semester, participating faculty provided information on their fall courses such as course subject, class size, and planned use of VR. Throughout the semester faculty were asked to submit Learning Event Surveys after each classroom VR use, reporting teaching application, details of the teaching application, and their perspectives regarding the VR-assisted teaching experience. At the end of the Fall 2023 semester, participating faculty and the students in their classes were separately surveyed using a faculty and student survey, respectively. In addition, some faculty volunteered for post-semester interviews, which were conducted asynchronously with faculty asked to write their responses to a written interview protocol.

3.1. Faculty Findings

The final study included 24 faculty members teaching in 25 courses with 565 registered students across 19 universities. Of the 25, roughly 84% are undergraduate courses and 16% are graduate courses with 52% are business courses, 28% are in the STEM field, and the balance represents education, social sciences, law, and the humanities. A third of all classes had 21–40 students, another third had 10–20 students, and the rest of the class sizes were either small (<10) or large (>40).

In their onboarding process, only 22% faculty reported prior use of VR for teaching the same course and 56% reported personally using VR outside their work. The faculty self-reports for planned VR use for teaching indicated 33% for VFTs, 33% for hosting lectures, 25% for developing and creating VR environments and assets, 12% for role play and interpersonal interaction, 8% for interactive labs, and 12% for data visualization–totals don't add to 100% as faculty can select multiple VR uses in their course.

In defining the successful use of VR for their courses 46% of the faculty indicated improved learning, 42% wanted to see a positive learning experience, 21% wanted their students to create and work in VR and 17% wanted students to perceive the benefits of VR.

During the fall semester, 15 faculty (62.5%) submitted 41 learning event surveys that represented around 350 students (61.9% of all students represented). In these surveys about 62% indicating successful use of VR versus about 4% reporting unsuccessful use of VR with over 65% reporting that students learned the intended content versus under 2% indicating the learned content was not learned. Over 80% indicated that the learners were engaged and 90% indicated that they plan to reuse VR in the classroom.

Seven faculty participated in the post-semester survey and asynchronous interviews. While six faculty indicated that their expectations were either met or exceeded, one indicated dissatisfaction, which could potentially be attributed to the asynchronous course format. All faculty indicated that VR delivered a positive impact on student learning enabling a learning experience that would otherwise have been unattainable.

3.2. Student Findings

Of the 500 students invited to participate in the survey, 157 responded representing a 31.4% response rate. Students ranged in age from 17 to >40 with nearly 75% in the 17–22 years range. There were slightly more females than males with a minority of non-binary students. Regarding their learning using VR, 89% of the students believed VR enriched their learning, and 78% believed VR had a positive impact on their learning outcomes. A majority of students had a positive view of VR use with 62% wishing that classes used more VR, and 71% indicating that they would consider registering for courses with VR in the future. This preference for VR-assisted pedagogy was reinforced in the results with more students indicating that more VR use enriched their learning experience as well as had a positive impact on their learning (Figure 1).

< Figure 1 >

Digging deeper into the data using the qualitative data collected from the in-depth interviews and student comments, we see common themes emerging resembling those from our review of the literature. These themes represent the problems or limitations of technology. Students' comments like, "It would log you out and that would cause the loss of all progress." Another comment relating to the limitations of the technology, "It was hard working with a group since the game is not multiplayer," referring to the challenges of a group activity, which due to technological constraints of processing power is currently single user access. Cyber- or motion-sickness also appeared as another theme with the following representative comment, "I wasn't really a fan of the virtual reality headsets, they gave me a headache." Another theme was the fit of pedagogical approaches as exemplified in comments like this,

"Something I would suggest is to make the project more long- term (several weeks), I would suggest some form of information regarding each specific portion of the project i.e., tutorial videos, I did like the fact that it was open-ended but in some ways, I felt that trying to pull everything together was overbearing given our lectures have taught each function somewhat independently as well."

Suggesting a different pedagogical approach in terms of the length a topic is covered as well as how and when the material is presented in class versus in the VR learning activity. Feedback such as this speaks to the need for grounding VR education in appropriate pedagogical theories and finding the right fit between the pedagogical approach and learning goals and objectives.

Mirroring the literature review, VFTs using 360° video in immersive VR were very popular with comments like,

"My favorite part of our VR experience was how we were able to see what it's like on a cargo ship and inside a factory while not actually having to go there. I think it was interesting and beneficial as a learner of supply chain."

In addition, the experiential aspect of learning by doing in VR was emphasized by students as in this comment, "[G]etting to see how all the aspects of a supply chain from class came together to run the factory," and, "[M]y favorite part was being able to control the supply chain as a whole." Comments like these speak to the potential value of VR to bring learning to life for students and allow them a safe environment in which they can get some real-world experiences.

4. VR-Assisted Pedagogy for SCM Education

We conducted a review of the SCM pedagogical literature (Table II). The SCM education literature has emphasized the salience of experiential learning for teaching and learning SCM. Sweeney *et al*. (2010) emphasize the importance of real-world experience in preparing students for their future careers. Wong *et al*. (2014) identify a hands-on experience skills gap between SCM program curricula in the UK and employer needs. Thus, they advocate for greater experiential learning content in the UK SCM course curriculum. Fawcett and Waller (2015) advocate embracing technology and leveraging SCM's "natural affinity for professional engagement" to add more experiential leaning content to the SCM curriculum. VR-assisted SCM education can enable new forms of training outside the physical constraints of the classroom (Dwivedi *et al*., 2022). The bibliometric content analysis conducted by Zhao *et al*. (2023) finds that an effective application of VR-assisted education is to extend the physical classroom to engage in active, hands-on, low-risk, experiential learning opportunities. Chen *et al*. (2011) offer one example of a VR negotiation role playing game and Hsiao (2021) offers another application of VR for the experiential-learning based training of social workers.

< Table II >

Relatedly, simulations, whether computer-based on real-life, have always been an accessible method to provide an engaging and close to real-world approach to deliver experiential learning content to SCM students. Beginning with the beer distribution game (Goodwin and Franklin, 1994), which can now be played online (Jacobs, 2000), simulations are an integral part of SCM pedagogy. Similar to the original beer distribution game table-top simulation, Holweg and Bicheno (2002) develop a LEGO® based system-dynamics simulation. The diversity of SCM pedagogy gamification is exemplified by Liu and Mackelprang (2023) using origami to teach process design and competitive priorities, and Trautrims *et al*. (2016) using global virtual teams solving a case study to prepare students for future careers in global supply chains. Hence, VR-assisted gamification is a natural fit for SCM education. Araiza-Alba *et al*. (2021a) found that students' performance solving a problem-solving game was best done in immersive VR where they transferred those skills to a real-life scenario. Lamb *et al*. (2018a) find that VR is equivalent to hands-on, in-person games with the added benefit of enjoyment and engagement, especially in remote settings.

As highlighted by Trautrims *et al*. (2016) approach SCM students need to be prepared for careers as part of global supply chains, which is also emphasized by Gravier and Farris (2008) and Fawcett and Waller (2015). VR is a natural fit in a global world as it provides the ability to transcend time and space (Giron *et al*., 2023; Zhao *et al*., 2023). For example, Liu and Shirley (2021) used VR as a study abroad program during the COVID-19 pandemic. Similarly, during the COVID-19 pandemic Lopez *et al*. (2021) developed a VR manufacturing simulation that can be remotely accessed by multiple students to learn logistics concepts such as inventory management and queuing theory. The most accessible VR approach to introduce students to global supply chains is through 360° enabled VFTs

(Fink *et al*., 2023; Won *et al*., 2023). For example, with a simple Cardboard® (https://arvr.google. com/cardboard/) students can be led on publicly available VFTs of manufacturing plants at Toyota (https://youtu.be/bvqDVjk56EI?si=bwNgF7IiEh_yPKpf), Bremen Mfg. (https://youtu.be/iF9kOrP7cr8?si=WNgBNn2xj9klfEPd), LEGO (https://youtu.be/ZOgBQekxuuM?si=luNIcQUM7A4WsrN6) and Tesla (https://youtu.be/vmHvvZjV87U?si=2wiyyVmvrRZ7tXCt) or tour the Maersk Triple-E class of ship (https://youtu.be/g6U5bksU_-c?si=BfORDjPUSZITHBo8). VFTs have the additional benefit of mitigating health and safety risks for SCM consultancy or capstone courses (Bak and Boulocher-Passet, 2013).

As Gravier and Farris (2008) points out, globalization has seen the emerging importance of soft skills training for logistics and supply chain managers. Consequently, the SCM pedagogy literature have been emphasizing the need to fill the skills required by employers such as communication (Birou *et al*., 2022; Fawcett *et al*., 2023; Gámez-Pérez *et al*., 2020; Lutz *et al*., 2022), teamwork and collaboration (Birou *et al*., 2022; Fawcett *et al*., 2023; Gámez-Pérez *et al*., 2020; Jordan and Bak, 2016; Lutz *et al*., 2022), creativity (Birou *et al*., 2022; Lutz *et al*., 2022; Merkert *et al*., 2023), ethics (Birou *et al*., 2022; Lutz *et al*., 2022) and problem solving (Gámez-Pérez *et al*., 2020; Fawcett *et al*., 2023; Jordan and Bak, 2016). VR-assisted education has shown the capability of being able to be used for developing soft skills including communication (Tiwari *et al*., 2023) such as, presentation skills (McGovern *et al*., 2020) and for neurodiverse learners (Hutson and McGinley, 2023), teamwork and collaboration (Tiwari *et al*., 2023; Lowell and Tagare, 2023), creativity (Barrett *et al*., 2021), ethics (Sari *et al*., 2023; Sholihin *et al*., 2020) and problem solving (Araiza-Alba *et al*., 2021a; Lowell and Tagare, 2023). A key component in these soft skills is the need to mimic real-life and real-time inter-personal interactions. As discussed in our review of the VR-assisted education literature in Section 1, the fidelity of reproducing users' real-time body movements and expressions in VR represents a significant barrier to communication via non-verbal cues (Lamb *et al*., 2020b; Petersen *et al*., 2022; Reeves *et al*., 2021). Dwivedi *et al*. (2022) discuss the possibility of how the use of artificially intelligent (AI) embodied non-playing characters (NPCs) to assist with or scaffold users' learning experiences (Lamb and Etopio, 2020). Of particular salience to the use of such NPCs is that through the use of machine learning (ML) and AI, they should grow and evolve to meet user needs (Dwivedi *et al*., 2022).

While VR-assisted education especially for soft skills required in inter-personal interaction is still a work in progress there are a number of ways to leverage the affordances of VR to enhance SCM education. The greatest benefit of VR is the benefits afforded by immersive experiential learning for procedural learning (Morélot *et al*., 2021), fostered by engagement and situational interest (Petersen *et al*., 2022) including for complex engineering tasks (Oje *et al*., 2023), and technical skills (Ebnali *et al*., 2021).

5. Discussion

While the foregoing synthesis of the VR-assisted education and SCM literature streams does not provide a solid theoretical framework for educators to use in developing VR-assisted SCM pedagogy, it offers some emergent themes that can be explored in future work to build such a framework. To do this we will build on the largely atheoretical development of VR-assisted pedagogy. Citing the cognitive-affective model of immersive learning (CAMIL) Li *et al*. (2023) quote Makransky and Petersen (2021) who state that, "it is not the medium of [immersive] VR that causes more or less learning, but rather that which instructional strategy used in an [immersive] VR lesson" (p. 940). Therefore, using the synthesis of cumulative knowledge from VR-assisted education literature and that of the

SCM-pedagogy literature, we utilize the Kolb (2014) experiential learning cycle model to develop research propositions for developing effective VR-assisted pedagogy for SCM and logistics.

5.1. Research Propositions

Oje *et al*. (2023) and Radianti *et al*. (2020) recommend that VR application and development must be informed by the appropriate learning and instruction theories. Kolb (2014) experiential learning cycle begins with a concrete experience. SCM and logistics students are most likely to experience concrete examples by way of 2D videos, computer-based simulation games, hands-on activities, or field visits (Fawcett and Waller, 2015; Holweg and Bicheno, 2002; Liu and Mackelprang, 2023; Trautrims *et al*., 2016). VR-assisted learning offers many more possibilities for this especially with 360° VFT (Araiza-Alba *et al*., 2021b; Earle and Leyva-de la Hiz, 2021; Fink *et al*., 2023; Kuvar *et al*., 2024; Tiwari *et al*., 2023; Won *et al*., 2023; Zhao *et al*., 2023). This is a benefit we saw in the qualitative feedback (Section 3.2) from our mini case study. Hence, we propose:

Proposition 1a: VR-assisted pedagogy can benefit SCM and logistics education by the use of 360° VFT to provide concrete examples of SCM and logistics phenomena.

Similar to the use of textual annotations in VR 360° training videos, SCM VFTs can be annotated for enhanced learning outcomes (Albus *et al*., 2021; Li *et al*., 2023; Araiza-Alba *et al*., 2021b). Hence, we propose:

Proposition 1b: Annotated 360° videos can enhance the training outcomes for training purposes and VFTs of SCM and logistics phenomena.

Soft skills are best learned through experience and practice and VR-assisted pedagogy offers many options. As (Fawcett and Rutner, 2014) state, "[C]ritical thinking, engagement, teamwork, ideation, and collaboration skills engendered by an experiential education are difficult to acquire watching a YouTube video—no matter how polished or convenient it is" (p. 7). Our synthesis of the VR-assisted education and SCM pedagogy literature in Section 4 provides many examples of VR-assisted opportunities for acquiring soft skills in SCM education (Araiza-Alba *et al*., 2021a; Barrett *et al*., 2021; Lowell and Tagare, 2023; McGovern *et al*., 2020; Sari *et al*., 2023; Sholihin *et al*., 2020). Hence we propose:

Proposition 2: The teaching and learning of SCM Soft skills such as collaboration, global orientation and cultural sensitivity, communication, problem-solving, and ethics can be enhanced using VR-assisted pedagogy.

The next step is reflective observation when the learner compares their concrete experience to their understanding. VR-assisted pedagogy improves recall and procedural learning (Morélot *et al*., 2021), which are good for learning complex tasks (Ebnali *et al*., 2021; Oje *et al*., 2023), like those in SCM and logistics. In addition, learners can return and replicate the experience multiple times in VR to solidify their understanding and recall of the experience (Albus *et al*., 2021; Araiza-Alba *et al*., 2021b). Hence, we propose:

Proposition 3: Greater recall and reflective observation can enhance learning using VR-assisted pedagogy for teaching and learning SCM and logistics.

The next step in the (Kolb, 2014) experiential learning cycle is abstract conceptualization or the building of a new mental model or modification of an existing mental model that reflects learning. VR-assisted pedagogy has been found to enhance learning especially when designed with the appropriate teaching and learning theory to *fit* the instructional task (Oje *et al*., 2023; Radianti *et al*., 2020). We saw this in the qualitative feedback reported in our mini case study (Section 3.2). It is also what motivated our use of the Kolb (2014) experiential learning model. However, for individual learning activities and lessons, it would be beneficial to follow appropriate theories such as social cognitive theory to understand the key mechanisms to trigger cognitive, emotional, and behavioral responses (Hernandez-Pozas and Carreon-Flores, 2019; Suh and Prophet, 2018). Hence, we propose:

> **Proposition 4**: SCM and logistics learning can be enhanced by VR-assisted teaching and learning activities grounded in the appropriate teaching and learning theory to fit the instructional activity.

In the final step, the learner applies their accumulated learning to actively experiment and observe the results, which in turn reinforces the learned concepts. While there are very few examples where interactive VR (Ebnali *et al*., 2021), has been shown to enhance learning, as the technology advances there is potential for VR to fully mediate a real-world interactive experience. As we approach this technological frontier, students can be offered opportunities to apply their knowledge in a safe and controlled environment (Dwivedi *et al*., 2022), such as in Ebnali *et al*. (2021). This can be especially powerful with tools such as procedural content generation using deep reinforcement learning (Cunningham *et al*., 2020; Lopez *et al*., 2019), and AI-enabled embodied NPCs to provide scaffolding for learning (Dwivedi *et al*., 2022; Lamb and Etopio, 2020). Hence, we propose:

> **Proposition 5**: Interactive VR can allow SCM and logistics students to reinforce their learning by allowing repeated experimentation in a safe and controlled environment.

VR-assisted pedagogy will put students in greater control of their own knowledge acquisition requiring instructors to shift focus from the sage-on-the-stage to e-moderators mediating hands-on learning experience (Dwivedi *et al*., 2022). This new learner style will require new teaching styles. To ensure this approach has a fair chance to succeed it is especially important that appropriate faculty and student training is conducted (Strojny and Dużmańska-Misiarczyk, 2023), and VR-assisted pedagogy is followed (Lamb *et al*., 2020a; Lamb and Etopio, 2019). Including following VR-assisted educational practices that are known to yield positive results such as scaffolding learning with the use of textual annotations in VR (Albus *et al*., 2021; Li *et al*., 2023). Hence, we propose:

> **Proposition 6**: The new learner styles required by VR-assisted pedagogy will require a shift and new type of instructional training in SCM and logistics pedagogy to e-moderators mediating hands-on learning experiences.

In designing research studies to investigate these research propositions SCM researchers must keep in mind the socio-technological factors that pervade the use of VR-assisted pedagogy as it pertains to SCM higher education. Namely, the Skulmowski (2023) concern that VR is unsuitable in all learning contexts. Following the suggestions by Strojny and Dużmańska-Misiarczyk (2023), academic researchers must adopt rigorous and replicated research designs to increase the knowledge of correct VR-assisted SCM pedagogy. Furthermore, SCM educators must increase their knowledge and literacy of VR (Skulmowski, 2023), which will enable a more informed discernment and application for their specific SCM course learning objectives. As cyber- or motion-sickness can be widely encountered including in the TechInc case study implementation, Skulmowski (2023) recommends administering spatial ability tests and offering 2D alternatives to the VR immersive experience. Skulmowski (2023) also recommends adopting an informed consent process as well as working with technology providers to ensure that anonymization is offered as a standard feature to the students to avoid misuse of student data collected by VR vendor platforms. Finally, Skulmowski (2023) also recommends allowing students to lower the level of realism, which will mitigate the danger of students being manipulated by VR realism.

6. Conclusions

In this research we set out to achieve three research objectives. First, we introduce key literature from education, psychology, engineering and the business disciplines to provide an overview of VR-technologies used in educational settings. Second, our review reveals the affordances or potential benefits afforded by the VR technologies, barriers to their use in education, and successful use cases of VR-assisted education. In general, we find that:

1. 360° VFTs are a popular use of VR in the classroom (Araiza-Alba *et al*.,2021a; Fink *et al*., 2023; Kuvar *et al*., 2024).

2. Immersive VR can reduce distractions (Kuvar *et al*., 2024), and is therefore, beneficial to neurodiverse learners (Hutson and McGinley, 2023; Trivedi, 2024).

3. Allows soft failures in dangerous settings (Ebnali *et al*., 2021; Lamb *et al*., 2020a), which Dwivedi *et al*. (2022) recommends for SCM education.

Third, we follow the recommendations of Oje *et al*. (2023) and Radianti *et al*. (2020) to inform VR application and development by the appropriate learning and instruction theories. To do this we start by synthesizing the SCM pedagogy literature and the learning from the VR-assisted education literature across multiple higher-education disciplines for a preliminary understanding of the most appropriate VR-assisted SCM education applications. Given the salience of experiential learning for SCM education (Fawcett and Waller, 2015; Sweeney *et al*., 2010; Wong *et al*., 2014), we ground our findings in the Kolb (2014) experiential learning cycle model.

6.1. Implications and Future Research for SCM Education

Our results yield six research propositions that we recommend SCM scholars explore in rigorous and replicated studies (Strojny and Dużmańska- Misiarczyk, 2023). Our expectation is that the results of such a research program will yield a robust framework for VR-assisted SCM pedagogy and serve the future of SCM education as it evolves through the various iterations of industrial digitization.

Our literature review reveals gamification of learning as a repeated theme in SCM education (Holweg and Bicheno, 2002; Liu and Mackelprang, 2023), which has often been used as a means of providing experiential learning opportunities (Fawcett and Waller, 2015). Future research can start by exploring 360° VFTs in immersive VR recommended by our research proposition 1 to provide concrete examples that trigger the experiential learning cycle and transcend time and space (Dwivedi *et al*., 2022).

Interactive experiences using textually annotated VFTs or other interactive VR games are beneficial for allowing soft failures, particularly in dangerous settings (Ebnali *et al*., 2021; Lamb *et al*., 2020a), which Dwivedi *et al*. (2022) points to as a key requirement for VR-assisted SCM education. Reinforcement of learning from mistakes is a powerful learning tool. Our research proposition 5 recommends exploring the use of VR for such a reinforcement-learning approach including by the use of AI-embodied NPCs to provide personalized scaffolding for learners as recommended by Dwivedi *et al*. (2022). Given the barriers to VR education emerging in the literature, at a more basic level research into the fundamental efficacy of VR-technologies for interactive SCM pedagogy must be established, which is put forth in our research proposition 3.

The necessity for soft skills training for SCM managers in global supply chains highlighted by Gravier and Farris (2008) makes research into VR-assisted soft-skills training in SCM an important area for future research. Hence, our research proposition 2 to explore the many benefits of VR-technologies for soft skills such as creativity (Barrett *et al*., 2021) and problem solving (Araiza-Alba *et al*., 2021a; Lowell and Tagare, 2023). The importance of having inter-personal engagements highlighted by Dwivedi *et al*. (2022) for education and in industry as highlighted by Dolgui and Ivanov (2023) elevates the urgency for research into the use of VR for building soft skills such as teamwork and collaboration (Giron *et al*., 2023; Hsiao, 2021; Liu and Shirley, 2021; Lopez *et al*., 2020). Doing so will also fill critical needs in the SCM-skills gap between industry requirements and SCM program offerings (Birou *et al*., 2022; Fawcett and Rutner, 2014; Fawcett and Waller, 2015; Jordan and Bak, 2016; Lutz *et al*., 2022; Merkert *et al*., 2023; Sinha *et al*., 2016; Wong *et al*., 2014).

With VR-assisted education we are now in what the Kuhn (1970) model might characterized as the chaos stage of SCM pedagogy wherein the in-person predominant lecture-based pedagogy is being supplanted by digitally mediated pedagogy. The COVID-19 pandemic was a catalyst for the challenge posed by digitally mediated learning, including via VR technologies, to the lecture-dominated brick-and-mortar higher education in the U.S. (Cooper, 2019). Online learning platforms such as Coursera® and MIT's OpenCourseWare that were already in ascendancy received a boost from the pandemic. Thus, Dwivedi *et al*. (2022) is right to call for a new model for SCM educator, transitioning from the sage-on-the-stage to an e-moderator. In keeping with this period of emergence of such a paradigm shift (Kuhn, 1970), it is imperative that SCM pedagogy researchers develop frameworks that can guide this shift, which is suggested by our research proposition 6. As the research into

VR-assisted SCM pedagogy matures and builds SCM scholars must evaluate the value of this research through rigorously designed systematic literature reviews and meta-analyses. This is critical to determine the efficacy of the new VR-assisted pedagogical paradigm. In doing so, it is important to consider the importance of the use and fit of the appropriate learning theories to fit the instructional activity, as put forth in our research proposition 4.

6.2. Limitations

While VR technology has been around for decades and has seen some limited applications in the educational literature, VR-assisted education as we know today using standalone, consumer-friendly, untethered HMDs such as the Oculus Quest has been around for less than a decade. Partly spurred by the remote learning mandates of the COVID-19 pandemic VR-assisted education has seen an explosion of interest (Dwivedi *et al*., 2022). Consequently, as we are in the chaos stage (Kuhn, 1970), of a pedagogical revolution in higher education involving digitally mediated education of which VR is a small piece, the literature on VR-assisted education albeit burgeoning is disorganized. For this reason, we cast a wide net across a multitude of disciplines to glean the lessons. We could have included other disciplines such as health care, however, we chose to exclude health care as we determined that the applications of VR-assisted education in healthcare provided minimal value over what was already provided by the general education literature. Also, the VR-assisted education literature in healthcare is more focused on skills training, which has very limited application for SCM and business education in general.

We attempted to complement the limited scope of the VR-assisted literature in higher education with the addition of our mini case study. However, the case study involves a single technology vendor implementing their platform across a sample of partner university customers who opted-in to the study. As such, the case study is composed of a convenience sample of participating universities. Nevertheless, the students can be considered to be a pseudo random sample as there is very little control of the student enrolled in the classes. Hence, the results of the mini case study should not be considered as scientific and are only to be viewed as supporting our findings from the literature. As we set forth in our research propositions future scholars must conduct rigorously designed scientific enquiry through systematic literature reviews and meta-analyses to establish the overall efficacy of VR-assisted pedagogy in SCM.

Notes

[1]Note that in Dolgui and Ivanov (2023) the reference year is 2023 for Ivanov (2024). This is because they used the online version available at the time, which was published online on May 31, 2023

[2]360° video can also be viewed on 2D monitors, phones, or a less expensive device like the Google Cardboard®

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Table I: Selected VR-assisted pedagogy literature.

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
Chen et al. (2011)	Business	How does the level of environment abstraction in a virtual space impact students' reported feelings of presence during business negotiation role-playing? Does the level of environment abstraction influence the negotiation values used by students?	Open Wonderland, an open-source virtual reality software.	Experimental study with a quantitative approach, using surveys to measure feelings of presence and negotiation values.	A high abstract environment reduced feelings of presence compared to a low abstract environment. There was no significant difference in the negotiation values used by students across different levels of environment abstraction.
Cheng and Wang (2011)	Business	How effective is a 3D virtual supermarket environment (3DVS) in enhancing business students' ability to apply theoretical knowledge to practical situations?	VR	Experimental study with a control group (CG) and an experimental group (EG), using pretest and posttest assessments.	The experimental group, trained with the 3DVS, performed significantly better in terms of knowledge application in the posttest compared to the control group. The 3DVS was found to be effective in transforming students from passive learners to active participants, enhancing their ability to apply marketing mix theory in practical situations.
Harman et al. (2015)	Business	How effective is the role-playing approach in improving the accuracy of process elicitation?	3D virtual world?	Experimental study	The 3D virtual environment assists in placing experts into a familiar environment during task specification, potentially aiding memory recall and cognitive processing. Participants using the virtual world approach showed differences in how they interacted with the environment and constructed process models compared to the 2D approach.

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
Alhalabi (2016)	Engineering	To evaluate the impact of VR systems on students' achievements in engineering programs	VR	Experiments	Students are more engaged and motivated with HMD VR, which shows the highest student-performance achievement
Barricelli et al. (2016)	Education	How can semiotic theory be applied to understand virtual reality (VR) as a communication process? What framework can be developed to classify and describe different types of VR systems for e-learning and collaboration?	VR	Conceptual and literature review, combined with a semiotic analysis of VR systems.	The semiotic analysis of VR can be organized into three levels: syntactic (structure), semantic (model), and pragmatic (interaction). A framework was developed to classify VR systems based on these levels, providing a structured way to evaluate and design VR applications. The study classified eight popular VR systems for e-learning and collaboration, demonstrating the applicability of the framework.
Harman et al. (2016)	Business	What are the differences in process modelling outputs/approach between those who use the virtual world role-play tool and those who use a regular process modelling tool?	3D virtual world?	Experimental study	Participants using the virtual world role-play tool remembered more task steps, specified fewer erroneous task sequences, and were more consistent with their naming compared to those using the S-BPM process modelling tool. Virtual world participants were more confident in their performance and made fewer model alterations. The virtual world approach allowed participants to recall more information and construct models faster.
Jimeno-Morenilla et al. (2016)	Engineering	How can the use of virtual reality (VR) in an industrial design engineering course improve the creativity skills of students?	VR	Experimental study	The paper presents the methodological framework and does not provide empirical findings.
Kurilovas (2016)	Education	What are the existing methods of evaluating the quality of VR/AR/MR	VR, AR, MR	Literature Review	The potential of VR/AR/MR in education is significant, with many

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
		learning systems/environments and the ways to personalize these systems according to learners' needs?			studies indicating improved motivation and satisfaction among students. Most applications are still limited to simple visualizations, and the developed systems have not advanced beyond demonstration prototypes. There is a lack of technologically and pedagogically sound frameworks to personalize VR/AR/MR learning systems.
Lamb (2016)	Education	The use of 3 dimensional serious educational games, 2 dimensional laboratories and traditional lecture based instruction, are used to compare student content learning.	Computer learning games	case Study	Levels of success in learning are increased by using 3-dimensional serious educational games.
Lytras et al. (2016)	Education	How can virtual reality technologies be utilized effectively in learning, collaboration, and behavior contexts?	VR	Literature Review	Virtual reality has the potential to revolutionize learning systems and collaboration platforms. VR applications are being integrated into various learning and collaboration systems worldwide, indicating a shift from traditional classroom-based models to technology-enriched paradigms. VR can enhance the learning experience by providing immersive environments that facilitate effective learning and collaboration.

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
Lee et al. (2017)	Business	How beneficial is VR (3D, 360° video) in comparison with flat-screen (FS) (2D video) as a content delivery platform in business classrooms?	VR-360° video content	Experimental study	No significant differences were found between VR and FS conditions for content-related measures (novelty, reliability, understandability). Participants in the VR condition reported higher levels of enjoyment and interest compared to those in the FS condition.
Wong *et al.* (2017)	Education	What are the effects of virtual reality (VR) technology on learners' attitudes and perceived learning effectiveness when used to teach complex cargo terminal operations?	VR	Survey and Statistical Analysis	Participants who are open to new IT experiences find VR training more useful and have a more positive attitude towards learning.
Lamb et al. (2018)	Education	Investigates the hemodynamic responses associated with four different approaches to teaching life sciences.	IVR, Games	Case Study	Parity with learning outcomes and cognitive processing was found between hands-on learning, VR and SEGs.
Lamb et al. (2018)	Education	Meta-analysis of different forms of gaming on student cognition, affect and learning outcomes.	Games	Case Study	Higher cognitive gains and positive affects towards learning were exhibited by subjects using SEGs, SGs, and Educational Simulations.
Suh and Prophet (2018)	Education	What are the trends and focus, major theoretical foundations, research methods, and research contexts and samples of immersive technology literature and studies?	AR and VR	Literature Review	Immersive technology research has rapidly increased, with a significant number of studies published in recent years. Two main research streams were identified: the effects of immersive technology features on user experience and the enhancement of user performance through immersive technologies. Quantitative methods, especially experiments and surveys, dominate the research methodologies used. The majority of studies involved student samples.

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
					Factors influencing immersive technology use were categorized into system features (e.g., visual displays, auditory modalities, haptic interfaces, movement tracking) and content features (e.g., learning and training, psychotherapy, virtual journeys, interactive simulation, gaming).
Grivokostopoulou et al. (2019)	Business	How effective is a gamified entrepreneurship education framework in improving students' motivation, attitude, and overall learning experience in higher education?	VR	Experimental study	The gamified learning activities increased students' motivation and intention to pursue entrepreneurship. Students' entrepreneurial knowledge levels, self-efficacy, and entrepreneurial attitude improved significantly after participating in the gamified learning activities. The gamified framework was found to be effective in enhancing students' learning interest and engagement.
Hernandez-Pozas and Carreon-Flores (2019)	Business	How can Virtual Reality (VR) be used as an innovative, cost-effective solution to practice competencies in international business (IB) education?	VR	Conceptual analysis and interviews	Students recognized the VR learning method as innovative, attractive, realistic, important, useful, and safe. Students felt more conscious of their behavior, were able to practice and apply knowledge, and found the experience engaging and valuable.
Lamb and Etopio (2019)	Education	What roles do textbooks, VR, and a mixture, play in the development of summary and argument writing?	IVR, Textbooks	Case Study	Participants that were exposed to a VR environment prior to reading information about that environment in a textbook demonstrated significantly greater hemodynamic responses than those who had

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
					access to either the VR or the textbook alone.
Lopez et al. (2019)	Engineering	How can reinforcement learning (RL) be utilized to generate new environments for virtual reality (VR) learning applications?	RL and VR	Case Study	The RL agent was able to model a policy that allowed it to automatically generate new and functional VR environments for learning purposes. The generated environments have the potential to facilitate experiential learning and maintain user engagement over time.
Makransky and Petersen (2019)	Education	What affective and cognitive factors play a role in learning with desktop VR?	VR (desktop)	Case Study	Learning in VR can be increased by two different paths following the VR lesson; affective and cognitive.
Cunningham et al. (2020)	Engineering	How can a Deep Reinforcement Learning (RL) approach be used for Procedural Content Generation (PCG) to automate the generation of multiple related virtual reality (VR) environments for enhanced personalized learning?	Deep Reinforcement Learning (RL) and Procedural Content Generation (PCG) for VR environments.	Experimental study involving the development and testing of a Deep RL-based PCG method using case studies in different VR environments.	The proposed Deep RL-based PCG method successfully generated multiple VR environments with consistent themes, demonstrating its potential to enhance personalized learning. The method was capable of dynamically accepting user input to generate environments that satisfied specified parameters, illustrating the robustness and flexibility of the approach.
Lamb and Etopio (2020)	Education	To investigate and compare interactive VR-based preservice teaching environments with real-life teaching environments	IVR	Case Study	The use of VR allowed preservice science teachers to learn from VR simultations and enabled them to transfer the skills from VR to Classroom use.
Lamb et al. (2020)	Education	What roles do textbooks, VR, and a mixture, play in the development of summary and argument writing?	IVR, Textbooks	Case Study	Participants that were exposed to a VR environment prior to reading information about that environment in a textbook demonstrated significantly greater hemodynamic responses than those who had

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
					access to either the VR or the textbook alone.
Lamb et al. (2020)	Education	Investigates barriers to content learning and immersion with a VR Lab at a large University System.	IVR	Case Study	Methodologies used and the VR Laboratory environment, at the time of the study, was not ready for large-scale implementation.
Lopez et al. (2020)	Engineering	How effective is the Connected Learning and Integrated Course Knowledge (CLICK) approach (a VR-based approach) in improving students' motivation, engineering identity, and learning outcomes in an introductory probability course?	VR	Experimental study	The CLICK approach improved students' motivation, particularly in terms of confidence and satisfaction. There was no significant effect on students' engineering identity or knowledge gain.
McGovern et al. (2020)	Business	How can virtual reality (VR) technology enhance the quality of students' learning experiences, specifically in improving communication skills for presentations and public speaking events?	VR	Experimental study	VR significantly improved students' attention distribution, audience engagement, reduction of filler words, hand gestures, and overall presentation scores from their first to their second presentations. The use of VR provided real-time feedback, which was beneficial for students to understand and improve their presentation skills.
Radianti et al. (2020)	Education	Focusing on design elements, research agenda and lessons learned, researchers conducted a systematic review of IVR applications for higher education.	IVR	Literature review	VR has educational potential, but educators should take learning theories into consideration and focus should be placed on the usability of apps instead of learning outcomes.
Sholihin et al. (2020)	Business	Is there a difference in ethical efficacy between groups who take ethics	VR	Experimental study	VR-based learning significantly increases ethical efficacy compared to traditional methods.

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
		learning using VR versus those who do not use VR?			Students using VR found the learning process more motivating and interesting. VR increased perceived learning effectiveness. Significant improvement in self-efficacy was observed in the VR group compared to the control group.
Albus et al. (2021)	Education	To investigate the effects of signaling, in the form of textual annotations, on laerning outcomes and cognitive load in a virtual reality learning environment.	VR	Case Study	Annotations improved learners' recall performance and germane cognitive load (GCL) compared to a control group, but had no effects on deeper levels of processing and on extraneous cognitive load (ECL).
Araiza-Alba et al. (2021)	Education	Comparative analysis to determine if VR impacts problem-solving skills.	IVR and 2D App/ board game	Case Study	Students using IVR solved a game better than those using a tablet or board game, supporting the idea that problem-solving skills learned with IVR technology transfer to real-life.
Araiza-Alba et al. (2021)	Education	Can 360-degree VR videos be used as a tool for teaching water safety to children	IVR - 360-degree videos / traditional videos / poster	Case Study	VR videos are more engaging and motivating than traditional learning methods, although learning outcomes across three mediums were equally effective.
Barret et al. (2021)	Education	How can high-immersion virtual reality (VR) be effectively used to teach English paragraph writing structure? and what factors influence learners' acceptance of high-immersion VR systems?	High-immersion virtual reality system using Oculus Rift + Touch for learning English paragraph	Survey and Statistical Analysis	Perceived Usefulness (PU) had a strong positive effect on learners' intention to use (ITU) the VR system. Perceived Ease of Use (PEU) had a weak positive but non-significant effect on ITU. Immersion significantly influenced PU but had no significant effect on PEU.

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
			writing structure.		Interaction had a significant positive effect on PEU but a non-significant effect on PU. Imagination had a significant effect on PU but not on PEU. Immersion's direct influence on PU and PEU was weak, suggesting it should be repositioned to impact interaction and imagination.
Earle and Leyva-de la Hiz (2021)	Engineering (Sustainability Education, Design Thinking, Emerging Technologies)	How can the intersections of design thinking and emerging technologies in augmented and virtual reality (AVR) help address system-level challenges in sustainability-focused education?	Augmented and Virtual Reality (AVR)	Conceptual analysis	AVR can make sustainability challenges more salient and proximate to students. AVR can democratize access to the design thinking process. A conceptual model was developed suggesting AVR's potential for facilitating sustainability education through design thinking.
Ebnali et al. (2021)	Education	Examines how varying levels of interaction fidelity in virtual environments impact first-time users of highly automated vehicles.	IVR	Case Study	High fidelity VR supports improvement
Hsiao (2021)	Education	How does the application of Virtual Reality (VR) to experiential education affect the self-efficacy and learning motivation of social workers?		Experimental study	Experiential education with VR significantly affects self-efficacy and learning motivation. Self-efficacy has a notably positive effect on learning motivation.
Liu and Shirley (2021)	Education	To transform a business study abroad course into a collaborative online learning experience for U.S. students with their educational partners in Germany, Brazil and India	VR	Mixed-methods case study and survey	Students were engagedVR-assisted study abroad course anabled active learning activities and cultivated students' intercultural competence developmen

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
Lopez et al. (2021)	Engineering	How effective is the Connected Learning and Integrated Course Knowledge (CLICK) approach (a VR-based approach) in improving students' motivation, engineering identity, and learning outcomes in an Operations Research (OR) course?	3D simulation	Experimental study	There was no statistically significant difference in overall motivation and engineering identity between the control and intervention groups. Students in the intervention group reported higher confidence levels. The CLICK approach helped maintain students' motivation and engineering identity during remote learning due to COVID-19. Students' self-assessments were positively correlated with their grades, motivation, and engineering identity.
Morélot et al. (2021)	Education	To investigate how VR immersion impacts the sense of presence for fire safety training.	VR - Fire Safety	Case study	The sense of presence does not affect procedural or conceptual learning
Reeves et al. (2021)	Education	To investigate the experiences of UG students learning Chemistry in VR labs.	IVR	Qualitative	Four Qualitative experiences were discovered by the six participants.

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
Rejeb et al. (2021)	Business	What are the potentials of AR applications in SCM and logistics?	AR	Literature Review	AR can add value in five main areas: warehousing, manufacturing, sales and outdoor logistics, planning and design, and human resource management. AR has the potential to improve business processes, operational efficiencies, and overall competitiveness in SCM and logistics.
Dwivedi et al. (2022)	Education	What are the implications of the metaverse for current pedagogical methods and teaching strategies?	The Metaverse, encompassing various applications and implications for immersive learning environments, AI-enabled adaptive learning systems, and multimodal data analytics	A multi-perspective approach, gathering insights from invited expert contributors	The metaverse can better facilitate new forms of training beyond the capabilities of physical classrooms and traditional e-learning platforms. The metaverse can enhance the simulation of physical classrooms and provide new learning opportunities. Educators can gain insights into student responses and behaviors through AI and data analytics in the metaverse

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
Hadi et al. (2022)	Business	How effective is the augmented reality (AR) mobile application in teaching accounting ethics, specifically in improving users' intention to use the application?	AR	Surveys	The AR application received a pre-test SUS score of 80.00 (good to use) and a post-test score of 90.27 (excellent to use). Potential users intend to use the application, influenced by perceived ease of use and perceived usefulness.
Petersen et al. (2022)	Education	To explore the process of learning with VR technology using the Cognitive Affective Model of Immersive Learning (CAMIL) as its framework.	IVR	Case Study	The process of learning involves situational interest, and embodied learning.
Wuttke *et al.* (2022)	Business	How can virtual reality (VR) be effectively used to teach supply chain management, specifically addressing the challenges of abstraction and illustrating the bullwhip effect through Jay Forrester's Beer Game?	VR and WebXR	Survey and Statistical Analysis	The VR simulation allowed for better visualization and understanding of supply chain dynamics and the bullwhip effect. Data collection capabilities facilitated classroom discussions and analyses.
Boffi et al. (2023)	Education	The study investigates the impact of IVR on learning outcomes through the exploration of a Roman Domus.	IVR	Case Study	Engagement in VR was increased while learning was equally effective in all experiences (3D, 2D and Slide-based).

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
Dolgui and Ivanov (2023)	SCM	How will the metaverse impact supply chain and operations management (SCOM)?	The metaverse and related technologies such as cyber-physical systems, digital supply chain twins, cloud supply chains, and Industry 4.0/Industry 5.0.	Conceptual study using elements of literature search and keyword analysis from SCOPUS.	The metaverse will likely lead to a co-existence of physical SCOM, metaverse SCOM, and SCOM for the coordination of physical and metaverse worlds. New research areas can emerge for SCOM processes and decision-making in the metaverse, such as joint demand forecasting for metaverse and physical products, digital inventory allocation, and integrated production planning. New performance measures, such as virtual customer experience level, availability of digital products, and digital resilience and sustainability, will be important.
Fink et al. (2023)	Education	Explores the variables connected to the usability of IVR through an interactive VR field trip.	IVR	Case Study	Ease of use, usefulness, presence and extraneous load predict system usability and usefulness, presence and intrinsic cognitive load explain the variance in satisfaction.
Giron et al. (2023)	Business	How can immersive virtual reality (VR) case studies improve the teaching and learning of business administration strategy?	IVR	Case Study	The use of VR case studies was well-received by students and improved their understanding of business concepts. Students reported high levels of information processing, clarity, and enjoyment. Immersive VR content can create similar engagement levels whether accessed at home or in the classroom.

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
Hutson and McGinley (2023)	Education	How can extended reality (XR) technologies be used in a neuroaffirmative manner to empower individuals with Autism Spectrum Condition (ASC) through immersive learning environments?	XR	Literature Review	XR technologies can provide a supportive and accommodating environment for individuals with ASC by addressing four key factors: Indirect social engagement, digital communication preferences, sensory sensitivity, and avatar-based communication. XR technologies can help reduce anxiety, enhance social engagement, and improve learning outcomes for individuals with ASC. XR can create a more inclusive and equitable environment in both educational and professional settings.
Kasapakis et al. (2023)	Education	What is the impact of high-fidelity non-verbal cues in Virtual Reality?	SVR	Case Study	Implementing non-verbal cues (Finger motion, gaze direction, facial expression) into VR simulations significantly enhances the learning experience.
Li et al. (2023)	Education	How does summarizing scaffolding and textual cues on learning performance, mental model development and cognitive load enhance learning in VR?	VR	Case Study	
Lowell and Tagare (2023)	Education	Proposes a theoretical framework for the integration of gen-AI into the design and delivery of courses to promote authentic learning.	AI	Conceptual	Challenges included the development time and effort required for the VR modules, students' preference for different types of systems, and the need for more extensive training on VR use.
Oje et al. (2023)	Engineering	A scoping review of 51 studies on VR-assisted engineering education, revealing trends and gaps in research.	VR - Engineering	Literature Review	VR studies in engineering should be informed by theories of learning and instruction that address the

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
					cognitive and socio- cognitive aspects of learning (VR Pedagogy).
Sari et al. (2023)	Business	Is the effectiveness of VR-based business ethics learning media influenced by the interaction between the user's perception of VR and learning styles?	VR	Experimental study	VR technology positively affects the quality and accessibility of technology. The learning style moderates the relationship between technology quality and self-efficacy (SE) as well as technology accessibility and SE. Active learners (accommodators and convergers) benefit more from VR in terms of SE compared to passive learners (divergers and assimilators).
Skulmowski (2023)	Education	To provide guidelines for ethically sound utilization of VR and realism.	VR	Qualitative	Negative consequences of educational VR use (spatial ability testing, alternative paths in VR to prevent manipulation and using algorithms to remove PII generated through educational VR use.
Strojny and Duzmanska-Misiarczyk (2023)	Education	A review of the methods used to measure the effectiveness of virtual reality (VR) tools.	PRISMA guidelines of VR	Bibliometric Analysis	The duration and number of training sessions could affect the effectiveness of VR-based Training.
Won et al. (2023)	Education	How learning in immersive VR was designed in contemporary educational studies.	IVR	Statistical Analysis	The study shows how researchers navigate practical and educational concerns to show the diversity of learning tasks possible in immersive VR.
Tiwari *et al*. (2023)	Education	What are the current applications and resulting advantages, and future prospects of AR and VR in online education?	AR and VR	Literature Review	AR and VR have demonstrated substantial contributions to facilitating teaching in various fields. The technologies have shown a potential to make online education more engaging and effective.
Zhao et al. (2023)	Education	What are the trends and gaps of research on Virtual and Augmented	VY and AR	Bibliometric Analysis	Key research areas include the impact of VR and AR on

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
		Reality in Education according to the Web of Science database?			visualization, human-centered computing, engineering education, and medical training.
Conrad et al. (2024)	Education	Analysis of 30 research articles comparing effectiveness of IVR-based learning and its impact on learner engagement.	Immersive VR	Literature Review	IVR has a positive impact on learning when conducted in learning environments that prioritize active engagement and constructive application.
Kuvar et al. (2024)	Education	Study that analyzed the effectiveness of Virtual Reality on TUT (Task-unrelated thought) during learning	Virtual Reality	Case Study	Students are less likely to experience TUT in VR and more likely to receive better grades on posttess after exploring a 360 video vs a 2D video.
Mota et al. (2024)	Medicine	How virtual reality (VR) technologies can be effectively integrated into learning environments to enhance collaboration and behavior?	VR	Literature Review	VR technologies offer significant potential to transform learning experiences by providing immersive and interactive environments. VR can enhance collaboration among students and improve engagement and motivation.
Ratmono et al. (2024)	Business	How does virtual reality (VR) impact perceived learning effectiveness in accounting studies? What is the mediating role of task-technology fit (TTF) in the relationship between VR use and perceived learning effectiveness?	VR	Survey and statistical analysis	VR positively affects technology quality, technology accessibility, and task-technology fit. Task-technology fit enhances reflective thinking and reduces cognitive overload, contributing to increased perceived learning effectiveness. Reflective thinking positively influences perceived learning effectiveness, while cognitive overload negatively impacts it. TTF mediates the relationship between VR use, learning behavior, and perceived learning effectiveness.

Article	Discipline	Research Question/Objective	Focal Technology	Methodology	Findings
Ronaghi and Forouharfar (2024)	Business	How does VR technology usage affect entrepreneurial intention (EI)?	VR	Experimental study	VR-based entrepreneurship training significantly increased the students' entrepreneurial intentions compared to traditional methods. VR training improved students' personal attitudes and perceived behavioral control but did not significantly affect subjective norms. Traditional teacher-centered training also increased entrepreneurial intentions but was less effective than VR-based training.
Shi et al. (2024)	Education (language)	What are the differences in students' achievement of oral English skills among students instructed by a traditional teaching method, immersive VR embedded in the traditional class, PjBL approach, and PjVR instructional model? Whether the iVR-assisted PjBL instructional model can significantly improve students' achievement of oral English skill from grammar and vocabulary, discourse management, pronunciation, and interactive communication respectively? Whether the iVR-assisted PjBL instructional model can significantly improve students' cognitive, affective behavioral, and social engagement respectively?	iVR	Experimental study	The PjVR group students significantly outperformed the other three groups in oral English skills. Students' skills in grammar and vocabulary, discourse management, pronunciation, and interactive communication all improved significantly in the PjVR group. Behavioral, affective, cognitive, and social engagement also improved significantly in the PjVR group.

Table II: Supply chain management pedagogy literature.

Article	Research Question/Objective	Pedagogical Innovation/Contribution	Method	Key Findings
Holweg and Bicheno (2002)	Describes a participative simulation model to demonstrate Forrester's supply chain dynamics and model improvements for the entire supply chain.	Lean Leap Logistics Game. LEGO brick-based table-top simulation.	Descriptive case study	Simulation as an effective tool for illustrating complex abstract concepts for holistic supply chain optimal solutions.
Gravier and Farris (2008)	Provide a historical perspective, current state-of-the-art and future trends for logistics education to foster advancements in logistics education	SCM teaching requirements to meet future needs	Literature review	Computer skills and soft-skills such as communication, interpersonal, and multiculturalism in global teams are valued by employers. More realistic computer simulations are required.
Sweeney *et al*. (2010)	The benefits and challenges of offering a course using commercial software	Commercial software use in SCM class	Descriptive case study	Modeling real-world supply chains using commercial software is a key differentiator for students and provides real-world experience to relevant decision-support tools.
Bak *et al*. (2013)	Challenges faced in a SCM consultancy course	SCM consultancy course	Case study	Several client and lecturer resource constraints including health and safety risks, privacy and skills assessment.
Fawcett and Rutner (2014)	How well are universities, associations and publications meeting stakeholders educational goals and keeping up with a changing business world.	Gap between education offering and needs	Survey	Two gaps, first between educational providers and stakeholders needs, second between academic and practitioners perceptions.
Wong *et al*. (2014)	Compare UK SCM courses design with employer's job requirements	Gap between education offering and employer needs	Content analysis	An imbalance between program curriculum and employer needs. Employer needs more hands-on experience in basic SCM skills.

Article	Research Question/Objective	Pedagogical Innovation/Contribution	Method	Key Findings
Fawcett and Waller (2015)	What is the future of SCM education	SCM teaching requirements to meet future needs	Editorial	Embrace technology and SCM's natural affinity for professional engagement to add more experiential learning content
Gibson *et al*. (2016)	Discuss a university-industry collaboration to accelerate SCM learning for forward-looking SCM.	University-industry collaborative course	Exploratory case study	A framework for a university-industry collaboration aimed at accelerating SCM learning.
Horejsi *et al*. (2016)	A game platform for teaching student how to create VR digital factory simulations for education.	VR digital factory platform	Descriptive case study	Benefits of using the platform for education of students to create VR digital factory content for training purposes.
Jordan and Bak (2016)	Skill requirements for modern supply chains in the UK	Gap between education offering and needs	Survey and interviews	Key skills needs are collaboration, problem solving, IT skills and understanding of regulations.
Sinha *et al*. (2016)	Examine the gap between demand and supply of SCM knowledge areas and ways to close that gap.	Gap between education offering and employer needs	Content analysis of job boards and university curriculum	Undersupply in analytics, production and operations management S&OP, WMS, ERP,
Trautrims *et al*. (2016)	Examine the use of global virtual teams simulation to prepare students for future careers.	Global virtual teams	Case study	Global teams simulation addresses the skills required by SCM managers including global orientation, technical savvy, cross-organizational interaction and leadership.
Gámez-Perez *et al*. (2020)	Propose a university-industry collaboration model to develop SCM competences in students	University-industry collaborative course	Action research	Four competences identified 1. Project management skill, 2) Problem solving skill, 3) Analytical skill, and 4) Communication and teamwork.
Birou *et al*. (2022)	Report on the current state of SCM courses at universities in the U.S.	Gap between education offering and employer needs	Survey	Technology, creativity, ethics and interpersonal skills are lacking in course content

Article	Research Question/Objective	Pedagogical Innovation/Contribution	Method	Key Findings
Fawcett *et al*. (2023)	Describe a deliberate-practice case pedagogy to close SCM skills gap and re-engage students.	Deliberate-practice case	Case study	Recruiters view skills gap in problem solving, communication, collaboration and professionalism. The deliberate-practice case pedagogy closes career-readiness gap and helps students build confidence to achieve early career success.
Liu and Mackelprang (2023)	Describe an origami activity to teach students how to achieve competitive priorities through process design and evaluate process performance for potential improvements.	Origami activity	Descriptive case study	Post-activity survey indicates students had a positive learning outcome and was successful in learning process design and competitive priorities.
Lutz *et al*. (2023)	Survey of SCM courses	Gap between education offering and employer needs	Survey	Technology, creativity, ethics and interpersonal skills are lacking in course content
Merkert *et al*. (2023)	What are the future skills required to excel in future SCM careers.	SCM teaching requirements to meet future needs	Survey	Emphasize data analytics, creativity (soft skills) and learn to learn.
Patrucco *et al*. (2023)	Value of a data-driven category management case study for teaching data analytics to purchasing and SCM students	Data-drive purchasing and supply management case study	Case study	The case enhances student learning and comprehension of pruchasing and supply management spend analysis classification and visualizations.

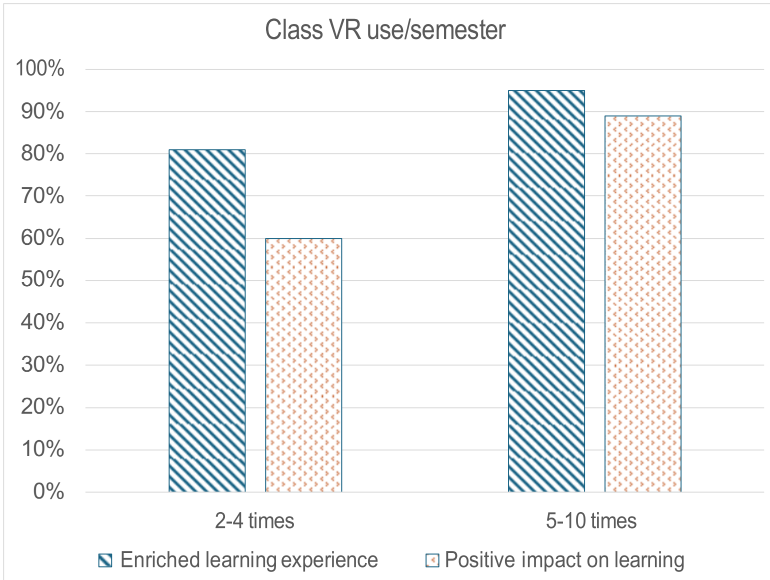

Figure 1: Frequency of class VR per semester and students' perceived effect on learning outcomes and experience.