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A Conceptual Learning Design in Virtual Reality − The Cognitive VR Classroom for Education After the Pandemic Era

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ABSTRACT

The COVID-19 pandemic has created extraordinary global crises and unprecedented disruption to education. The current situation has become changeable and unpredictable, which may lead to chronic cognitive issues for students who have no access to education. At the same time, the use of virtual reality (VR) technology has emerged as a powerful instrument for re-thinking and enhancing the current educational patterns during the post-pandemic era. However, although ample reviews have summarized developments in VR and education, few studies have synthesized these findings into an integrated learning design. In response to this insufficiency, this study discusses potential solutions for current educational challenges and presents a novel design – the cognitive VR classroom. It is a conceptual design that could enable students to access rich learning resources within an immersive VR system. The design of the cognitive VR Classroom is based on the amalgamation of brain-based learning theory (BBL) and the cognitive-affective model of immersive learning (CAMIL). Further, six extended dimensions of classroom learning were developed to structure the cognitive VR classroom. To examine their validity, a correlation analysis was conducted to present the correlation coefficient and the strength of the association. The result shows that the cognitive VR classroom is a promising theoretical framework to facilitate educational diversity and a powerful model to develop smart classroom learning.

KEYWORDS: The Covid-19 Pandemic, Virtual Reality, Cognitive Education, Classroom Learning

1 INTRODUCTION

The Covid-19 pandemic has led to extraordinary global crises and unprecedented disruptions to international education. During the school closure, students were compelled to face relevant inconvenience, disruptions, and challenges. Also, students affected by the pandemic who might be at risk of long-term mental health impairments (Lee, 2020). For example, recent research has reported that 74 percent of students have been struggling to maintain a routine due to school closures (Active Minds, 2020). Twenty percent of students from higher education claim that their mental health has significantly worsened during this period of time (Active Minds, 2020). The main pressures reported by students were loneliness, isolation, concerns about school work, and deteriorating health condition as a result of lockdowns. What is more, many students have suffered from anxiety and depression, including self-harm, loss of motivation, and hopelessness (Young Minds, 2021). Increasing evidence has shown that characterized anxiety and depression have serious influences on students' cognitive development. With the educational landscape becoming changeable and unpredictable, the pandemic uncertainty may cause chronic educational and mental health issues for students (de Figueiredo et al., 2021; Majumdar et al., 2020). Meantime, many educational designs have exposed their rigidity, impracticality and unprogressive status in remote learning during the pandemic (Aeschliman, 2008; Davis, 2017; Popenici & Kerr, 2017; Tom, 1997). Therefore, preventing these crises from becoming generational catastrophes is urgent and critical. Schools and educators now more than ever need to harness leading technologies and new methods to develop innovative learning designs.

2 BACKGROUND

Previous studies have indicated that utilising appropriate technology to build distinct learning experiences can re-kindle students' motivation and curiosity (Abumalloh et al., 2021). The use of internet technology to improve educational practicability and diversity has been widely discussed. Moreover, Popenici and Kerr (2017) have convinced that advances in cutting-edge technology open new possibilities and challenges for innovative education. These factors can fundamentally change governance and the internal architecture of institutions within all levels of education. On the other hand, immersive virtual reality (VR) has become increasingly adopted for teaching and learning purposes. It is defined as a computer-generated environment that synthetizes multisensorial stimulation, immersive scenes, and simulated real-world contexts (Wedel et al., 2020). Research has validated that VR contributes to the understanding of technology-mediated collaborations and offers new solutions to educational purposes (Wang et al., 2021). Hence, this research employs immersive virtual reality (VR) as a representative technology, developing a VR-mediated education design as a solution to present challenges in education.

2.1 Defining VR Technology

VR is defined as a computer-generated environment that synthetizes multisensorial stimulation, immersive scenes, and simulated real-world contexts (Wedel et al., 2020). In a typical VR format, the user wears a headset with a stereoscopic screen, where animated images of a simulated setting can be experienced in real-time (Lowood, 2015). The application of VR is based on the unique method of modelling real environments with the ever-growing development of computer-generated graphic technology. The virtual setting has been used as a replacement or extension of the physical world, allowing users to experience six degrees of freedom ((Wang et al., 2021), based on principles of environmental immersive interactivity (Freina & Ott, 2015). To date, the standard VR system utilizes both VR headset and multi-projected settings to generate verisimilar images, videos, sounds and other sensations which could simulate an immersive environment for users. By providing the optimal control for experimental conditions within a safe and observable setting (e.g., choice of avatars, environments, sounds, perspective), VR can improve the interactive experience (Bohil et al., 2011; Pan & Hamilton, 2018). As an emergent technology, VR simulates a variety of senses in an immersive setting with the potential to present realistic and dynamic social scenarios, which trigger individuals' responses with a real sense of being there (Riva et al., 2019).

3 METHODOLOGY

There has been an increasing number of reviews summarizing developments of VR and educational design, whereas few studies have synthesized these findings into an integrated learning design (Fig. 1). This research presents a conceptual design for students to access multi-dimensional education within an immersive learning setting – the cognitive VR classroom. This concept is inspired by brain-based learning theory (BBL) and the cognitive-affective model of immersive learning (CAMIL) and aims to provide a conceptual learning design as a solution for current educational plights and a theoretical exploration for future educational development.

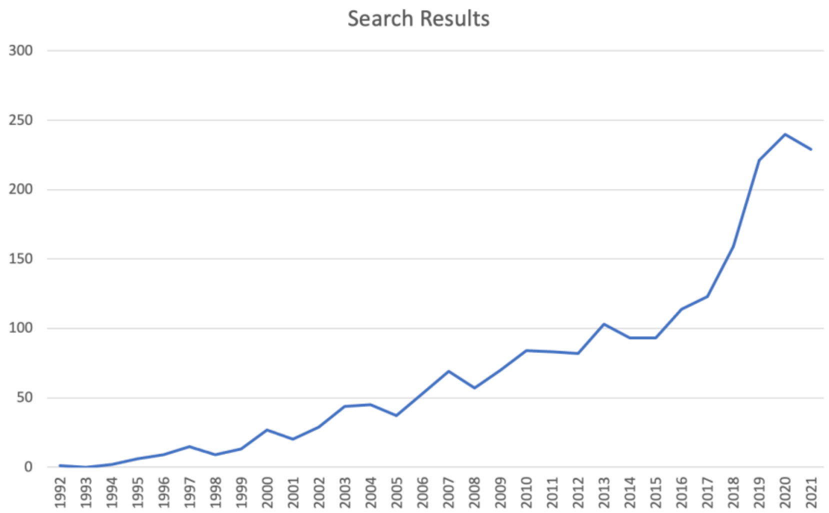

Figure 1: Number of studies on the Scopus database refer to VR and educational designs

Note: The following search string was applied: TITLE-ABS-KEY (virtual AND reality OR vr AND (educational AND design* OR learning AND design)) AND PUBYEAR < 2022. Retrieved December 12, 2021.

3.1 Perspectives of BBL

BBL theory states that educational environments and curriculum designs should follow the nature of how the brain learns (Craig, 2003). It explains brain-information processes and their connections with learning activities. For example, it suggests a learner-centred and teacher-facilitated approach which is accomplished by learners' cognitive endowments (Olaoluwa & Ayantoye, 2016). This innate cognitive ability relates to the brain structure and brain function in different aspects. As noted by HINTON et al. (2008), the relative activity level at each synaptic connection regulates various neuron connections. Brain functions such as thinking, assimilating, memorialising, and concretizing are shaped by these neuron connections. BBL utilizes this bio-neurological mechanism to highlight meaningful learning, which suggests that information should be acquired intelligibly and effectively, as opposed to memorizing information. Jensen (2008) argues that meaningful learning can be achieved by re-ensuring environmental factors in the classroom, e.g., relaxed alertness, deep immersion, and timely processing. Previous research supported that the learning process becomes productive and substantial while the learning setting meets three conditions: (i) abstract concepts can be concretized to comprehensible knowledge, (ii) combing the theory with empirical studies and ecological settings, and (iii) learning and motivation can be rewarded during the process (Flagel et al., 2011; Phan & Ngu, 2018). Therefore, the core of BBL is to organize learning materials by focusing on brain mechanisms, so that it can be a feasible solution to learning problems (Uzezi & Jonah, 2017).

3.2 The Connection Between VR and the Learning Process

Previous studies have noted that VR shares the same basic mechanism for processing information from the environment as does the brain, a concept referred to as “embodiment” (Riva et al., 2019). Riva et al. (2018) has presented a hypothesis of predictive coding 94–96, which proposes that the brain creates embodied simulations from reality to command the body effectively. The embodied process has a connection with orbitofrontal cortex (OFC). It is located in the frontal region of the brain and plays an important role as a processing station for visual information (Chaumon et al., 2013). It links the sensory system (e.g., motion, vision, auditory, olfactory, and gustatory) to higher-order thinking processes of the outer cerebral cortex. Also, processing incoming visual information from social stimuli (Northoff, 2016). The OFC influences interactions between humans and the environment, e.g., VR embodied experience includes the highest level of opioid receptors in the cerebral cortex with stimulation reward (Nelson & Panksepp, 1998; Šimić et al., 2021).

In addition, when viewed through the lens of neurobiology, the learning process and associated neural changes are seen to be activated by attention. This neurobiological mechanism activates neurons to change and strengthen connections between and across the synapse (Sarter et al., 2001). Similarly, VR can reproduce the external features of the body connections by using vision and auditory (Riva et al., 2019). It is a non-invasive technological paradigm based on wearable acoustic and vibrotactile transducers, also, a possible approach to connect and augment the contents of the inner body. Current studies have provided strong evidence to support the mechanism of the brain embodiment in the VR experience (Perez-Marcos, 2018). Hence, we predict that such a powerful tool can play a leading role in teaching and learning in the future.

4 THE NATURE OF THE COGNITION VR CLASSROOM

In recent years, there have been increasing interests in technology-based learning designs for teaching and learning during the covid-19 pandemic. Intellectualised learning designs (e.g., interactive learning and artificial intelligence classes) have shown significant growth in the educational market. Although the foundation of these designs is based on technology, technology is mainly used to promote educational diversity, rather than dominate educational practices by differentiating learning environments. More specific, technology can support classroom learning in various means, valuable learning primarily requires educators to meet the needs of different learners (Wang et al., 2019). Therefore, the nature of our conceptual design – the cognitive VR classroom, is a functional design that uses cognitive theories and VR technology as driving forces to overcome educational barriers and challenges under the Covid-19 pandemic. It also aims to match with various pedagogical aspects and create a smart, situated, and multi-sensory learning environment. In doing so, we harnessed BBL theory as a foundation and developed three extended pillars to establish a framework for the cognitive VR classroom. These include Pillar 1 – Embodiment of abstract concepts, Pillar 2 – Enhancement of cognitive competence, and Pillar 3 – Edutainment mechanism (Fig.2).

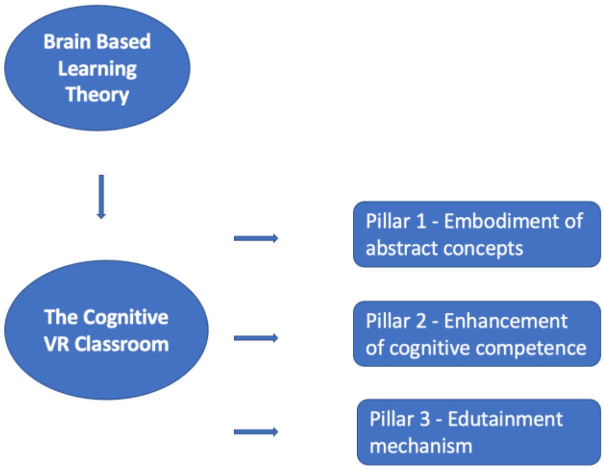

Figure 2: Three Extended Dimensions of The Cognitive VR Classroom Adapted From The BBL Theory

4.1 The embodiment of Abstract Concepts

Traditional classroom teaching and learning often require students to have complex and abstract cognitive capacities to imagine scenarios and settings which no longer exist. Such concepts represent one of the most sophisticated abilities of the human imagination. Teaching abstract concepts (e.g., metaphor and analogy) often involves complex factual and process-based knowledge which are ambiguous and difficult (Lodge et al., 2018). To support students to have a better understanding of abstract concepts, the cognitive VR classroom can embody abstract and obscure knowledge in a visualised way, enabling nonrepresentational to become vivid and concrete, which largely increases students' interests and motivation (Zhang & Bowman, 2021). Neuroscientific evidence has shown that visual inputs are easier to impress as synapses activation and cognitive development are co-occurring when the brain is learning (Kim et al., 2018). Visual function relates to the primary visual cortex and prestriate cortex that take part in the process of embodied learning, linking neuron networks that represent and store the information (Macedonia, 2019). In particular, neurons in visual and haptic areas are connected to represent the shape, colour and texture of the objective presences (Macedonia, 2019), next, the sensorimotor networks mirror all experiences of the physical body (Di Paolo & Thompson, 2014; O'Regan & Noë, 2001; Pulvermüller, 1999). These activities reveal how the brain accepts learning input and produces learning output (Duffy & Jonassen, 2013). Thus, immersive VR can visualize abstract concepts, presenting the image, animated materials, and videos in multiple-sensory dimensions. Applying this technology in the classroom can enhance individuals' understanding and turn elusive concepts into deep learning (Zhang & Bowman, 2021).

4.2 Enhancement of Cognitive Competence

González-Forero and Gardner (2018) have addressed that the human brain expansion is driven largely by the ecological environment. It is largely determined by complex interactions with the social environment (Barsalou, 2010). The brainwork of human-environment interaction relates to memory encoding (Herweg & Kahana, 2018). Once the individual engages in the encoding process, the formation of social memory would be boosted. Neuro-ecological evidence has indicated that the active memory of social interaction is significant to striatal-memory networking during the hippocampus-amygdala projection. Thus, social memory is considered a powerful mechanism that intervenes the development of human cognition (Shamay-Tsoory & Mendelsohn, 2019).

In addition, cognitive development believes that early learners construct an understanding of the world through the surrounding environment, experiencing discrepancies between the existing structures (accommodation) and new information from the environment (assimilation). The final product of this notion is "equilibration" (Piaget, 1936). Nowadays, immersive VR can be valued as the new "equilibration" as it is an effective way to process information between the brain and the environment. It is also a useful instrument in social neurosciences for simulating social interaction and evaluating cognitive competence (Lopatina et al., 2020). A recent study has revealed that the use of VR has resulted in increasing connections of the hippocampus with other brain regions (Fajnerová et al., 2018). Research has proved that VR can enhance cognitive function for individuals through a series of practices (Dawkins & Young, 2020). VR contributes considerable information on sensorimotor integration, decision making, and spatial navigation generating various stimuli to preserve and increase emotional/social cognition (Dombeck & Reiser, 2012). Utilizing this concept for educational practice, Żuromski et al. (2018) believe that VR can improve the presentation of domain ontologies by deeper embodied scenes. The immersive function of VR allows students to discover and experience objects and phenomena in various means that they cannot reach in real life (Taxén & Naeve, 2002). Similarly, the cognitive VR classroom can provide rich resources to generate diversity in teaching and learning, as well as information acquisition. With its audio and video components, it can intrigue students to have reciprocal explorations via telepresence (Alicea, 2020).

4.3 Edutainment Mechanism

Edutainment is a concept combining education and entertainment. In Edutainment, the learning process jumps from the traditional class to interactive learning by embedding educational elements from technology (Rapeepisarn et al., 2006). VR in education is a reflection of Edutainment. For instance, VR stimulation can boost the reward circuitry in the brain and improve attention, memory and motivation (Renninger & Hidi, 2020). Evidence from brain studies has found that once the student is attracted to a particular object, they will be interested in seeking relevant information. This seeking behaviour may reactivate the reward circuitry system, forming an effective circulation mechanism (Gottlieb et al., 2013). In this way, taking part in entertaining activities can increase the reactivity to visual cues that are associated with the particular exposure. Exposures in VR thereby substantially enhance students' episodic memory, semantic memory, and procedural memory (Bazzett et al., 2018).

On the other hand, VR's immersive endowment allows educators and students to process learning material with more visual support and less abstract imagination (Smutny et al., 2019). The various scenarios made by VR systems provide considerable information with less ambiguity and confusion. Many VR settings can be poised to replace real environments during the pandemic situation, motivating learners to gain knowledge from alternative simulated settings (Christou, 2010). This ability has been demonstrated by Xie et al. (2019) who conducted a study for students to learn Chinese as a foreign language through VR Cardboard. The purpose was to examine students' perceivable benefits and challenges when using VR tools for language and culture acquisition. Findings have reported that VR scenarios reproduce vivid virtual venues and cultural atmospheres which deeply sparked learners' interest in cultural exploration and language study. At the same time, this study has also highlighted the importance to have support from educators to help students stay engaged, actively exploring the hidden mechanism – the relationship between teaching and learning, as well as how the brain works. Meanwhile, teachers have been suggested to take advantage of smart technology and methods to interact with students in an effective way (Xie et al., 2019). Likewise, the cognitive VR classroom harnesses the edutainment mechanism to inspire innovative teaching and learning. This theoretical design firmly supports educational practice to raise engagement and improve diversity.

5 The Cognitive Affective Model of Immersive Learning (CAMIL)

Makransky and Petersen (2021) presented the cognitive-affective model of immersive learning (CAMIL), which integrated existing educational studies into an immersive VR setting. CAMIL posits that VR systems have a multi-sensory nature to support information coming from more than one source at a time, adding to the experience and making it more visual and engaging. There are six cognitive factors which influence immersive VR learning outcomes, including self-efficacy, interest, motivation, cognitive load, embodiment, and self-regulation. these dimensions reinforce learning from multiple sources. VR's immersive capability creates vivid scenarios in providing quality educational context which allows students to retain more knowledge (Olmos et al., 2018). In addition, due to the higher sense of presence in VR education, the CAMIL model substantiated that students' could have greater academic performance in a cognitive VR class compared to a simplex video input class (Olmos et al., 2018). However, as a burgeoning learning model, it needs to be tested, extended, and improved by more studies (Makransky & Petersen, 2021). Thus, to echo this perspective, we further developed three core elements. These are Core 1- Multisensory stimulation, Core 2 - Situated learning, and Core 3 - Interdisciplinary study (Fig. 3). Synthesizing these Cores with the Pillars previously discussed. We structure the foundational framework of the cognitive VR classroom with guidance from BBL theory and CAMIL (Fig. 4).

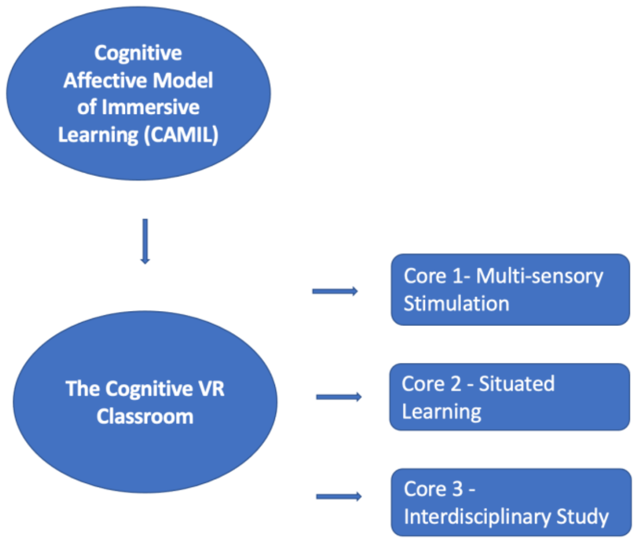

Fig. 3 Three extended dimensions from CAMIL

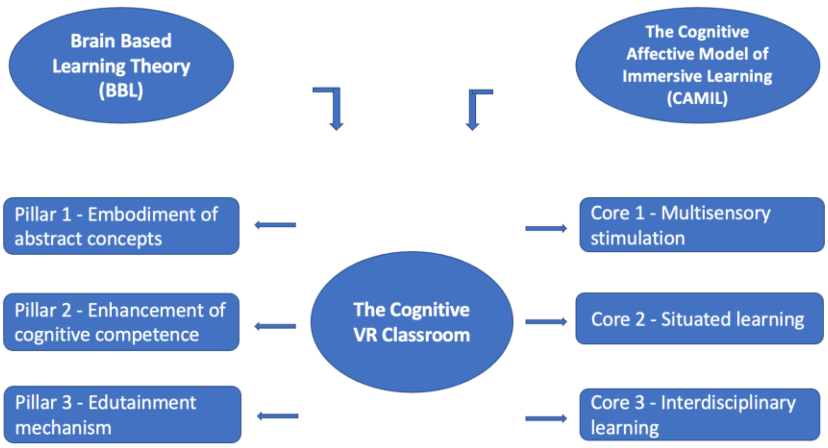

Figure 4: The Visualized Concept of The Cognitive VR Classroom

5.1 Learning with Multisensory Stimulation

The cognitive VR classroom yields multisensory education to teach, learn, and feel the educational materials through seeing, hearing, speaking, touching, moving, and perceiving. Teaching through multisensory stimulation supports students to apply new information to previous learning, and understand its hidden logic and connections (Katai & Toth, 2010). Research has revealed that the brain learns and functions optimally while information is intermixed with multiple sensory inputs (Shams & Seitz, 2008). In the process of information integrating, external object characteristics can be perceived and handled in different visual areas in the human brain. Moreover, multisensory neurons' characteristics only could be kindled when more than one sensory modality is activated, their response speed (supra-additivity) can be enhanced by the presentation of co-occurring events (Katai & Toth, 2010). VR is a powerful instrument when it is applied to specific learning tasks and objectives (Holopainen et al., 2020). It ideally supports kinesthetic learning – active learning which combines a hands-on approach and body movement. Based on this function, the cognitive VR classroom encourages students to actively get involved in the setting and to learn through touch, space, and motion by physically doing (Craig, 2003). Hence, students' learning outcomes might be increased by the development of creativity and collaboration with VR (Wu & Tai, 2016). This simulated multi-sensory visualization can provide high-definition (HD) virtual reality 3D environment, which is an effective method for classroom learning (Tsaramirsis et al., 2016).

5.2 Situated Learning with Immersive VR

Constructive knowledge and learning skills can be acquired by situated activities and interactions with objects exploration. Utilizing VR to construct situated learning facilitates students to critically develop their thinking (Li et al., 2015). For example, students learn terms while seeing the exact applicability from the materials, instead of mechanically memorising abstract facts which are isolated from the context (Chiou, 2020). The situated learning approach occurs in the context of the experience. The cognitive VR classroom embeds knowledge and skills in the context of real life, reflecting how knowledge is obtained and applied in daily life. The cognitive VR classroom integrates immersive environments from authentic content into the immersive setting. It also emphasises relationships and interactions between teachers and students to build trust, understanding, and constructive interactions. As a consequence, effective learning happens by making connections to the teacher, previous knowledge, and real life practice (Kurt, 2021).

5.3 VR for Interdisciplinary Learning

Although academia has devoted considerable resources to interdisciplinary studies in recent decades, the dynamics of interdisciplinary collaborations remain rather poorly understood by people from non-academic backgrounds (Siedlok & Hibbert, 2014). Subject barriers still exist between distant disciplines, such as between natural and social sciences. Technology drives innovation in many aspects and has a tight correlation among various disciplines. Immersive VR has an ever-growing potential to be valued as a potent way to transform approaches in which we learn and stimulate interdisciplinary communication (Leung et al., 2018). For example, abstract concepts can be embodied by VR to reduce students' cognitive load and simplify the amount of complicated materials. Image-based VR generates situated learning and visualizes texts into pictures and videos. With the support from visual technology, students may be able to transform complicated information from different subjects, and synthesize allied knowledge from a range of disciplines (Gisbert & Bullen, 2015). Ultimately, it could be formatted as a new approach for classroom learning to deliver inter-disciplinary knowledge to younger students, breaking through barriers between disciplines and enabling knowledge to be shared by younger and larger groups.

6 Correlation Analysis and Results

The cognitive VR classroom is built on educational concepts of interaction, collaboration, personalization, interdisciplinary learning, and neuroscientific inspiration. This conceptual learning design is an innovative model which combined texts, images, videos, audio, motion, and multisensory system. To examine its validity and adaptivity as a powerful theoretical framework for the smart classroom, we conduct a rating assessment for its six elements based on the smart classroom inventory ((SCI)) (Li et al., 2015). The four principles of SCI are 1) It is a learning environment based on technology support with a combination of both physical and virtual systems. 2) It provides rich learning materials, including constructive learning tools for a variety of teaching and learning activities. Also having support for active learning and interactive activities. 3) it should be able to collect and analyze massive data of students and optimize educational decisions. 4) It is an open learning environment to bring the students to can stimulate learning motivation, and creativity with authentic learning from real-life practices (Li et al., 2015). Following these principles, the research team use a 5-point Likert-type evaluation with anchors from totally not match (scored as 1) to totally match (scored as 5) (Table 1). Next, a correlation analysis is conducted by R studio to display relationships among the Pillars and the Cores (Fig. 5, and Fig. 6).

Table 1 Smart Classroom Inventory Assessment of the Cognitive VR Classroom

SCI	Pillar 1	Pillar 2	Pillar 3	Core 1	Core 2	Core 3
Principle 1	5	5	4	5	5	5
Principle 2	4	3	5	4	5	5
Principle 3	2	3	3	2	3	4
Principle 4	5	4	5	5	5	4

Note. SCI = Smart Classroom Inventory

Figure 5: Plot of Correlation Analysis in Numbers

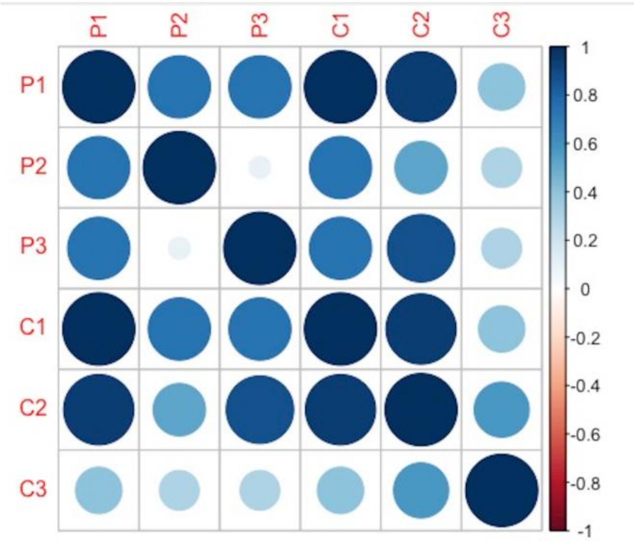

Figure 6 Visualization of Numerical Correlation Analysis

Note. P1= Pillar 1- Embodiment of abstract concepts, P2= Pillar 2 - Enhancement of cognitive competence, P3= Pillar 3 - Edutainment mechanism, C1= Core 1 - Multisensory stimulation, C2 =Core 2 - Situated learning, C3 = Core 3 - Interdisciplinary learning.

7 Conclusion

This study elaborates how VR can be used to facilitate education after the Covid-19 pandemic, suggesting that VR could be used as a powerful weapon to fit with a series of pedagogical concerns. In response to urgent educational adjustments and prospective challenges, we extended the BBL theory, the CAMIL model, and previous studies to generate an advanced learning design for future education – the cognitive VR classroom. It is a conceptual learning design for students to access a multi-sensory learning setting with interactive and entertaining devices and facilitate inter-disciplinary learning at the same time. This study intends to create an intelligent, integrated, and inter-disciplinary learning design to improve the present educational system. We utilize VR technology to create a novel theoretical model of the smart classroom and enable students to get into multi-functional learning and gain rich educational resources in a virtual learning environment. Also, we apply a Likert rating assessment of the six extended elements following the principles of SCI along with valid correlation analysis. As a consequence, results confirmed that there are co-effective associations among the Plillrs and Cores, which can strongly support the conceptual design. Therefore, we suggest that the cognitive VR classroom should be employed to develop prospective classroom learning after the pandemic era.

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