THE EFFECTIVENESS OF VIRTUAL REALITY CLASSROOM WITH DIFFERENT IMMERSIVE LEVELS ON LEARNING ACHIEVEMENT, COGNITIVE LOAD, AND SELF-EFFICACY AMONG STUDENTS WITH DIFFERENT SPATIAL ABILITY

WANG JIAWEI

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WANG JIAWEI

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF ACRONYMS

VR	Virtual Reality
VRC	Virtual Reality Classroom
IVR	Immersive Virtual Reality
LIL	Low Immersive Level
HIL	High Immersive Level
LSA	Low Spatial Ability
HSA	High Spatial Ability
CAMIL	Cognitive Affective Model of Immersive Learning
CLT	Cognitive Load Theory
ELT	Experiential Learning Theory
SET	Self-efficacy Theory
ATID	Alessi and Trollip Instructional Design
DMR	Design Marking Rubric
CLS	Cognitive Load Scales
GSE	The General Self-Efficacy Scale
SAT	Spatial Ability Test
ANOVA	Analysis of Variance
ANCOVA	Analysis of Covariance

LIST OF SYMBOLS

N	Sample size (full sample)
n	Sample size (sub-sample)
M	Mean
SD	Standard Deviation
SE	Standard Error
F	F statistic or F-value
df	Degree of freedom
KR20	Kuder-Richardson Formula 20
Partial $\eta 2$	A measure of effect size

LIST OF APPENDICES

KEBERKESANAN BILIK DARJAH REALITI MAYA DENGAN TAHAP IMERSIF BERBEZA TERHADAP PENCAPAIAN PEMBELAJARAN, BEBAN KOGNITIF, DAN EFIKASI KENDIRI DALAM KALANGAN PELAJAR DENGAN KEUPAYAAN SPATIAL BERBEZA

ABSTRAK

Dalam pendidikan tinggi di China, reka bentuk pembungkusan adalah salah satu daripada beberapa kursus yang melibatkan objek dua dimensi dan tiga dimensi, dan kebanyakan kolej reka bentuk telah menyenaraikan kursus ini sebagai subjek wajib bagi pelajar reka bentuk komunikasi visual. Tujuan kajian ini adalah untuk mereka bentuk dan membangunkan aplikasi bilik darjah realiti maya (VRC) bagi meneroka kesan dua persekitaran realiti maya dengan tahap imersif yang berbeza terhadap pencapaian pembelajaran, beban kognitif, dan keberkesanan diri pelajar yang mempunyai keupayaan ruang berbeza (HSA and LSA). Reka bentuk faktor kuasi-eksperimen 2 x 2 telah diambil dalam kajian ini. Pembolehubah bebas yang terlibat dalam pembelajaran kursus reka bentuk pembungkusan adalah dua tahap imersif VRC, iaitu tahap imersif tinggi (HIL) dan tahap imersif rendah (LIL). Keupayaan ruang pelajar digunakan sebagai pembolehubah moderator dalam kajian ini, manakala pembolehubah bersandar adalah pencapaian pembelajaran mereka, beban kognitif, dan keberkesanan diri. Sampel kajian ini ialah 124 pelajar dari empat kelas di universiti tertentu di selatan China, dan semua peserta dibahagikan kepada sama ada kumpulan eksperimen (HIL) atau kumpulan kawalan (LIL). Menggunakan skor pra-ujian pelajar ini sebagai parameter, analisis kovarians (ANCOVA) telah digunakan untuk menentukan sama ada terdapat perbezaan yang signifikan dalam pencapaian pembelajaran, beban kognitif, dan keberkesanan diri antara dua kumpulan pelajar. Analisis varians dua hala (ANOVA) telah digunakan untuk menentukan interaksi antara pembolehubah bebas, pembolehubah moderator, dan pembolehubah bersandar. Keputusan menunjukkan bahawa cara pelajar kumpulan eksperimen dalam pencapaian pembelajaran, beban kognitif, dan efikasi kendiri hampir lebih baik daripada kumpulan kawalan. Markah pelajar LSA dalam kumpulan eksperimen adalah lebih baik daripada markah kumpulan kawalan. Selain itu, kedua-dua aras rendaman yang berbeza (HIL dan LIL) tidak mempunyai interaksi yang signifikan dengan keupayaan spatial pelajar terhadap beban kognitif pelajar tetapi mempunyai interaksi yang signifikan terhadap pencapaian pembelajaran dan efikasi kendiri pelajar. Oleh itu, kajian ini berjaya membangunkan aplikasi dengan dua tahap rendaman, memberikan pandangan berharga untuk institusi pendidikan dan penyelidik dalam pelbagai disiplin yang berusaha mencipta bahan pembelajaran VR yang mengasyikkan untuk memenuhi keperluan pembelajaran pelajar.

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ABSTRACT

In Chinese higher education, packaging design is one of the few courses involving two-dimensional and three-dimensional objects, and most design colleges have listed it as a compulsory subject for students of visual communication design. The purpose of this study was to design and develop an virtual reality classroom (VRC) application to explore the effects of two virtual reality environments with different immersive levels on learning achievement, cognitive load, and self-efficacy of students with different spatial abilities (HSA and LSA). A 2 x 2 quasi-experimental factorial design was adopted in this study. The independent variables involved in learning the packaging design course were the two immersive levels of VRC, namely high immersion level (HIL) and low immersion level (LIL). The students' spatial ability was used as a moderator variable in the study, while the dependent variables were their learning achievement, cognitive load, and self-efficacy. The sample of this study was 124 students from four classes in a certain university in southern China, and all participants were divided into either an experimental group (HIL) or a control group (LIL). Using the pre-test scores of these students as parameters, analysis of covariance (ANCOVA) was used to determine whether there were significant differences in the learning achievement, cognitive load, and self-efficacy between the two groups of students. Two-way analysis of variance

(ANOVA) was used to determine the interaction of independent variables, moderator variables, and dependent variables. The results show that the means of experimental group students in learning achievement, cognitive load, and self-efficacy are almost better than those of the control group. The scores of LSA students in the experimental group are better than those of the control group. In addition, the two different immersion levels (HIL and LIL) had no significant interaction with students' spatial ability on students' cognitive load but had a significant interaction on students' learning achievement and self-efficacy. Therefore, this study successfully developed an application with two immersion levels, providing valuable insights for educational institutions and researchers in various disciplines who seek to create immersive VR learning materials to meet students' learning needs.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

The development and application of multimedia technology enable human society to feel the convenience it brings in all work and life. Over the past few decades, technological advancements have significantly influenced the realm of education and reshaped how learners learn and acquire knowledge (Wardynski, 2020). Different from conventional learning methods, the addition of technology may help enhance the learning atmosphere and bring a positive educational experience to learners (Raja & Nagasubramani, 2018). In the past few years, the application forms of multimedia technology represented by Virtual Reality (VR), Mixed Reality (MR), and Augmented Reality (AR) are increasingly used by educators engaged in higher education (Majchrzak et al., 2022; Du et al., 2022; Banjar et al., 2023). The purpose of these educators is to hope that these technologies could build new vitality for the current education industry, establish an appealing educational environment and new forms of learning materials for learners.

As a multimedia technology that has received much attention in recent years, this technology has made great progress in recent decades since the term "virtual reality" (VR) was first proposed in the 1960s (Godulla et al., 2021). During the early eras of VR, Milgram and Kishino (1994) pointed out that VR, Mixed Reality (MR), and Augmented Reality (AR) are not separate and ultimately opposed to each other but are part of the same underlying concept: the reality-virtual continuum. The reality-virtual continuum refers to the range from completely real (reality) to completely virtual environments (virtual) that people can observe when viewing the real world. The difference between AR and VR is that AR enhances real-world scenes, while VR creates an immersive virtual environment. VR technology creates a one-of-a-kind 3D virtual educational environment that strives to reproduce the appearance of things and physical phenomena in the real world (Kamińska et al., 2019). It also allows students to perform various learning activities in a virtual environment and provides a multi-sensory learning experience, which contributes to the improvement of learning achievement (Ott & Freina, 2015, Liu et al., 2021).

A recent study by Garca-López et al. (2021) determined that fully immersive, semi-immersive, and non-immersive are the three current types of VR. The least immersive and most affordable VR system is non-immersive VR, sometimes experience by computer or smartphone screen. This technology typically interacts with keyboards, mice, and monitors. Semi-immersive VR is characterized by a high degree of immersion with the ease of operation of desktop VR. Fully immersive virtual reality (IVR) is more expensive than the other two types, but unparalleled immersion is its most significant advantage, such as head-mounted display (HMD) and Cave Automatic Virtual Environment (CAVE). Currently, VR mainly assists users in creating visual effects throughout the immersive experience process via the HMD system, enabling participants to manipulate the controller (Zhang, 2017).

HMD is a tool that enables a fully immersive VR experience, and its system interacts with the virtual world through body motion tracking and objects (Concannon et al., 2019; Al-Jundi & Tanbour, 2022). Although both belong to immersive virtual reality (IVR), HMD has performance, preference, and usability advantages over CAVE regarding natural hand interaction (Molina et al., 2022). Throughout the 1980s and 1990s, a few visionaries built VR structures and the first virtual worlds began to emerge (Ambrosio et al., 2020). However, due to the lack of the immersive experience expected in the technological era at that time and the arrival of the Internet era, the VR industry briefly disappeared in the 1990s (Timothy, 2021). It is worth noting that IVR has limits and drawbacks in the classroom, particularly technical complexity and expensive equipment costs, discouraging most educational institutions and businesses from using it (Häfner, 2020; Cook et al., 2019). Some recent research by Ventola (2019) and Çoban et al. (2022) shows that the current cost of VR hardware decreases with technological innovation, which undoubtedly accelerates the speed of VR popularization. It could be found that the application of VR in many different fields of education, especially the trend of application in higher education, is constantly improving.

In recent years, many researchers around the world have emphasized the need to develop art education, especially in design-related majors that try to incorporate different emerging technologies to provide learners with better learning materials (Mohamed & Sicklinger, 2022; Ye & Li, 2022; Guerra-Tamez, 2023). However, most chinese art teachers still use oral narratives to explain the content of books when instructing students in design-related courses, which is a prevalent conventional teaching method. Due to constraints in learning settings, art students need to complete practice in a design studio or painting studio. The application effect of multimedia technology in art education is not outstanding, and it is required to employ multimedia technology with other technologies in an integrated strategy (Liu et al., 2021). VR in classrooms has been effectively adopted in different disciplines for many years to bring advantages to students in their learning journey (McGovern et al., 2020; Young et al., 2020; Lee et al., 2022). The rising scholarly output on this issue worldwide demonstrates a strong interest in expanding the application of VR in art education, especially in higher education (González-Zamar & Abad-Segura, 2020). Furthermore, as the usage of mobile devices in education has grown, current technology advancements have progressively begun to cater to learners with interactive demands.

Furthermore, the advantage of the user wearing an HMD is that the teacher may immerse the students in the lesson without interruption. Students wearing the HMD put in more effort in these lessons because they take more interest in the situation (Makransky & Mayer, 2022). The VRC application blends virtual animation and virtual space to externalize abstract concepts and provide users with a highly open, dynamic, and immersive 3D learning experience (Dong, 2016). This means incorporating IVR technology into the design-related education process might enable students to engage with the 3D virtual scene while increasing efficiency. Nguyen et al. (2018) also noted that Desktop VR's practicality and ease of use make it easy for learners to accept, allowing people to create immersive and interactive VR applications, including users with no programming experience.

Moreover, this study investigates the relationship between VRC and users' spatial abilities, focusing on the differences between learners with different spatial abilities when manipulated at two different immersion levels. According to Desme et al. (2024), spatial ability refers to an individual's ability to process and mentally manipulate spatial relationships between objects or within an environment, and it includes cognitive processes such as mental rotation, spatial visualization, and spatial orientation. This ability is essential for understanding geometric relationships, interpreting visual spatial representations, and when tasks require reasoning about three-dimensional space. There are currently many studies showing positive results in immersive virtual reality (IVR) and its relationship to spatial abilities, such as Obeid and Demirkan (2020), De Back et al. (2020), Li et al. (2020). It is worth noting that while spatial ability should be regarded as fundamental in design-based fields, its importance is not always recognized or given the attention it needs. (Williams & Sutton, 2011).

While VRC as a learning environment has been proven to benefit the learning process in other educational fields, its application in visual communication design majors in China is still in its infancy. Therefore, the researcher thought it would make sense to develop a VRC application that could provide different levels of immersion. The objectives of this research on the VRC application is to combine design content with painting to create a learning environment that is interactive, reduces cognitive load, improves self-efficacy and learning achievement for students.

1.2 Background of study

At the start of China's educational growth, the aim was to promote exam-oriented education, which prevented the Chinese government from training too many qualified teachers to teach painting, design, sculpture, and other art majors (Liu et al., 2022). This refers to the fact that the education system that focuses on students' academic performance during examinations has caused most people to ignore the importance of developing art education. Furthermore, the government does not provide enough funds and opportunities for art-loving scholars to study art education in depth. A recent study by Zhao et al. (2020) proposed that based on China's national conditions and the development of art education in the past few decades, the public should correctly understand the gap between the concept of art education and Western countries and improve the current shortcomings.

Since the 1980s, 90% of design degrees at Chinese colleges have been divided into four groups: visual communication design, environmental design, industrial design, and fashion design (Liu and Kah, 2020). According to the latest announcement the Ministry of Education, design was promoted to a first-level discipline in 2012, and design was identified as a discipline with disciplinary characteristics in 2013 (Ministry of Education, 2019). Different from other majors, visual communication design, as a major reformed from Western graphic design, started relatively late in China (Bian & Ji, 2021). In China's higher education, it is common for this major to have courses consisting of font design, packaging design, poster design, and illustration design. With the rapid development of the national economy and the market beginning to pay attention to visual experience, the demand for skilled visual communication design talents has grown significantly (Liu & Liu, 2016). In order to meet this demand, the field of visual communication design needs to adapt to this demand and provide learners with more comprehensive teaching content and more advanced facilities to meet the expectations of the industry.

Currently, chinese contemporary design education is still based on classroom and studio learning in most universities and colleges, aiming to provide students with professional theoretical knowledge and design practice (Halverson & Sawyer, 2022). However, the technological revolution and industrial transformation in recent years have brought new challenges to the conventional studio learning model. As emerging technologies and evolving industry demands reshape the design landscape, conventional learning tools are gradually unable to meet learners' needs for design software and hardware (Lin & Tu, 2021). Moreover, Meyer & Norman (2020) were worried about the failure of design education to keep up with the new requirements of the 21st century and proposed the expansion of learning materials and learning methods that existing design schools need. It is worth noting that students majoring in visual communication design in the School of Fine Arts and Design are required to complete the packaging design course, which is an interdisciplinary, comprehensive course involving 3D composition. Although this course will also appear in industrial design classes, a large number of teaching tasks in this major focus on the design and development of products and models to make it easy for learners to understand. The core content of visual communication design is mainly for learners to complete the appearance design of product packaging, which means that while completing the appearance design, they also need to understand the structure of the product. However, the current teaching model of this course is single and lacks practical links, which often makes many students find the knowledge points difficult to understand and sometimes distracted (Feng, 2023; Yang, 2023).

Correspondingly, lecturers in art and design colleges urgently need to take specific measures to enable learners to reduce cognitive load in the learning process, improve self-efficacy and learning achievements in the design process. A recent study by Liu et al. (2021) states that most conventional innovative thinking education focuses on non-interactive media, such as theoretical exploration of design concepts, manual sketches, and established design methods. While the educational methods of human-computer interactive media may stimulate designers' innovative spirit, innovative thinking, and design skills. It is essential in packaging design courses to provide students with a learning environment that stimulates their design thinking and cognitive skills in the process of understanding design concepts (Yang & Hsu, 2020). The improvement of design thinking and cognition can help learners improve their self-efficacy in completing design tasks and reduce unnecessary cognitive load. Therefore, higher education workers and some researchers have begun to recommend and apply emerging multimedia technologies in recent year, including VR technology.

Multimedia technology, as a visual symbol communication medium, provides a communication platform for modern design and serves as an information transmission medium in the training process of visual communication design (Zhang & Zhao, 2023). Multimedia technology may enhance the learning material and improve the learning style for visual communication majors. Mai (2019) pointed out that the use of multimedia-assisted teaching in current chinese design-related learning has become one of the crucial directions for expanding university art learning resources. Moreover, VR, as a representative of emerging multimedia technology, usually accesses materials through desktop computers, HMDs, or automated virtual environments in caves. It is worth noting that the processes by which learners learn and teachers teach are constantly changing, as are space and time (Sharma et al., 2013). Virtual classrooms may provide a platform for the education field to provide students with memorable and immersive experiences in the classroom through VR technology. VR is available to each student and might be easily monitored by the teacher. In addition, students are engaged and motivated in novel and strong ways by virtual experiences. Learners' sense of on-site experience and dynamism is a psychological structure generated through immersion and interaction. The IVR tracks the user's head and movement position and is able to render different images to create visual cues for depth perception (Makransky & Petersen, 2021). Ruan (2020) explained that in chinese art and design classrooms may significantly improve students' artistic ability and design efficiency with the support of VR.

Self-efficacy is generally defined as an individual's belief in their ability to organize and execute the actions necessary to achieve specific goals (Bandura, 1997). This belief influences how people face challenges and the level of effort they exert when completing tasks. It is worth noting that visual communication design students are usually expected to regularly convey their ideas and design thinking to a variety of audiences. Because student self-efficacy is regarded as context-specific and influences learning achievement, it is crucial to consider self-efficacy (Gaffney, 2011; Doménech-Betoret et al., 2017). A recent study by Binhajib et al. (2022) believes that educators need to think about how new technologies may impact students' self-efficacy and the planning of lessons while attempting to introduce them. According to the basic concepts of cognitive load theory, learners' ability to learn effectively is significantly influenced by the demands that educational topics make on their memory and ability to learn (Bai, 2021). Gao and Kuang (2022) suggested that students studying art and design have faced challenges in accessing knowledge due to practices of hoarding or withholding information in certain learning environments. Thus, analyzing the impact of cognitive factors in art and design virtual education environments is crucial.

At the same time, it is hard to ignore that spatial ability is one of the most important abilities for each learner engaged in design majors, especially in courses involving 3D composition. The set of cognitive functions and abilities that play an important role in manipulating and processing visual-spatial information is called spatial abilities (Castro-Alonso & Atit, 2019). Buckley et al. (2018) also elaborated that spatial ability could be defined as the ability to perform the following tasks: mental rotation of objects, understanding how objects appear at different angles, and how objects relate to each other in space. This means that spatial abilities potentially help learners identify and create 3D images, shapes and spaces. The difference in spatial ability also indirectly affects whether they can successfully convert 2D or 3D spatial information, and learners with higher spatial skills have an easier time learning using visual images (Cho, 2017; Jelatu et al., 2018). In order to better explore learners' performance and their own status in completing design tasks, it is also necessary to examine the impact of spatial ability. It is worth noting that recent advances in VR technology have enabled it to be integrated into each aspect involving spatial components and relationships in the field of spatial design (Cho & Suh, 2023). In addition, researchers have also demonstrated that learners with different spatial ability levels perform differently when using different VR modes. For example, people with strong spatial abilities may perform well in fully immersive VR environments that require complex spatial reasoning, while people with poor spatial abilities may benefit more from non-immersive or semi-immersive VR experiences (Lee & Wong, 2014; Sun et al., 2019).

Therefore, a virtual reality classroom (VRC) application was designed and developed for this study to investigate the effects of students with different spatial abilities learning a packaging design course in a VRC application with different immersion levels. There will be high and low immersion level experiences in the VRC application with a HMD and desktop VR experience for learners. It has contributed value in boosting students' learning achievement, cognitive load, and self-efficacy in visual communication design major.

1.3 Preliminary Study

According to Smith et al. (2015), conducting a preliminary study is an essential step before developing a pilot study or collecting data, as it helps refine the research design, identify potential challenges, and ensure the feasibility of the trial. The preliminary research for this study was undertaken in four stages to gather information about the Packaging Design course in Visual Communication Design major from the perspective of students and lecturers of the School of Fine Arts and Design in a certain university in China. The first phase for the researcher to review the results of the final project with the help of the lecturer to understand the performance of visual communication design students in packaging design courses. In addition, this preliminary study obtained some opinions of several lecturers on the current teaching of packaging design through interviews. Subsequently, 35 randomly selected students who had completed registration in October 2022 received questionnaires and pre-test on using VR equipment for packaging design. None of these students had any relevant experience in operating VR. Table 1.1 describes the preliminary study process and the goal of each preliminary investigation stage. Appendix A contains all of the results from this section.

Table 1. 1 The Method and Purpose of the Four Phases of Preliminary Study

Phase	Method	Purpose
1	Analysis of final project results	To determine student achievement levels in Packaging Design courses from School of Fine Arts and Design data.
2	Interview with six lecturers or professors	To identify the issues or problems related to Packaging Design course in current visual communication design major learning from the perspective of lecturers.
3	Questionnaire for students (six questions)	To find the issues or problems related to Packaging Design courses in current visual communication design major learning from the student perspective.
4	Pre-testing with VR device	To measure student feedback after trying out sketches with VR application (Gravity Sketch) by HMD and Web version.

The results of the first-semester Packaging Design of students majoring in visual communication design at the School of Fine Arts and Design were first checked in a preliminary study. According to China's academic grading system (Chinaeducation, 2023), students' grades could be divided into four levels on a percentile scale: Level A (85-100%), Level B (75-84%), Level C (60-74%) and Level D (0-59%) . The four levels are excellent, good, average ,pass, and fail. In order to achieve good result in China, students need to score at least level C (75%) and above in the assessment (Chinaeducation, 2023). However, based on the final project scores of the two classes studying packaging design provided by the lecturer, the researcher found that the average scores of the 60 students in the two classes were below 75 points, and both were in the C grade (60-74%). This indicates that most students struggled to achieve higher performance levels in the packaging design course. It is worth noting that only 16 students (27%) achieved level B (75-84%) or higher, which reflects the huge differences in students' grades. After interviewing six lecturers and professors, the survey results show that the current learners' learning efficiency is not ideal. Educators believe that this is due to the difficulty of conventional teaching methods to work effectively, in which verbally described knowledge (such as design principles and theoretical explanations) is often difficult for students to visualize complex spatial layouts without additional visual or interactive support during the design process. Meanwhile, Packaging Design is the course where most students get low marks. They believe that it is feasible to use more interactive learning tools to solve the problems students encounter in the learning process.

Furthermore, the results of the questionnaire show that some students find it challenging to learn Packaging Design courses. Current course and learning materials and tools lack interactivity and are sometimes difficult to use and maintain concentration. When asked about their preferences, students expressed a desire for tools and materials that provide a more engaging and interactive experience, which they believe will improve their efficiency in completing design tasks. Moreover, in order to understand these students' acceptance of VR technology, the researcher randomly selected 5 students to experience the painting function of the Gravity Sketch (VR application) on different VR devices for 5 minutes. From the pre-test results of students using VR devices (HMD and Desktop) to design, it can be found that learners are interested in new design methods based on VR and are excited about using new technologies.

In summary, based on the results of the four phases of the preliminary study, it can be found that the current learning achievement of most students has not yet reached a good level. In addition, interviews with lecturers and answers to student questionnaires showed low learning achievement among most students in Packaging Design courses. The conventional teaching tools and materials currently used make them inefficient in completing design tasks. It is worth noting that the introduction and application of VR have been encouraged by lecturers and the pre-test also has a positive impact on these students who have never been exposed to this technology.

1.4 Problem Statement

Packaging Design is a required course for visual communication design majors in Chinese universities, and learners need to complete all basic design courses in the first year of university before they can study it in the second year. As an advanced course, this course involves the design of product packaging and the design of product 3D models (Liu et al., 2022). Currently, in packaging design courses, students in Chinese universities still rely on lecturers to verbally explain slides or books when acquiring design techniques and case content. This way of learning will lead to a lack of interaction among students and limit their imagination of the learning content, resulting in low learning efficiency and low learning achievement (Sajnani et al., 2020; Chen et al., 2021). With the development of the times, learning materials needs to be constantly innovated, and art and design education should constantly seek new forms of expression brought by new technologies (Jia et al., 2017). Using new technologies will make students gradually feel more artistic investment and inspiration, showing interest in artistic creation and a desire to explore (Sun et al., 2022). Therefore, integrating multimedia technology with other new technologies is crucial to improving the current learning materials and environment in packaging design courses.

Studies by Wang & Liu (2021) and Venkatesh & Ma (2021) successfully validated that an immersive learning environment with interactive elements is essential for art and design students. In the past few years, researchers have tried to integrate emerging technologies such as AR and VR into art and design classrooms to provide students with new learning materials and learning experiences. It is worth noting that the advantages of AR technology in art education are often reflected in its ability to enhance the effect of traditional learning materials and enrich the content of artworks. For example, 2D graphics on books can be projected into 3D models and provide learners with a smoother art navigation experience (Chang et al., 2019; Yip et al., 2019). However, this approach may not be directly applicable to packaging design courses, which require students to focus on more complex design tasks, such as creating functional packaging solutions and considering different material properties for design.

In contrast, the immersive technology provided by VR helps increase students' interactive experience with things in the virtual environment and improve their cognitive abilities (Han, 2023). Students will have more opportunities to explore the learning environment and complete design tasks on their own during most of the time in the virtual environment. At the same time, the use of VR in the classroom has brought something new to the education industry and is leading to better acceptance in many disciplines (Radianti et al., 2020; Dick, 2021; Madden et al., 2020). As an emerging technology, VR also makes it easier for lecturers to detect changes in students' emotional expressions and that students will show high engagement when using it for the first time (Phoon et al., 2021).

It is important to note that exposure to poorly structured instructional material in the classroom may lead to distraction and additional load (Castro-Alonso et al., 2021). This means that some of the texts included in the learning materials may need to be integrated with prior knowledge, which can easily lead to additional cognitive load for students with little prior knowledge or limited expertise and further hinder their ability to effectively process and understand the content. In designing VRC, one of the challenges for the researcher is to control the external cognitive load to the lowest level and increase the internal cognitive load to the most beneficial level for students. This may include considering simplifying interfaces and operations during the design process, providing clear instructions, gradually introducing complexity, encouraging users to actively participate and solve problems in the VR environment, and minimizing unnecessary distractions in the VR environment. In addition, students who have low spatial ability may be unable to imagine some actual events due to some low cognitive load (Sun et al., 2019). Since the ability to mentally navigate and manipulate 3D space is essential in a VR environment. Therefore, it is necessary to adjust VR devices and provide different VR learning environments to accommodate students' different spatial abilities.

Additionally, self-efficacy is also one of the problems that learners often face in the learning process and it plays an important role in art education in China (Jin & Yuan, 2022). Since design students need to regularly communicate their ideas to diverse audiences, their self-efficacy is closely related to the learning environment and learning materials in the design studio. Bandura (1977) believes that students with high self-efficacy will show greater interest when faced with difficult tasks and will recover quickly from emotional disappointment. People with weak self-efficacy will choose to avoid tasks and are unable to concentrate because of the difficulty of the task. Therefore, it is also necessary for VRC designers to consider improving learners' self-efficacy. Providing a good learning environment and learning materials may help learners better communicate their design ideas and increase their self-efficacy.

Moreover, the concept of students learning in VRC has not been discussed and applied much in visual communication design-related majors in Chinese universities. Currently, some types of immersive VR that are frequently used for experimentation and development in higher education include high-immersion VR (HMD) and low-immersion VR (desktop) (Radianti et al., 2020). The findings from preliminary research also clearly shows that the average learning achievement of students in two classes at School of Art and Design in Packaging Design courses only reached Level C. This means that these students face great challenges in mastering the core concepts about product 3D modeling in the packaging design course, which is a fundamental aspect of the packaging design course. This difficulty may come from the complexity of 3D modeling, which requires strong spatial reasoning and technical ability. It could also be seen from the viewpoints of several School of Fine Arts and Design lecturers and professors who were interviewed that they agree with this. Therefore, the researcher hopes to design and develop a VRC application for the Packaging Design course by providing two immersive levels for students with different spatial abilities. In this study, learning achievement, cognitive load, and self-efficacy are the variables that investigate the effectiveness of students experiencing VRC in two immersive levels.

1.5 Research Objectives

This study aims to establish a compelling virtual reality classroom (VRC) for packaging design through an immersive learning environment (ILE) on students learning achievement, cognitive load, and self-efficacy. The objectives must be clearly outlined to achieve the study's principal goal. The objectives of this study are:

i. To design and develop a Virtual Reality Classroom (VRC) application with different immersive levels for students with different spatial abilities to learn packaging design.

ii. To investigate the effects of using VRC application with a high immersive level (HIL) and low immersive level (LIL) in learning packaging design on the learning achievement of students with different spatial abilities.

iii. To investigate the effects of using VRC application with HIL and LIL in learning packaging design on the cognitive load of students with different spatial abilities.

iv. To investigate the effects of using VRC application with HIL and LIL in learning packaging design on the self-efficacy of students with different spatial abilities.

v. To investigate the interaction effects of VR immersive levels and spatial abilities on students' learning achievement, cognitive load, and self-efficacy.

1.6 Research Questions

The following research questions have been investigated in this study:

i. What are the effects of using Virtual Reality Classroom (VRC) with a high immersive level (HIL) and low immersive level (LIL) on students' learning achievement in learning packaging design with different spatial abilities?

(a). Is there any significant difference in students' learning achievement when utilizing VRC application with High immersive level (HIL) compared to Low immersive level (LIL)?

(b). Is there any significant difference in students' learning achievement when utilizing VRC application with HIL compared to LIL among the high spatial ability (HSA) students?

(c). Is there any significant difference in students' learning achievement when utilizing VRC application with HIL compared to LIL among the low spatial ability (LSA) students?

ii. What are the effects of using VRC with HIL and LIL on students' cognitive load in learning packaging design with different spatial abilities?

(a). Is there any significant difference in students' cognitive load when utilizing Virtual Reality Classroom (VRC) with High immersive level (HIL) compared to Low immersive level (LIL)?

(b). Is there any significant difference in students' cognitive load when utilizing VRC with HIL compared to LIL among the HSA students?

(c). Is there any significant difference in students' cognitive load when utilizing VRC with HIL compared to LIL among the LSA students?

iii. What are the effects of using VRC with HIL and LIL on students' self-efficacy in learning packaging design with different spatial abilities?

(a). Is there any significant difference in students' self-efficacy when utilizing Virtual Reality Classroom (VRC) with High immersive level (HIL) compared to Low immersive level (LIL)?

(b). Is there any significant difference in students' self-efficacy when utilizing VRC with HIL compared to LIL among the HSA students?

(c). Is there any significant difference in students' self-efficacy when utilizing VRC with HIL compared to LIL among the LSA students?

iv. What are the interaction effects of VR immersive levels and spatial abilities on students' learning achievement, cognitive load, and self-efficacy?

(a). Is there any interaction effects among VRC with two different immersive levels (HIL and LIL) and students' spatial ability on students' learning achievement?

(b). Is there any interaction effects among VRC with two different immersive levels (HIL and LIL) and students' spatial ability on students' cognitive load?

(c). Is there any interaction effects among VRC with two different immersive levels (HIL and LIL) and students' spatial ability on students' self-efficacy?

1.7 Research Hypothesis

The following hypotheses were formulated from the above research questions.

The probability level of 0.05 will be used to test for statistical significance.

HO.A.1: There is no statistically significant difference in students' learning achievement when employing Virtual Reality Classroom (VRC) with High immersive level (HIL) compared to Low immersive level (LIL).

$H_{O.A.2}$: There is no statistically significant difference in students' learning achievement when employing VRC with HIL compared to LIL between the HSA students.

$H_{O.A.3}$: There is no statistically significant difference in students' learning achievement when employing VRC with HIL compared to LIL between the LSA students.

$H_{O.B.1}$: There is no statistically significant difference in students' cognitive load when employing Virtual Reality Classroom (VRC) with High immersive level (HIL) compared to Low immersive level (LIL).

$H_{O.B.2}$: There is no statistically significant difference in students' cognitive load when employing VRC with HIL compared to LIL among the HSA students.

$H_{O.B.3}$: There is no statistically significant difference in students' cognitive load when employing VRC with HIL compared to LIL among the LSA students.

$H_{O.C.1}$: There is no statistically significant difference in students' self-efficacy when employing Virtual Reality Classroom (VRC) with High immersive level (HIL) compared to Low immersive level (LIL).

$H_{O.C.2}$: There is no statistically significant difference in students' self-efficacy when employing VRC with HIL compared to LIL among the HSA students.

$H_{O.C.3}$: There is no statistically significant difference in students' self-efficacy when employing VRC with HIL compared to LIL among the LSA students.

HO.D.1: There is no significant interaction effect among VRC with two different immersive levels (HIL and LIL) and students' spatial ability on students' learning achievement.

HO.D.2: There is no significant interaction effect among VRC with two different immersive levels (HIL and LIL) and students' spatial ability on students' cognitive load.

HO.D.3: There is no significant interaction effect among VRC with two different immersive levels (HIL and LIL) and students' spatial ability on students' self-efficacy.

1.8 Theoretical Framework

This theoretical framework displayed the theories and models used for this study. A theoretical framework is a crucial component of a research study as it provides a conceptual foundation for understanding and interpreting the research problem. The three theories used in the process of developing learning materials are experiential learning theory, cognitive load theory, and self-efficacy theory. The Cognitive Affective Model of Immersive Learning is used for the develop of the VRC application and Alessi and Trollip's Instructional Design Model is used for instructional design. Figure 1.1 showed the theoretical framework of this study.

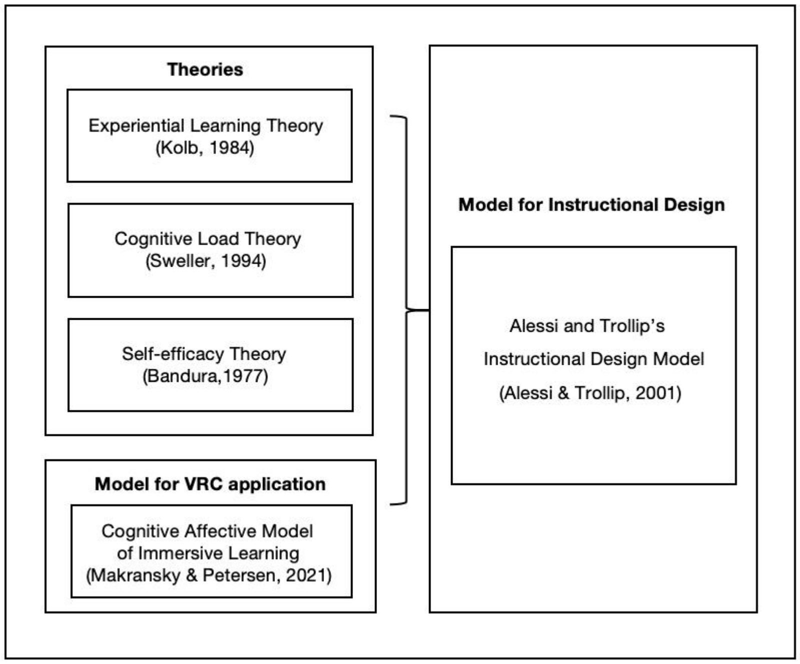

Figure 1.1 The Theoretical Framework

1.8.1 Cognitive Affective Model of Immersive Learning

CAMIL was used in this theoretical framework as a model to describe the learning process of learners using IVR. Interest, motivation, self-efficacy, embodiment, cognitive load, and self-regulation are the six affective and cognitive factors that the model mainly describes IVR-based learning outcomes (Makransky & Petersen, 2021). The model emphasizes on enabling learners to learn in a virtual environment with a greater sense of presence and agency by leveraging the immersive nature of IVR. CAMIL was used to develop the VRC application because it enhances learner learning through a pedagogical approach that enriches learning with a higher presence or agency.

1.8.2 Alessi and Trollip's Instructional Design Model

The Instructional Design Model proposed by Alessi and Trollip (2001) is driven by the principles of cognitive psychology and is divided into three stages: Planning, Design, and Development. Unlike the conventional education method from the perspective of learning content, this model will consider learning more from the learners' perspective. Facilitating learner learning includes presenting information, providing learners with instructions and exercises, and assessing learning after completion. The application of this model may guide the process of developing the virtual reality classroom.

1.8.3 Experiential Learning Theory

The theory concerns learning from experience, in which knowledge is created through experience transformation. According to Kolb (1984), acquiring abstract concepts is required in the learning process and could be flexibly applied in different situations. The theory proposes that learning needs to go through a four-stage cycle that is followed. The researcher will follow the four stages of learning proposed by this theory in the instructional design process of this study, including providing participants with real and direct experience learning activities, providing reflection on their own experience, providing some knowledge frameworks, models or theories, and designing relevant learning activities for participants.

1.8.4 Cognitive Load Theory

In 1988, John Sweller pioneered the cognitive load theory. Since everyone's working memory has a limited cognitive capacity, requiring too much capacity in the learning process would hinder progress. The argument for this idea is that enhancing the