Learning Design Thinking Online: Studying Students' Learning Experience in Shared Virtual Reality

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Declaration

This doctoral study was conducted under the supervision of Dr. Pam Meecham and Dr. Nicholas Addison.

I hereby declare that, except where explicit attribution is made, the work presented in this thesis is entirely my own. This work has not been submitted for any other degree or award in any other university or educational establishment.

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Kung Wong, LAU

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Abstract

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My study attempts to deepen understanding about the learning experiences of design students in undertaking design-thinking exercises in a shared virtual reality. This study has identified the areas of an appropriate pedagogy for E-Learning and the use of a shared virtual environment for students in tertiary design education. Specific questions arising from this research are: (1) in what ways can the virtual environment release the creative potential of design students? (2) how does the virtual space affect the students' learning experience? and (3) what is the role of computer and virtual technology in design education? I started with the premise that virtual technologies, particularly shared virtual reality, have potential to enhance design students' learning experiences during their creative thinking processes. TWO directional hypotheses in the areas of computer-simulated learning environments and collaborative learning were introduced for the multimodal interaction research in Phase FOUR and the post-lesson online interviews in Phase FIVE. Multimodal interaction analysis, conversation analysis and textual analysis were employed to analyze diverse data from different phases. In addition, a tailor-made shared virtual reality was established in ActiveWorld ©for the multimodal interaction research. Surprisingly, the preset two directional hypotheses were not fully supported by the findings, whereas THREE new study domains which have been found useful in enhancing design students' creative thinking, namely (1) stimulated virtual environment, (2) game-like learning approach and (3) role-playing simulation. Similarly, this research found that design students learning experiences are enhanced by virtual stimulation, game-like learning and role-playing practices.

Keywords

(1) Design Thinking and Creativity; (2) Virtual Stimulation; (3) Shared Virtual Reality; and (4) Game-like Learning Environment

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Chapter ONE: Background of the Study

My name is Kung-wong (Robert) LAU, and I am an assistant professor in visual communication at the School of Design (SD) at The Hong Kong Polytechnic University (HKPolyU). I am interested in developing design students' creativity, particularly with the assistance of Information and Communication Technology (ICT) and virtual platforms. I have been teaching the design module called "SD 2000 Design Thinking" in SD. SD 2000 is a foundation module for all design students who are studying visual communication, advertising, industrial and product design, and environmental and interior designs. This module aims at releasing design students' creative potential and removing their unhelpful pre-conceptions. Since HKPolyU, with SD, is the only university in Hong Kong that offers University Grants Committee (UGC) funded undergraduate programmes in higher design education, every local undergraduate design student has to take this fundamental module first, studying his or her own professional design domains in subsequent years.

In this study, my research area was concerned with enhancing students' thinking skills while engaging in learning about design in virtual environments. Specifically the topic is "Studying students' learning experience in a shared virtual reality". Obviously, the learning experiences that students have while engaging in virtual reality constitute the major part of the study. However, there are a number of core questions to be answered before actually studying students' virtual learning experiences. These include the pedagogical planning of the learning environment, the students' expectations of learning environments and the methods being used to assess creativity. These questions are important because *learning* is a complex process. Students learn in different ways, particularly in virtual environments which I believe promote a high degree of interactivity and autonomy in learning. Therefore, the learning process cannot simply be automated, it is necessary to integrate, and to create the right balance of, pedagogy, technology and innovation (Liu, et al, 2002).

To date, while there has been a considerable amount of virtual learning experience research addressing the areas of primary, secondary, and higher education, and in training (e.g. Pantelidis, 1993; Thurman and Mattoon, 1994; Lochlan, 1997; Gaggioli, 2001; Mantovani, 2001; Dirckinck-Holmfeld, 2002; Stott, 2007), there has been very little that has focused on design education, especially the thinking skills used in the design process. Studies of the use of computer simulations to enhance design students' learning experiences are virtually non-existent. In other words, the value of virtual reality as a learning tool for enhancing design students' creativity has not been substantiated by research. Therefore, this study attempts to deepen the understanding of the learning experiences of design students as they undertake design-thinking exercises in a shared virtual reality.

In the existing research about the application of virtual reality in education and training, much of the focus has been on using computer simulations in virtual reality as the main tool to assist learning and teaching (e.g. Winn, 1993; Lochlan, 1997;

Goldberg and Knerr, 1997; Standsfield, Shawver and Sobel, 1998; Johnson, et al, 1998; Roussos, et al, 1999; Gaggioli, 2001; Stott, 2007). There have also been claims that it is important to create a constructive and collaborative learning community in virtual reality in order to enhance students' learning experiences (e.g. Baym, 1995; Jones, 1995; Cherny, 1999; Jonassen, 1999; Kendall, 2002; Herring, 2004). Therefore, these two directions have been chosen as the initial focus in investigating design students' learning experiences in virtual reality in this study.

As mentioned above, there are some important questions to be answered before studying students' virtual learning experience in virtual reality. The FIVE major questions to be addressed are;

(1) Why do design educators need to use virtual learning environments for design education in Hong Kong, particularly in teaching and learning about design thinking?

(2) What are the design students' expectations of a creative learning environment for undertaking creative exercises? In particular, what do they expect of a computer-simulated creative learning environment?

(3) What is the definition of creativity in design education and how can design students' creativity or creative performances be measured?

(4) How can appropriate learning activities for creative thinking be arranged within a virtual learning environment?

(5) What are the major advantages and disadvantages of using a shared virtual reality in design education?

In this study, Chapters ONE to FIVE have addressed these five questions in order to provide a theoretical framework for the main study of design students' virtual learning experiences. Chapters SIX and SEVEN present analyses of the learning experiences of tertiary design students in Hong Kong working in a shared virtual reality. These chapters also provide a critical exploration of factors that affect the actual implementation of E-Learning in design education.

From the discussion of various studies of students' learning experiences in virtual reality, presented in Chapters FOUR and FIVE, TWO potential aspects of virtual reality can be identified, namely (1) hyperrealistic simulation in virtual reality; and (2) virtual communities for collaborative learning. Various researchers believe that these two aspects can be utilized to enhance students' learning experience through virtual reality (e.g. Beck, 1979; Pollard, 1990; Pantelidis, 1993; Mantovani, 2001; Dirckinck-Holmfeld, 2002; Green and Bavelier, 2003; Blascovich and Bailenson, 2006; Stoerger, 2008). This belief has given rise to the formulation of TWO directional hypotheses underpinning the design of a shared virtual reality. They are;

H 1 – Establishing a computer-simulated learning environment is a factor for developing students' design thinking skills.

H2 – Constructing a virtual community for hyperlearning is important in establishing collaborative learning among design students engaged in design thinking.

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Surprisingly, these TWO directional hypotheses have not been fully supported in my study. The findings showed that these two directional hypotheses were not the crucial factors for enhancing students' learning experience in virtual reality in this specific research. For the first hypothesis, according to my findings (See Chapter SEVEN), it appears that the most important effect of using a shared virtual reality in teaching and learning design thinking skills is not about creating computer simulations that enable students to tackle real-world situations, but rather about creating unusual environmental stimulations to motivate them to explore new ideas. Furthermore, hyperrealistic and game-like environments can help design students to develop learning behaviors in design thinking that are conducive to creativity. This happens because these environments make the learning process fun for the students and this appears to be more stimulating to creative thinking than the provision of simulated real-world situations. Indeed, students do not need real-world simulation in design thinking since there is no "typical" situation that can be simulated in the design profession. Therefore, design educators should concentrate on creating *virtual stimulations* in their learning environments instead of creating *real-world simulations*.

For the second hypothesis, the findings of this study (See Chapter SEVEN) suggest that it is very difficult to construct a virtual learning community for design students. This is not because of the core issue of promoting a constructivist learning approach, but rather comes down to the basic communication methods in a virtual learning environment, since an effective learning community needs strong communication channels among students. This does not mean only text-based chat or simple emotional displays. These default communication functions in existing immersive virtual platforms are far from being enough to replace face-to-face communication, especially for discussing abstract concepts and idea exploration in design education. Furthermore, because of the inadequacy of communication support, group size also becomes a great problem in the actual implementation.

Nonetheless, although the said TWO directional hypotheses have not been fully supported by my research findings, THREE new directional areas have been found. They are **D1 - Creating environmental stimulation to facilitate design students' creative thinking; D2 - Developing a game-like virtual learning environment to enhance design students' learning experience; and D3 - Using avatars as role-playing simulation to develop design students' creative-friendly learning behavior.** These THREE new directional areas are the main contributions of this research to knowledge for triggering further studies in the areas of virtual creativity training and virtual learning experiences for design education.

Based on the above findings, I am able to argue the following in relation to design students' learning experiences in shared virtual reality:

(1) their learning experiences were stimulated by virtual environments;

(2) they obtained a game-like virtual learning experience; and

(3) they had a creative-friendly learning experience through the role-playing simulation by using avatars.

In view of the structure of this thesis, this first chapter will provide readers with the background to the study by (1) reviewing the foundation creativity training module SD 2000 and its challenges under globalization, as well as the problems I have discovered in conducting SD 2000 using conventional pedagogy without computer assistance; (2) discussing the importance of establishing a creative-friendly space for design thinking and identifying the factors of developing a heuristic shared space for design students within the virtual platform; (3) probing the major components of developing design students' creative-friendly learning behaviors and the ways in which the virtual platform can help; and (4) evaluating the existing ICT development in design education in Hong Kong and highlighting some advantages of using ICT to conduct creativity training in design education according to my prior study.

1.1 The foundation creativity training module: SD 2000 Design Thinking

SD 2000 Design Thinking is a foundation creativity training module designed for first-year undergraduate design students who are studying visual communication design, advertising design, industrial and product design or environmental and interior design. SD 2000 is a common compulsory module for all design disciplines (*Definitive Programme Document*, 2005/6) in SD. This module aims at helping incoming students explore their creative, organizational and instrumental thinking skills by formulating a hypothesis, identifying problems, organizing creative development and testing proposed design solutions. In the following sections, I will explain the educational approaches used in SD and the aims and objectives of SD 2000 Design Thinking. Moreover, I will explore the problems discovered in conducting SD 2000 using the conventional pedagogy, and how globalization urges evaluation of foundational design subjects.

1.1.1 The overall educational approach of SD

According to the *Definitive Programme Document* of SD in the academic year 2005-06, design students must be equipped with specialist knowledge and skills, wide-ranging knowledge of other design disciplines, business and management skills, communication and presentation competences, and excellent use of information technologies. Design education is no longer a standalone subject, but involves working beyond the boundaries of traditional design disciplines, such as engineering, marketing and other areas of expertise. The SD programme document also defines the

FOUR main elements which contribute to the new design approach within the Hong Kong context: (1) awareness of the roles of designers in the region; (2) mastery of techniques and technology of design production; (3) sensitivity towards the aesthetic appeal of forms; and (4) an understanding of the social, cultural and economical factors in the application of design solutions. SD aims to model design and design education on the needs of the twenty-first century. The School supports dynamic thinking and independent learning, particularly by encouraging design students to take risks and break rules.

The Bachelor of Arts (Hons) in Design (BA), offered by SD, has been the sole local design programme in Hong Kong at the undergraduate level since 1967. Although there are some part-time BA design programmes introduced by overseas universities in other community colleges, the HKPolyU offers the only UGC funded full-time design programme at tertiary level in Hong Kong. Therefore, SD plays a significant role in not only developing a quality curriculum for training professional designers, but also in establishing models for design education in Hong Kong and other southern Asian regions. The BA (Hons) in Design programme in SD contains FOUR disciplines of design: (1) Advertising, (2) Environment and Interior, (3) Industrial and Product and (4) Visual Communication. All disciplines involve the completion of a required number of common compulsory subjects as well as discipline-specific compulsory and elective subjects. The design programme is normally undertaken over THREE years of full-time study with a maximum duration of SIX years for extension. In Year-one study (Level 2), the curriculum provides a wide-based foundation in common design and thinking skills across all disciplines. Students are given the chance to explore their areas of interest as well as to shape their future academic paths in Level 2. It is important to note that in this first year of study in the BA in design, the curriculum emphasizes the acquisition of creative thinking in generating strategic design solutions (*Definitive Programme Document*, 2005/6; 2006/7; 2007/8). Apparently, creative and critical thinking skills are given a high priority in the foundation year in SD. Design students are supposed to learn diverse thinking skills in the elementary subject SD 2000 Design Thinking, and in all other subsequent design subjects. By means of a lablog, which is a record of creative and design experiments, students experience the professional design process in a creative and critical manner by drawing on references and design theories and by producing reflective reports of their development.

1.1.2 The aims and objectives of SD 2000 Design Thinking

Before joining SD, students have already developed personal perspectives and unwritten rules about how they tackle problems and routines. According to Kuhn (1962), individuals have a tendency to follow existing paradigms rather than create new ones. De Bono (1970) described this tendency as made by the individual's patterning system and self-organization mechanism, which helps individuals to develop routine ways of doing things in professional and domestic life. These students' pre-conceptions, or perhaps Pattern-Making System mentioned by De Bono (1970), can be described as the intrinsic assumption about students' prior lives and working behaviors, which they usually take for granted. As a result, these pre-conceptions mould students' fixed paradigms towards any problem solving, perhaps under the influence of what Bourdieu and Passeron (1990) called "symbolic violence".

Positively speaking, students' paradigms help them to organize and evaluate new information effectively. But this mindset may also prevent them from actively seeking new opportunities and solutions in design contexts. Thus, the foundation creativity training module is crucial to challenge design students' fixed paradigms by introducing various creative and design thinking styles, as well as by shifting their habitual ways of doing things. Apart from reconstructing students' established mindsets, it is also significant for new design students to develop a creative working process. A creativity training module such as SD 2000 should give new students chances to develop and exercise their creative design processes individually and independently by introducing certain stages of design thinking, for instance problem identification, process formulation and analysis, and generating innovative ideas and solutions based on acquired knowledge and context.

In SD, the foundation creativity training module for all year-one design students is SD 2000. This module aims at helping students to explore creative, organizational and instrumental thinking skills by formulating hypotheses, identifying problems, organizing creative development and testing proposed design solutions. Some fundamental design skills, such as analysis and synthesis, are also introduced through a series of creative exercises. The expected learning outcomes of SD 2000 are focused on TWO main aspects: (1) Professional skills: The module expects students to understand diverse modes of thinking and how to apply operational skills for testing and evaluating design; and (2) Transferable skills: The module aims to enhance students' abilities in creative and critical thinking in a global context as well as developing their cultural appreciations and social responsibilities. The indicative content of SD 2000 helps design students to: (1) Acquire direct experience through a series of exploratory creative exercises; (2) Develop their abilities of *learning by doing* and *learning to learn* by participating in various creative learning activities proactively; and (3) Enhance their skills in researching information, problem identification and creative thinking. SD 2000 introduces creative and design thinking skills that require all fresh students to develop a more specialized capability and advanced work within a multi-disciplinary context.

Simon (1981) highlights that a real subject of contemporary intellectual free trade is that of deliberate thinking processes, such as creating, judging, deciding and choosing. In design education, this means that if our students are only equipped with analytical skill in design thinking, it is not enough to generate strategic design solutions and imaginative concepts. Similarly, intuition and creative ideas are insufficient to make creative solutions unless supported by critical evaluation and rigorous testing. In figure 1, which indicates the expected learning outcomes of SD 2000, it can be seen that SD believes a strategic design solution is developed by making use of: (1) design thinking skills, which are the ability to apply inventive, creative, and various styles of thinking, and to manipulate these mental representations of experiences; (2) morphogenesis skills, which are the sense of form creating and generating processes, communication, construction and representation; and (3) operation skills, which are the capabilities of identifying situations and problems, evaluating social needs, accessing and researching information, and evaluating proposed solutions.

Design thinking	Morphogenesis	Operation
• The nature of creative and inventive thinking • Styles of thinking • Mental models as representations of experience • Building and manipulating mental models • Externalization by actual or virtual modeling	• Form generating processes of the natural world • Approaches to the creation of form • Images, music and choreography • Representation, modeling and communication • Structure and form • Processes of fabrication and construction	• Defining direction: Situations and problems • Evaluating physical and psychological needs of society • Accessing and researching, interpreting and summarizing information • Generating and communicating ideas • Testing and evaluating proposals • Being organized and operating effectively

Figure 1: Expected Learning Outcomes of SD 2000 Design Thinking (Definitive Programme Document 2005)

The conventional teaching and learning methods of SD 2000 are based on a series of lectures and creative exercises. The main learning activity is through a student-centered exercise supported by workshops and group tutorials.

1.1.3 The problems discovered in conducting SD 2000 in conventional pedagogy

In the information age, the design industry is getting more complex and knowledgeable. It is easy to imagine that all design students have to be equipped with versatile professional knowledge within a very short period of time (e.g. three years of full-time study in the undergraduate programme with a total of 96 credits). Because of this competitive situation, the credit weighting of SD 2000 was reduced from 2 credits to 1 credit in 2005/06 (Definitive Programme Document, 2005/06). This means that the duration of the module has been cut from 28 hours to 14 hours (1 credit is equal to

14 hours). Thus, one of the possible solutions could be to seek help from ICT or virtual learning platforms which can possibly facilitate design students' learning processes outside the classroom. Moreover, according to my prior research in studying computer-aided creative thinking exercises for design students (Lau, 2006a; 2006b), I found that Hong Kong's design students were *passive* and *quiet* during the creative thinking process, especially in group discussion. This cultural paradigm of passivity could hinder the development of students' design thinking and creativity. One of the main reasons for being passive and quiet during the process could be that students are afraid of being criticized by others (e.g. Hallman, 1967; Cave, 1997a; 1997b; Ho, Chan and Peng, 2000; Ng, 2001; Sternberg, 2001). In order to address this problem, I discovered that the students were more open-minded and active in a virtual platform since their names (personal identities) had been hidden by using avatars as representatives (Lau, 2006a; 2006b). Thus, I reasoned that design students might participate actively in discussion and creative exercises with the help of a virtual environment. Last but not least, prior research (e.g. Feldhusen and Treffinger, 1980; King and Amderson, 1990; Amabile and Gryskiewicz, 1991; Sternberg and Lubart, 1995; Hunter, Bedell, and Mumford, 2005; Hemlin, Allwood and Martin, 2008; Kelly and Daughtry, 2008) has highlighted the importance of constructing a creative climate within physical environments for students who undertake creative thinking practices. The physical learning environment is always one of the important aspects of effective learning (Learning and Skills Council, 2005; Marmont, 2005; Joint Information Systems Committee, 2006). Unfortunately, Hong Kong's design students have limited living spaces and almost all design students lack working spaces for their design practices (See Section 2.3.3 - Findings of Phase ONE (Part 2): The photo ethnographic research). Thus, the virtual platform could be a solution to solve the

problem of limited working space by providing the students with a virtual environment for design practices.

1.1.4 The globalization urges evaluation on foundational design subjects

Globalization is a term which has diverse interpretations based on different situations, purposes and disciplines. Thus, this terminology is hard to define, apply and relate to contemporary theory, policy and critical pedagogy (Burbules and Torres, 2000). Positively speaking, Giddens (1999a) suggested that globalization brings with it a sense of global awareness of the planetary perspectives and enlarges the human sense of time and space within the global environment. . In contrast, Burbules and Torres (2000) expounded that it could mean a loss of nation-state sovereignty and a reduction of national autonomy. Nonetheless, globalization raises new issues, insights and directions on some old issues (McBurnie, 2002) and creates new cultural and economic zones within and across the existing nations (Giddens, 1999b). McBurnie (2002) paid particular attention to higher education in a globalized world and urged necessary changes, sharing problems and collaborations among global educational communities. The globalization of economics creates opportunities for the mobility of knowledge-workers and knowledge-seekers across the world (Uvali'c-Trumbi'c, 2002). According to Uvali'c-Trumbi'c (2002), the ultimate goal of higher educational communities is to be able to produce knowledge workers who can reconfigure and reshape knowledge in order to serve regional and global purposes. Regarding these potential changes in higher education, it would seem to demand imposing rules and priorities to promote international collaboration in education as well as integration mechanisms in the long run.

In view of reshaping Hong Kong's higher education, Sutherland (2002) reported the need to restructure the local tertiary educational system, extending from the original three-year-study of undergraduates to a four-year-study, which is proposed to be implemented by 2009. To simplify the explanation of this education reform, the Government coined the term "*3+3+4*" system which means three years in junior high school, three years in high school and the last four years in university. When comparing the 3+3+4 system to our existing 5+2+3 system, which means a total of seven years in secondary school and three years in university, it can be seen that one year of study has been taken from the secondary level and added to the foundation year at university. This restructure implies that the curriculum, syllabus, pedagogy and mode of teaching will be adjusted and refined for the first year of study in university in order to enhance students' generic skills with language and creative and critical thinking. Creative thinking is a generic subject in design study and now would be the right moment to review it, not only to echo the educational restructuring in 2009, but also to seek opportunities for international collaboration with globalized education communities. Professor John Heskett (2005), the chair professor in SD, reminded us to pay particular attention to the design profession and design study in the future. Heskett foresaw that THREE main areas of change in design study in the near future; namely (1) changes necessary to position design as a practice; (2) changes taking place in the context of business; and (3) changes that are functional as a potential means of human fulfillment and social improvement. Nonetheless, the underlying principle for any successful economy in the globalized world is strengthening human creativity no matter what changes occur in society; this is because creativity enhances products, processes and activities in order to match the constant change of social and cultural needs (Florida, 2002).

In addition to education reform in Hong Kong, Sutherland (2002) also highlighted that the world of education is changing and reshaping tremendously due to the rapid development and wide availability of new technologies. To give some examples, electronic based teaching is expanding the learning environment from classroom to anywhere with wired system; any possible implementation of E-Learning is highly accepted and encouraged by universities; and electronic based modules are sharing a certain proportion of course content. As the Studies Report from the U. S. Department of Education (2000) has indicated, traditional teaching and learning methods might not be effective at all to keep up with the learning styles of the 21st century. In HKPolyU, despite the existing WebCT learning platform for full-time and part-time students, the university established the Hong Kong CyberU (HKCyberU), in 2002, that mainly facilitates life-long and distance learning. Computer-aided learning and Information and Communication Technologies (ICT) tools are increasingly helping, or perhaps even shaping, the conventional pedagogies under the impact of globalization. In view of generic skills, specifically creative thinking in design study, using ICT to facilitate creative thinking could be one of the solutions to enhancing design students' competency in the globalized world. Obviously, ICT plays a significant role in carrying out creative learning activities effectively as well as exploring possible educational collaborations internationally through the Internet.

Moreover, nowadays everyone needs to be more creative than in the past because of globalization (Brocking, 2006). Some researchers (e.g. Olssen and Peters, 2005;

Jankowska and Atlay, 2008) believe that today's socio-economic changes are influencing curriculum design in higher education, and particularly in creativity training. Some studies have actually looked at the role of creativity in students' academic performance (e.g. Chamorro-Premuzic, 2006; Kelly, 2006) and pedagogic discourse (e.g. Bassett, 2005; 2006; Castree, 2005) in this new era. In order to address these questions, this research looked at how to use virtual technologies to facilitate design students' creative thinking and sought an appropriate pedagogy to carry out creativity training in virtual space.

1.2 The creative-friendly space for design thinking

In addition to the evaluation of SD 2000 and creativity training in design education in Hong Kong, another crucial factor for facilitating design students' creativity development is environmental stimulation. Similarly, the crowded living environment in Hong Kong hinders students from engaging in effective learning processes and experiences (Volery and Lord, 2000). Despite some cognitivists in creativity arguing that creativity development only happens within a disembodied mind (e.g. Norman, 1993), I deduce from professional observation that a creative-friendly environment plays an essential role in helping design students to release their creative potentials. In the following sections, I will evaluate the role of environmental factors in design thinking and creativity by discussing the socio-cultural stimulation and environmental stimulus. I will also explore the possibilities of creating a heuristic virtual environment for design thinking. Intresetingly, the findings of this research also suggested the essential role of environmental stimulation in virtual reality could help design students in enriching their learning experience in creativity training.

1.2.1 The environmental factors in design thinking and creativity

William James (1842-1910) was one of the earliest philosophers to point out the significance of *environment* over genetic inheritance in determining human ability. James (1890) challenged Galton's (1869) belief about the assumption of hereditary genius, that an individual's creative ability is inherited. Nonetheless, James's assumption triggered further studies (e.g. Jacobs, 1961; 1969; 1984; Vygotski, 1978;

Feldhusen and Treffinger, 1980; Amabile and Gryskiewicz, 1989; Ripple, 1989; Fischer, 1993; Sternberg and Lubart, 1995) that explored the relationship between human creativity and environment. After more than a century, researchers have commonly come to believe that *environment* plays an essential role in facilitating individuals' creative thinking processes. However, this does not mean that all kinds of environments can enhance individuals' creative performances. The deliberate arrangement of creative activities within creative-friendly environments, whether in classrooms, halls, game-centers or in virtual reality, is the key factor to releasing the individual's creative potential.

On the topic of design study, Green (1974) stated that design education is influenced fundamentally by *environment,* not only the hardware, but also the senses of sight, sound, taste and touch. Green explained that environmental elements, such as films and advertisements, that involve human decision making for design solutions contribute to design education. Actually, design education gives students chances to make decisions and develop value judgments (Green, 1974). Similarly, Richard et al. (1995) distinguished between the weak sense and strong sense of critical and creative thinking. Richard pointed out that the common weakness of creative thinkers is that they only concentrate on their interests and desires within their specific domains. I do not agree entirely with Richard's stance due to the difficulties of identifying and measuring creative thinking, however design students do need a broad sense of understanding of diverse cultures and social phenomena instead of only concentrating on their design projects. For instance, in visual communication, if a design student is asked to design a promotional item for a music festival, the student is required to not only study the content of this music festival or the styles of the songs, but also to investigate the culture of audiences and current issues happening within their social contexts. Some ideas and approaches to promoting this festival might be created based on the inspiration of environmental factors. Therefore, constructing knowledge and opinions from their surroundings and developing students' personal value judgments of current issues could be crucial factors in releasing students' creative potentials. In other words, environmental factors play a role in stimulating design students' creative thinking.

1.2.2 The socio-cultural environment as a stimulus for creative thinking

Arieti (1976) stressed that creative acts cannot be judged without reference to environmental factors. According to Arieti (1976), the creative act has TWO intentions, which are (1) creating new perspectives of seeing our world in social and culture domains; and (2) extending this existential space for further exploration. Arieti (1976) explained that the individual's creative ability in this new space is controlled predominantly by existing environmental factors. Likewise, Tradif and Sternberg (1988) agreed that individuals' creativity can only be assessed by considering the creative solution with respect to their culture. Lubart (1990) emphasized that creativity is manifests in different cultures; he stated that a cultural environment with rights and freedoms of every individual can facilitate the development of personal creativity. Similarly, Gruber (1988) and Gruber and Davis (1988) introduced an evolving systems approach to creativity; they expressed the belief that it is influenced by social relationships, historical and institutional factors. McLaren (1993) supported the study of various external validities as significant factors. Edward (2000) pointed out that individuals' creativity is highly related to the their prior knowledge and environment in which they have been operating. According to the above discussion, creativity can be interpreted as a novel association of concepts extracted from the surrounding environment while the creative idea is judged eventually by social and cultural factors. Thus, the individual's creativity depends significantly on social and cultural stimulation. Vidal (2003) highlighted that originality and creativity are linked to the socialization process, therefore creativity belongs to the process of social differentiation as well as to how individuals shape their personal identities. Since this *Personal Identity* is an individual's cognitive and affective system which helps people to situate their social roles in society (Vidal, 2003), creativity can be nurtured differently by social and economic environments (Florida, 2002).

Because of the influence of environmental stimulation, an individual's creativity can be enhanced or detracted within particular social and cultural contexts (Arieti, 1976; Gibson, 2005; Kijkuit and van den Ende, 2007; Leenders, van Engelen and Kratzer, 2007). In other words, the availability of cultural means is crucial in developing creativity and ways of thinking. To explain this simply, imagine that Einstein would not have been able to create the theory of *Relativity* if he had grown up in a different social class, for instance a farmer's family. Furthermore, some substantial explanations can be found in Aireti's (1976) idea. Aireti postulated NINE positive social factors for creating a creative society and culture: (1) the availability of cultural means; (2) openness to cultural stimuli; (3) stress on becoming and not just on being; (4) free access to cultural media for all citizens without discrimination; (5) freedom, or even retention of moderate discrimination, after severe oppression or absolute exclusion; (6) exposure to different and even contrasting cultural stimuli; (7) tolerance of diverging views; (8) interaction of significant persons; and (9) promotion of incentives and rewards. These NINE factors outline a creative learning environment that has to be open to diverse cultures with compromise and tolerance, and this inclusive learning space should provide easy access to all cultural stimuli, media and persons as well as facilitating interaction. I see that hyperspace could possibly fulfill these requirements since that space is inherently integrated and interacting with diverse cultures. Thus, my research studied how virtual reality works as an environmental stimulus for design students in the creative thinking process.

Although an individual's creativity is nurtured by diverse personal interests, knowledge, experiences and perspectives (Simonton, 1999; Kelly, 2006), creativity comes from people's social and cultural organizations which are the places where they generate their knowledge, explorations and discoveries. This idea can be understood in relation to "*communities of practice*" (Lave and Wenger, 1991; Brown and Duguid, 2000), in which individuals share ideas, find solutions and build innovations under similar social contexts and interests. Florida (2002) agreed that, although creative individuals come from diverse backgrounds, the commonality is that they are all nurtured and cultivated by organizations and environments. In fact, Piaget (1918) pointed out the significance of socio-cultural factors to creativity nearly a century ago. Piaget stated that an individual's personality is a social representation of himself/herself which is highly affected by his/her milieu. According to Piaget, this milieu is a process of how an individual transforms his or her ideal cultural representation into personal experience. Vygotski (1930) also explained that *art* is a significant component of children's lives, especially in their play, which is full of absurdities, nonsense and inversions. Vygotski believed *art* is the creative performance of a child which is affected by social environment. However, it is very difficult to identify or explain the said relationship in detail, as Vygotski (1930) admitted that there is no sociological theory that can actually explain the originality of ideology since the individual's consciousness is the origin of ideology and that consciousness interprets art. Vygotski (1930) described *culture* as a convergence of every individual's emotion by means of *art*; and these forms, techniques and ways of making artwork are developed historically and socially. In addition, Rogers (1954) focused on studying the relationship between socio-cultural factors and creativity; he underlined that the importance of the social environment is stimulating creativity by supporting an individual to pursue his/her own uniqueness spontaneously. Rogers believed creativity is encouraged by an individual's exploration of his/her personal aptitudes and interests.

In the last two decades, research on creativity has been shifting from focusing on the investigations of creative persons to a broader approach of studying the *creative* environment (Hunter, Bedell, and Mumford, 2005). Significant research called *Evolutionary Theory of Discovery and Innovation*, conducted by Scott Findlay and Charles Lumsden in 1988 at the University of Toronto, introduced a concept of "*Linking Thesis*" which introduced a series of interesting hypotheses regarding the relationships between creativity and other factors, for instance the linkage with the socio-cultural environment. Findlay and Lumsden (1988) believed creative activity comes about due to the result of the establishment of new linkages among neurons in responding to the existing socio-cultural structure and outer simulation. This is what they explained as *"a consequence of a novel sequence of group selection events"* (Findlay and Lumsden, 1988). In a further exploration of this hypothesis, Findlay and

Lumsden stated that there is a complex *interaction* among FIVE aspects of human existence and each of these aspects is influenced by others to a certain degree so as to release human creative potential. These FIVE aspects are the (1) *genotype* which is a genetic constitution of a person; (2) *brain development*; (3) *cognitive phenotype* which is a thinking mode developed in a genetically and environmentally determined manner; (4) *physical environment*; and (5) *socio-cultural environment*. According to their Linking Thesis (1988), environmental factors play an indispensable role in releasing individuals' creative potential by making linkages among cognitive thinking, physical and socio-cultural environments. Similarly, Csikszentmihalyi (1990) noted that the creative performance of an individual is bound closely to the THREE key factors: the (1) domain, (2) person, and (3) field. Csikszentmihalyi explained that an individual's creative thinking process works through the interaction of these factors. Accordingly, it can be interpreted as stating that a creative-friendly learning environment should facilitate these linkages by deliberately organizing learning spaces and applying socio-cultural stimulation. Nonetheless, socioeconomic and cultural factors are always a pathway to creativity (Niu and Sternberg, 2001; Gibson, 2005; Kijkuit and van den Ende, 2007; Leenders, van Engelen and Kratzer, 2007). In particular scientific creativity, also called technical creativity, is conceptualized by individual and socio-cultural capacities to solve complex scientific and technical problems in innovative and productive ways (DiLiello and Houghton, 2006; Heller, 2007).

1.2.3 Environment serves as stimulus and information provider for design study

In view of design study, Fischer (1993) pinpointed that the dual factors of establishing the design environment are (1) offering individuals some mechanisms that can help them to contextualize information to develop a strategy or solution; and (2) undertaking design activities with the help of rich information. Further elaboration from Fischer (1993) suggested that a design environment has to serve as a *stimulus* for individuals providing a multifaceted architecture and making suggestions for further development and decision making. In other words, successful environments for enhancing individuals' creativity ought to be multidimensional, stimulating and interactive (Jacobs, 1961; 1969; 1984). Regarding the learning environment, Addison and Burgess (2000) stressed that individuals are motivated by a well-structured and stimulating learning environment. Addison and Burgess believed that both autonomous learning and ownership of ideas are equally important in building a learning environment for students. Certainly, a stimulating, dialogical social environment does help students to grow up into an intellectual life (Vygotski, 1978).

In order to establish an environment of rich stimulation for design study, some strategies were employed to reinforce creative-friendly learning spaces, namely the *Climate Analysis* (e.g. Amabile and Gryskiewicz, 1989), the *Manipulations of Group Composition* (e.g. King and Amderson, 1990), and the *Role of Modeling or Mentoring* (e.g. Zuckerman, 1974). One of the remarkable strategies is the *Creative Climate* (Feldhusen and Treffinger, 1980). According to Feldhusen and Treffinger (1980), there are TEN recommendations to establish a creative climate within any environment: they suggested that the learning space (1) should be able, proactively, to accept any unusual ideas and responses from students; (2) should help students realize errors and meet acceptable standards within a supportive atmosphere; (3) can make students aware of their interests; (4) should provide sufficient time for students to think and develop their creative ideas; (5) should be able to establish a climate of mutual respect and acceptance from student-to-student and students-to-teachers; (6) should acknowledge that creativity happens in all curricular areas and disciplines; (7) should facilitate divergent learning activities; (8) should create a warm, supportive atmosphere which provides freedom and security in exploratory thinking; (9) should offer students choices and involve them in the decision-making process; and (10) should demonstrate the value of involvement by supporting students' ideas and solutions to problems and projects. A creative climate is indeed a subjective experience of various psychological responses which can possibly influence creativity (Hunter, Bedell, and Mumford, 2005). I have tried to compare the above TEN recommendations to Torrance's idea of creative teaching (Torrance, 1981) which focuses on FIVE indicators namely *motivation, alertness, curiosity, concentration* and *achievement.* Some common understandings can be found from both sources. For instance, items 8 and 9 focus on establishing a warm and supportive atmosphere which helps to *motivate* individuals to explore their ways of thinking under free and secure circumstances as well as offering choices for decision making. Items 2 and 6 state that individuals have to be aware of their own errors and realize how creativity takes place; this is a sense of *alertness.* Item 3 shows that the space has to acknowledge individuals' interests and ideas in order to develop *curiosity* towards everything within the environment. Regarding item 4, Feldhusen and Treffinger mentioned that providing sufficient time for creative development is crucial to enhancing individuals' *concentration* during the creative thinking process. Last but not least, items 2 and 10 aim at demonstrating the values of involvement by supporting individuals' ideas to help them to realize errors and meet acceptable standards. These items relate to the indicator of *achievement.* These common understandings indicate that a creative-friendly environment interacts closely with the creative teaching methods in order to produce a *creative climate* for students. In addition, these commonalities can also be applied to Aireti's (1976) NINE positive social factors for creating creative society and culture which I have mentioned in the previous sections. For instance, the availability, openness and free access to cultural stimuli and social factors can enhance students' motivation, alertness and curiosity properly during the learning process. Another important component of forming the creative climate is *stimulation.* Sternberg and Lubart (1995) emphasized the importance of environmental stimulation on creative enhancement. They suggested that creativity can be stimulated by THREE different levels, the (1) level of sparking creative ideas; (2) level of encouraging follow-up of creative ideas; and (3) level of evaluating and rewarding creative ideas. Based on Sternberg's and Lubart's idea (1995), I realized that one of the significant components of a creative-friendly environment ought to be the provision of *stimulation* for individuals in order to trigger their idea explorations and evaluations.

In addition, creativity can be interpreted as a way of suggesting novel solutions to problems within a subject domain. Thus, this problem-solving skill may require certain knowledge within the particular subject domain. According to the prior case studies in this area (e.g. Gruber, 1981; Gardner, 1983; Gruber and Davis, 1998), the creative individual is equipped with both *Formal* and *Informal* Knowledge. Further elaboration, from Csikszentmihalyi (1988), distinguishes that *Formal* Knowledge is acquired from the knowledge of particular domain, while *Informal* Knowledge is obtained by the knowledge of a field. For instance *Informal* knowledge can be developed from the social system within domains. In other words, to develop individuals' creativity in some ways is based on enhancing both *Formal* and *Informal* knowledge in their subject domains and environments. Current research (e.g. Kijkuit and van den Ende, 2007; Leenders, van Engelen and Kratzer, 2007) supported the idea that a working environment, with domain specific knowledge, could possibly facilitate creativity. Of course, the design educator has to be aware of the negative impacts of students' prior knowledge when they construct their informal knowledge from the environment. Students can easily develop unhelpful fixed knowledge or preconceptions during knowledge building. A successful example can be found in the *GameLab* project, conducted by Zimmerman and his colleagues (2003), in which they developed a game development studio for enhancing creative activities and constructing the *climate* of design research for designing and developing computer games.

"Any office is a nexus for the exchange of ideas, and at the GameLab we encourage staff to share the insights from their informal play research". (Zimmerman, 2003: p186)

The *GameLab* is equipped with a design research library which includes books, games, graphic novels, DVDs, toys, card games and other playful objects. This setting aims to foster design research and creative thinking by encouraging staff to collect and share cultural objects for any formal and informal investigations. In the *GameLab* project, both *Formal* (library) and *Informal* (share playing experience) knowledge have been developed within the creative environment. The concept of the *GameLab* can be applied to developing teaching and learning environments effectively. As I mentioned in the above sections, a creative-friendly learning environment requires a creative climate which is constructed by some important components, such as motivation, encouragement, simulation, openness, alertness and achievement. In fact, Wallach and Kogan (1965) had already pointed out the significance of the *development of the game-like atmosphere* for individuals during the creativity exercises. A playful environment creates a creative climate which allows individuals to be free while exploring, sharing and evaluating their creative thoughts. After all, a creative-friendly environment should be established carefully by deliberately arranging creative teaching methods and learning activities as well as promoting the creative climate inside. Additionally, the environment ought to provide a knowledge base which involves *Formal* and *Informal* knowledge for students; that is to say, an environment is perhaps not only responsible for fostering the exploration of possible solutions, but also providing underlying knowledge for idea analysis and evaluation.

To create a proactive learning environment for releasing individuals' creativity, *encouragement* is one of the crucial components. Chambers (1972) investigated the impacts and effects of teacher-student relationship, teacher personality and classroom behavior on individuals' creativity, in order to study the characteristics of students' creative behaviors. Based on his research, he suggested that *encouragement* is the best indicator for measuring student-teacher relationships for developing creativity. Chambers (1972) and Ripple (1989) specified how environment facilitates the creative performances of individuals by providing opportunities, or one may say encouragement, based on stimuli and relevant information; individuals are able to make use of this stimulation to develop their creativity by making connections among disparate events/objects. In contrast, individuals' creative abilities could be hindered by circumscribing these associations (Chambers, 1972; Ripple, 1989). Another similar idea was created by Torrance (1981), who stressed that the purpose of creative teaching is to establish a *responsible* environment through the teachers' teaching enthusiasm and their openness in appreciating individuals' differences.

Nonetheless, in order to understand the environmental factors in constructing learners' knowledge, some researchers (e.g. Goodson, 1992; Starko, 1995; Baer, 1997; Hickey. 1999; Kiely, 1998; Rejskind, 2000; Lam, 2002; Hemlin, Allwood and Martin, 2008; Kelly and Daughtry, 2008) found that a creative classroom environment or learning space can provide a brightly coloured, supportive, comfortable and welcoming atmosphere to students in order to help them to be cooperative, friendly, excited, interested and trusting. An example can be found in the research of Howard Gardner and his associates (Harvard Graduate School, 2004). They conducted continuous creative research called the "*Project Zero*" from 1972 to 2000 at the Harvard Graduate School of Education. This project aimed at understanding and enhancing learning, thinking and creativity in the arts. The research team suggested a new approach to help students, groups and institutions to develop their creative capacities - designing strategies for creating the *culture of thinking* within classroom. Gardner and his associates introduced the concept of *Smart Schools* which emphasized the development of students' deep understanding, and flexible and active use of knowledge. The research team believed that *learning* is a consequence of *thinking* (Harvard Graduate School, 2004). This constructional learning approach allows students to make their learning personally relevant, and that can, in turn, eventually establish students' knowledge base (Papert, 1990). The flexibility of using knowledge possibly enhances students' motivation and alertness in their learning process; however, the design educator also has to be aware of how a heuristic space is formed in order to avoid the negative impacts of environmental factors.

1.2.4 The heuristic shared space for design thinking

Jacobs (1961; 1969; 1984) reminded us that a creative community needs an appropriate physical environmental setting as well as someone who is able to generate ideas and facilitate the creative process. Human creativity is indeed multifaceted and multidimensional and thus must be nurtured and cultivated by both the individual's thinking habits and social stimulation within a community (Florida, 2002). Thus, it is easy to imagine that a sensible and effective communication among participants and a healthy community setting within a *space* would be two of the key factors in establishing heuristic shared space for facilitating the design thinking process. ICT is able to facilitate learning and communication among teachers, students and administrators within a learning community (Bouras, Philopoulos and Tsiatsos, 2001). This concept of interactive activities within a community can also be applied to design practices. Cross (1999) expressed the belief that computer technologies are able to support the *design process* in the areas of enhancing designers' creativity by using interactive systems as well as the development of computational machines that facilitate design practices. Cross provided a clue to the development of an ICT supported system for design practices; he mentioned that if the interactive system wants to support designers, then the system must be designed according to the cognitive behavior of designers. According to the prior studies, some attempts have established computer support systems for empowering the design creation process (e.g. Noguchi, 1998; Maher and Tang, 2003). Some other attempts made the computer more creative and modeled the computer-assisted creative process (e.g. Rogers, 1959; Koestler, 1964; Arieti, 1976; Hofstader, 1979; Boden; 1991). A distinguished example can be found by the research of Fischer et al (1993) which established versions of computational environments called *"Domain-Oriented Design Environments"* (Fischer, 1992). These design environments help individuals, particularly designers, to understand and explore diverse creative methods. Fischer et al (1993) suggested that these systems assist designers in enhancing their awareness of the breakdowns when they participate in the environment. Likewise, Edmonds and Candy (1996), who were concerned with the design of interactive systems for creative users, adopted criteria-based modeling to support designers within computer systems for completing creative tasks. Apparently computer technologies have been involved closely in creative and design thinking practices at different levels. Cross (1999) admitted that some of the existing design machines and applications already perform designers' professional practices; in other words, a machine can do what the designer does. However, under the blossoming explorations of ICT in design practices, Fischer et al (1993) reminded us that there are difficulties in constructing the computational environment to provide *right* information at the right time.

Reynolds et al (2003) asked 'Where is the evidence that the ICT improved the pupils' performance?" Of course it is not only about technology, but also includes the interwoven connections with the pedagogical arrangements – this is the complexity of e-learning (Gunawardena and McIsaac, 2004; Liu, 2004). Student performance can only be contextualized, but not generalized (Underwood, 2004). While some of the most recent research (e.g. Chandra and Lloyd, 2008) has found that ICT did improve student performance in terms of test scores, further studies are needed to explore the potential of ICT and virtual environments to enhance students' performances as well as their learning experiences in various educational domains.

1.3 The creative-friendly learning behavior for design thinking

In the above sections, I have discussed the TWO main extrinsic factors for developing design students' creativity and design thinking skills, namely creativity training and environmental stimulation. Thus, I would like to shift my focus from external factors to the intrinsic components, such as design students' learning behavior and their creative habits. Apparently, design students' learning behaviors and motivation in doing creative tasks are crucial to the release of their creative potentials. Generally speaking, people believe the creative individual should be open-minded and flexible in tackling problems. However, Albert Edward Wiggam, who was the author of the *"New Decalogue of Science"* in 1922, proposed a counter opinion to this assumption by making a clean-cut distinction between *open-minders* and *tight-minders* (Osborn, 1948). Wiggam noted that *open-minded* people have made NO contribution to human development in the history. Whether Wiggam was right or wrong in giving this harsh comment, it seems to me that being open-minded is not enough to develop students' creativity and that some other intrinsic components must be considered, for instance, being interested, positive thinking and constructive thinking in completing design tasks. Moreover, in view of design education, Buchanan (1995) reminded us that designers have to be *curious* in tackling design problems.

In the following sections, I am going to probe the factors for developing students' creative-friendly learning behavior by (1) analyzing students' thinking habits; (2) developing students' intrinsic motivation; (3) developing students' positive and forward thinking; (4) enhancing students' self-determination; (5) managing students' emotions; and (6) removing students' obstacles to creativity. In addition, I am also trying to seek any possible way of using ICT in helping design students to develop their creative-friendly learning behaviors.

1.3.1 Analyzing students' thinking habits

It is important for design educators to understand design students' thinking habits before developing creative-friendly learning behavior. One of the experimental classifications of thinking habits is developed by Harrison and Bramson which they called *"The Art of Thinking"* (Harrison and Bramso, 1984). They classified FIVE kinds of thinkers, interpreted as FIVE types of thinking habits in humankind: (1) Synthesist, who sees likeness in apparent unlike, seeks conflict and is interested in change; (2) Idealist, who looks at problems from a broader range of views and seeks ideal solutions; (3) Pragmatist, who seeks the shortest and fastest solution to solve a problem; (4) Analyst, who is interested in scientific decision making by comparing solutions in order to select the best one; and (5) Realist, who is concerned with concrete results and hard facts, such as expert opinions and statistics. This classification of human thinking habits is similar to that of Jerome Bruner (1977), who described the different conceptualizing strategies of human thinking styles. This in turn was based on Bruner's (1960) study report, which was the result of his five-year investigation in the area of understanding the nature of problem-solving skills in humankind comprised of perceptual categorizing and conceptualizing process. According to Burner, FOUR conceptualizing strategies have been identified: (1) Simultaneous Scanning, which is about the process of testing all hypotheses against the mass of data by gathering all relevant information together; (2) Successive Screening, which tests a hypothesis at one time by using limited relevant information; (3) Conservative Focusing, which tests a single example and alters an attribute at the same time in finding a correct solution; and (4) Focus Gambling, which tests a single example and keeps changing diverse attributes at the same time (Bruner, 1977). Another prevailing classification of human thinking habits was introduced by Edward De Bono (1985) which he called the "*Six Thinking Hats*". De Bono (1985) divided human thinking habits into SIX different styles: the (1) White hat, which is mainly for information gathering; (2) Red hat, which is about emotional expression; (3) Black hat, which is exclusive for survival and caution of thinking; (4) Yellow hat, which is the thinking habit for optimistic thinking and putting ideas forward positively; (5) Green hat, which is seeking novelty solutions; and (6) Blue hat, which is thinking about thinking, similar to metacognition.

To compare and summarize the above discussions in diverse thinking styles of humankind, I have classified the aforesaid ideas into THREE main thinking styles which are relevant to understanding the diverse thinking habits of design students: (1) Synthesis and Analytical Thinking Style: The student who tends to analyze information and data as well as synthesizing concepts and solutions; (2) Pragmatic and Realistic Thinking Style: The student who is practical and realistic, and usually thinks of ways of implementation instead of some theoretical considerations; and (3)

Idealistic and Forward Thinking Style: The student who has holistic and flexible thinking towards any concepts and solutions. Nonetheless, my classification system is not going to be used to analyze design students' psychological performances, but provides guidelines for design educators, when arranging and conducting creativity training, to be aware of the differences in design students' thinking habits. In other words, this system is not a model that is used to limit students to a few types of thinking processes, but rather enhances the alertness of design educators to differentiate diverse students' thinking habits in order to design appropriate creative training and learning spaces for them.

1.3.2 Developing students' intrinsic motivation through fun

Some hints about the importance of developing design students' creativity and creative behaviors can be found in the *"Learning-centered Psychological Principles"* from the American Psychological Association's Presidential Task Force on Psychology in Education (1993). In looking at Principles 4, 5 and 8; I found that Principle 4 highlights the importance of developing students' strategic thinking in problem solving; Principle 5 highlights the higher-order strategies for *thinking about thinking and learning* which facilitates students' creative and critical thinking; and Principle 8 raises the suggestion that intrinsic motivation in learning can possibly develop students' creative and higher-order thinking by stimulation from authentic learning tasks and novelty (Woolfolk, 1998). Likewise, Runco and Nemiro (1994) argued that individuals' intrinsic motivation is crucial in developing their creative thinking skills. Runco and Nemiro (1994) believed that the process of *problem finding* facilitates intrinsic motivation of individuals. Paulo (1993) used the term *Pedagogy of the Oppressed* to highlight the value of problem-posing in education. In other words, some difficult and complicated tasks could be meaningful to individuals if they can choose from them. Another effective way to enhance students' intrinsic motivation is to make the task *interesting*. De Bono (1999) points out that many intellectual people are only clever within their particular fields, which he called the "*Intelligence Trap*", but are not equipped with general thinking skills. De Bono (1999) emphasized that being intelligent is no longer enough to be creative, whereas being interested is one of the key factors to achieving possibilities and speculations fully. De Bono (1999) believed that *being interested* is a skill that can be developed by certain means because the human mind is full of possibilities and potentials to be interested, which helps individuals to tackle their tasks creatively. De Bono (1997) offered an elaboration of a physiological term "*being interested*" which is also called "*Humenes*". He explained that a chef knows how to add flavor because of his own interest in flavors based on his feelings, emotions and personal experiences. As design educators, we should understand the students' *humenes* by understanding their physiological behaviors, such as insight, humor and surprise. Then perhaps we would be able to develop their intrinsic motivation by giving them interesting tasks and projects.

Similarly, Osborn (1948) believed that creative thinking is *fun* intrinsically because the more an individual tries to create, the more he/she feels interested in and enjoys the process. In one of the early research studies in the 1940s, Joseph Rossman analyzed the incentives of 710 inventors with about 2,400 patents to their credits that motivated them in problem solving. He found the *fun of inventing* leads all other motives (Osborn, 1948). Likewise, Crutchfield (1962) pointed out that if individuals are only enjoying their work to a limited degree, they show little desire to be creative in doing tasks. This can be understood as meaning that an individual is able to perform with high creativity due to the strong intrinsic interest in the funniest tasks. Furthermore, Eisenberger (2003) explained that individuals are able to perform to their maximum creative ability, particularly when confronting challenging or interesting tasks, due to the phenonomenological stage that they are experiencing in order to prolong and invigorate their performance. Csikszentmihalyi (1990) introduced a notable psychological condition of human beings which he called the *"Flow"*. According to him, the *flow-like* experience is something like reaching the peak performance when individuals are engaged in high levels of thinking practices. In fact, the concept of *"Flow"* is similar to what Koestler called the *"Eureka Phenomenon"* in the early 1960s. Koestler (1964) stated that every creative solution to a problem happens in a flash during the incubation process of creative thinking. Moreover, Alder (2002) agreed that the *flow* experience is connected to creativity and that it is neither separated from individuals' behaviors nor a single and spontaneous insight. Alder (2002) reminded us that the *flow* experience usually takes place in conscious, complex or problematic contexts; hence individuals have to learn to avoid both mental and physical interruptions within this psychological stage. All in all, Hallman (1967) reminded us that *creativity is profound fun*. Therefore, making fun, interesting but difficult tasks could be one of the effective methods to release the design students' creative potential. My research aims to find out in what ways the design students' intrinsic motivation could be enhanced by their commitment to the interesting tasks, process of problem solving and environmental stimulation.

1.3.3 Developing students' positive and forward thinking

Osborn (1948) stated that individual's creative thinking needs a positive attitude; negative attitudes protect them from mistakes and danger as well as forestalling them from making deliberate decisions. However, the positive attitude encourages individuals to be self-confident with enthusiasm and make things happen. As De Bono (1985a) stated, this positive attitude could be a mixture of curiosity, pleasure, greed and the desire to create possibilities. Starko (1995) and Kelly (2006) agreed that a positive and forward learning behavior, namely willingness to take risks, openness to experience, tolerance for ambiguity, intuition and deep emotions, is the key for seeking novel and creative solutions. Sternberg and Lubart (1995) introduced the *Investment Theory of Creativity*, which underlined that the creative act should involve certain risk taking similar to the stock market; the individual has to sell high in order to obtain profits. Addison and Burgess (2000) stated that risk taking is an essential ingredient in developing human creativity, particularly in art, craft and design training. However, Piaget (1973) explained that the human tendency is related to the *formal thinking* which develops from the age of 12 years, and this mindset does not respect the uniqueness of new problems, and even fails to address the demands of social change. Apparently, this habitual thinking, or play-safe attitude, obstructs design students from being creative and taking risks in finding new solutions. Design students need to develop an attitude of *forward thinking* in order to help them to seek new notions. Sternberg (1988) accentuated that creative individuals actively defy existing beliefs, and seek out ideas in a forward looking fashion. According to Sternberg (1988), creative individuals actively seek all possible ways to solve problems instead of waiting passively for good ideas. Based on the above discussion, positive and forward thinking is crucial in developing students' creative-friendly learning behavior in problem posing and solving. Thus, my research studied how students' creative-friendly learning behavior can be enhanced by environmental factors, particularly in the shared virtual reality.

1.3.4 Enhancing students' self-determination

The Romantic philosopher Rousseau (1762; 1782) highlighted the significant role of self-determination and intrinsic motivation on creativity. Rousseau (1762; 1782) believed that self-fulfillment nurtures individuals' creative talents because the effectiveness of creative thinking is highly dependant on freedom of exploration and imagination. Some researchers have also argued that the anticipated *reward* is an essential component in facilitating students' creative thinking and performance (e.g. Watson, 1968; Amabile, 1996; Conry, 1977; Mansfield and Busse, 1981). In opposition, Deci and Ryan (1985; 1987) challenged this assumption of anticipated reward as enhancement to creative performance; they believed that the anticipated reward is a kind of limitation to individuals' creative development because it is related closely to anticipation and result-orientation. In other words, if individuals take *reward* into account in managing their attitude towards the task, it reduces their intrinsic task interests due to the reduction of the self-determination and autonomy (Deci and Ryan, 1985). Deci and Ryan (1987) also stressed that motivation is basically controlled by *when* and *how* activities are carried out, and that individual's creativity can be affected by perceived constraints on self-determination and autonomy. Deci and Ryan (1985) introduced the *Cognitive Evaluation Theory* to depict this psychological behavior which underlines that personal motivation is nurtured inherently by perceptions of self-determination and competence. An interesting piece of research on comparing TWO control groups, with and without anticipated rewards, was carried out by Deci and his associates in 1999. This research reported that individuals' motivation had been reduced significantly in the group with anticipated reward in comparison with the other group (Deci, Koestner, and Tyan, 1999). Likewise, in creativity development, individuals' creative ability will be reduced if they keep repeating the anticipated rewards for simple and uncreative performance (McGrow and McCullers, 1979; Schwartz, 1982; Eisenberger and Selbst, 1994; Eisenberger 2003). Furthermore, Joussement and Koestner (1999) found that if individuals were asked to produce as many creative responses as they could, the anticipated rewards failed to enhance individual's creativity under this condition. Based on the above discussion, I deduce that one of the effective ways to develop students' creative-friendly learning behavior may be to enhance their self-determination by giving them autonomy instead of the anticipated rewards in doing creative tasks. As I mentioned earlier, design students could possibly obtain a high level of autonomy in virtual space when doing creative exercises online (Lau, 2003). ICT and virtual environment could be an approach to develop design students' creative-friendly learning behavior by offering them self-determination during the creative thinking process.

1.3.5 Managing students' emotions

Among the preceding research that studied creativity in the 1960s, the research from Newell and his associates (Newell, Shaw and Simon, 1963) was an uncommon case which focused on areas of strategies and heuristics in human emotions. There has been increasing attention given to studying the relationships between creativity and emotion. For instance, Isen, Daubman and Nowicki (1987) employed the standard indicators of creative problem-solving ability to access individuals' creative performances under certain emotions. They found the *positive mood* of individuals could promote creative performances. In subsequent years, many researchers asserted that *positive mood* can enhance creativity (e.g. Isen and Baron, 1991; Isen, 1993; Benjafield, 1997; Hirt, McDonald and Melton, 1996; Hirt, 1999; Russ, 1999; Shapiro and Weisberg, 1999; Forgas, 2000; Schwarz, 2000). More specifically, positive mood can facilitate ideational fluency, speed of association and combination thinking (Jamison, 1993) as well as removing irrelevant intrusions in thought (Schuldberg, 1990; Shapiro and Weisberg, 1999). Abele (1992) studied the positive, negative and neutral moods of individuals by way of autobiographical recall. The result indicated that the positive-mood individual achieved remarkable performance on ideational fluency towards tasks. In another example, Hirt (1999) made claims for the robust effect of the positive mood creativity by comparing two groups of individuals. He formed two different groups in which participants were in either positive or negative moods while completing a creative task. The result was that the group with the positive mood performed more creatively on a range of tasks than did the opposite group. Therefore, it was suggested that the positive mood of individuals facilitates the fluency of idea production whereas the negative mood inhibits it (Vosburg, 1998).

Recently, Mumford (2003) put special emphasis on researching the relationship between affect and creativity. He criticized the traditional cognitive research in creativity as being too focused on *cold cognition*, which relates to information-processing, instead of studying the effect of emotional reaction on creativity. On the other hand, a counter idea of promoting individuals' positive moods to enhance creativity development was sustained by Anderson, Arlett and Tarrant (1995), who rejected the positive effect of the individuals' positive moods in creativity by their comparative investigation of positive, negative and neutral moods of participants in creative performance. By comparing the *neutral mood* condition, their investigation revealed that the positive mood can have an apparently negative effect on creative performance. Similarly, Kaufmann and Vosburg (1997) carried out two experiments on individuals' positive moods in creative problem solving; they found, by comparing them to other individuals in negative and neutral moods, that those with positive moods were the poorest problem solvers. Additionally, some researchers even asserted that an individual's negative mood could boost creative problem solving because this negative emotion helps individuals to work for new and alternative solutions (e.g. Getzels and Csikszentmihaly, 1976; Runco, 1994; 1999; Szymanski and Repetto, 2000). It seems to me that it is difficult to make a judgment on whether positive or negative mood is beneficial to design students' creative performance. Nonetheless, student's mood during the creative thinking process is, to some extent, affecting their creative performances. Therefore, I presume that the student's mood is one of the key components in shaping their creative-friendly learning behavior. My research investigated the kinds of moods that design students have been in during creative thinking process in the shared virtual reality, and how this learning behavior assists or obstructs their creative development.

1.3.6 Removing students' obstacles to creativity

Ng (2001) conducted a cross cultural investigation of the relationship between culture and creativity. He studied how different cultures affect creative behaviors by comparing the two major cultural bodies, namely *Western* and *Eastern.* In his categorization, the western cultural body included America, Britain, Canada, Australia and New Zealand, and Eastern cultural body was comprised of China, Japan, Taiwan, South Korea, Hong Kong and Singapore. Literally, this difference is between liberal individualism (open and democratic exchanges of ideas) and Confucianism (Social order and harmony in society) (Ng, 2001). Lubart (1990) stated that individuals who are from the societies with more *freedom,* namely America and Europe, are more creative than people in China and religious India due to the openness of the social environment. That is why Ng (2001) mentioned the cross-cultural variation of creativity. One of the reasons is that the Easterners behave in an interdependent manner which differs from Westerners' independent manner (Markus and Kitayama, 1991). In other words, the Western conception emphasizes the individual (Hsu, 1955; Baumeister, 1997) but the Eastern conception focuses on the social group (Markus and Kitayama, 1991; Tu, 1993). This social-minded manner in Eastern societies hinders individuals' openness in raising their voices, opinions and ideas. This is regarded as the negative effect of *groupthink* (Janis, 1982), in which the group members attempt to reconcile the argument by compromising others in order to maintain the cohesion inside the group. Despite the argument that Asians are really less creative than westerners, it is difficult to identify different kinds of creativity among nations; and, indeed, it is also hard to measure and compare individual's creativity (See Chapter 3.4). However, I do believe the impact of the social group is crucial in developing students' creative-friendly learning behaviors. In view of the Hong Kong design students, *fear of criticism* and *groupthink* seem to be two of the crucial barriers in obstructing their creative performances, particularly in tertiary design education (Lau, 2003). Hong Kong design students are afraid of expressing their ideas to other group members due to the fear of being criticized, and trying to maintain a sense of groupthink. Therefore, design students tend to employ a *silent* approach during group discussion or brainstorming exercises. Moreover, some students have a strong perception of the *right* answer in their minds; they are spontaneously filtering out the *wrong* answer if they believe it is not useful or creative. Students are too aware of their expected norms in the thinking process that will limit the quantity of ideas they could possibly make. Therefore, design educators need to play an essential role in releasing students' creative potential by intentionally removing all possible obstacles to creativity in order to facilitate the design students' creative thinking process and shape their learning attitudes constructively. To find out and address the impact of groupthink on Hong Kong design students, I studied students' learning experiences during their creative thinking process in the shared virtual reality in order to probe whether the ICT supported learning experiences could or could not be a way to remove these obstacles by bringing students to another arena without cultural boundaries.

1.4 The computer-aided pedagogy in design education

This section discusses the possibilities of using ICT and virtual platform in conducting creative thinking exercises in tertiary design education. I am going to evaluate the ICT supported design-related subjects in Hong Kong and the existing ICT tools which are employed in creativity training and design education. My prior study in computer-aided pedagogy in design education is also reviewed here in order to highlight some advantages of employing computer-aided teaching plans in conducting creative thinking exercises for design students in Hong Kong.

1.4.1 Insufficient ICT support of the design-related subjects in Hong Kong

The Hong Kong Government launched the policy of a Five-year Information Technology (IT) in education implementation strategy in 1997. This policy successfully equipped all primary and secondary school teachers in Hong Kong with the different levels of IT competency in 2003 (EMB Policy Report, 2004). Similar cases exist in the local tertiary level, where all universities and colleges established IT departments to support ICT in education and maintain infrastructures. Diverse learning portals, namely the WebCT and the Blackboard system, were set up as some learning partners for teachers and students among local universities and colleges. The popularity of using IT in education indeed not only changed the concepts of applying computers in teaching and learning, but also mutated the students' learning experiences. It resulted in urging the revision of conventional educational pedagogy and curriculum in all disciplines. The blossoming of IT in education is not only supported and funded by the Hong Kong Government, but also by other commercial and Non-Government Organizations (NGOs). An outstanding example can be found in the Hong Kong Education City (www.hkedcity.net) which was established in 2000. This learning portal mainly assists teachers' professional development and provides online support to schools and teachers through the hub of high quality digital resources.

In tertiary education in Hong Kong, universities established their online learning programs and E-Learning systems for local and overseas students in order to accelerate the emergence of new knowledge and stay competitive in this ever-changing society. A pioneer model occurred in 1994; the Chinese University of Hong Kong (CUHK) developed the Hong Kong School Net (HKSN), which is a non-profit-making platform that aims to advocate the use of the Internet among students, teachers and other educationists by educating them in an appropriate manner of using the Internet as well as facilitating the development of educational content online (HKSN, 1997). My university, which is the HKPolyU, has established a virtual university called the *"Hong Kong CyberU"* (CyberU) aimed at promoting life-long learning by helping working adults to pursue higher education in a flexible, practical and convenient learning manner. The CyberU offers about 33 online undergraduate programmes and short courses, mainly in the areas of business, management, law, engineering, information technology, Chinese medicine and language studies (http://www.hkcyberu.com/). As I stated earlier, the HKPolyU is the only local university which offers UGC funded design programmes, hence the HKPolyU is supposed to create art and design related programmes or subjects in this cyber platform. Regrettably, there is no design programme or subject to be found in the

CyberU at this time. I could imagine that it would be more difficult for other universities in Hong Kong to launch design-related programmes online due to their lack of expertise in design education. Moreover, there are no design-related subjects at the Open University of Hong Kong (OUHK), the biggest educational body in Hong Kong to offer mainly online and distance learning programmes. Apparently, Hong Kong is equipped with sufficient information infrastructures among schools and universities as well as solid teaching and learning experiences in E-Learning. However, the development of the E-Learning in design education and other creativity studies is lacking. What are the major obstacles for creating design-related subjects online? Are the learning experiences in design education fundamentally different from other subjects, especially when it comes to using the virtual platform? These are the additional research questions I would like to address in this study.

1.4.2 Evaluating existing ICT tools for creativity and design education

When the artificial intelligence system, called the "*Deep Blue*", defeated the World chess champion Garry Kasparov in 1997 (Casti, 1998), people came to believe that the computer can *think*. Despite the arguments about the *thinking computer* in subsequent years, Cross (1999) questioned the computer's ability to design - Could computers replace designers' work? Hitherto, there has been NO significant research proving that the computer is able to design automatically, but computers can assist designers to design as well as facilitating their creative thinking in some ways.

One of the most notable online learning portals for design education is the Apple Learning Services (ALS) (http://henson.austin.apple.com/edres/ccenter/), which offers various autonomous-learning materials for studying graphic design and visual communication. The educational development team of Apple.com regularly uploads free design-related learning kits for lifelong learners in the design profession. The ALS also emphasizes creativity training for designers. A learning kit called the "*Think Different Mini-Theme*" has been designed to help design educators in arranging learning activities for students. This learning kit fosters students to learn different types of creative thinking skills by providing 17 classroom activities. Some of the educational activities are constructive and interesting, for instance design educators can ask students to role-play a subject called "*Stories that end but aren't finished*", leading the students to come up with multiple solutions in problem solving by story making. Another interesting learning activity asks design students to compile their own lists of people they admire and analyze the differences among these notable people. The ALS tries to develop design education by providing actual teaching plans for design educators, however, these sorts of "canned" lesson plans are not applicable to the actual design education at the tertiary level, particularly in Hong Kong, because (1) the contents of the lesson plans are too simple and general; (2) the platform is only focusing on providing educational materials for teaching but does not emphasize learning and learning experiences; and (3) platforms lack quality assurance indicators and assessment criteria which are significant for educational evaluation.

A similar case is found at the Powerhouse Design Skills (PDS) (http://graphic-design.com/DTG/DTG-Solutions/Creative-Thinking.html) which offers online design courses in creative thinking and publication design. The PDS provides a series of analytical concepts to facilitate designers' creativity. An example is called the "*Five Steps for Success*" which aims at refreshing designers' basic understanding of the principles of design by introducing various conceptual tools. One of the most significant features in PDS is helping design students to build up their alertness to self-critique. The PDS provides a clear educational ladder including aims and objectives for autonomous learners. Nevertheless, the PDS still has room for further development before being applied to formal design education. For instance, the PDS is based mainly on the text-format without any interactive activity. It fails to simulate design students' motivation for self-learning; and the assignments are too simple in comparison with the traditional creative thinking exercises in design education. Another case study is the Brainstorming.co.uk (http://www.brainstorming.co.uk/) which offers comprehensive online support for teaching and learning in the subjects of creative and lateral thinking skills. This platform provides clear learning guidelines, lesson plans and educational materials for educators and students. One of the most distinguished features in this platform is the creation of 11 educational engines based on different educational needs for various disciplines of education. These educational engines provide diverse learning approaches for teachers to select and arrange for their own teaching purposes. However, most of the engines are similar in terms of learning objectives and outcomes, and educators and students are bored with doing similar exercises repeatedly. Additionally, some other examples can be found online, such as the Weekly Puzzles by Enchanted Mind (http://enchantedmind.com/html/esamples.htm), and the Visual Learning by Inspiration.com (http://www.inspiration.com/vlearning/index.com), but similar problems are found with these platforms.

The above online portals of teaching and learning creativity in design education only focus on providing teaching materials, namely lesson plans, instead of deliberately considering the arrangement and implementation of the learning activities for design students in facilitating their creative thinking. Özdemir and Alpaslan (2002) criticized most Internet-based learning systems as unintelligent tutoring systems. They only provide course materials for easy access. In my study, I pointed out the importance of the environmental stimulation and students' creative-friendly learning behavior in releasing the design students' creative potential in early sections. Therefore, design educators need to understand design students' learning experiences inside the virtual platform in order to carry out the learning objectives and obtain expected learning outcomes successfully with ICT support.

1.4.3 My prior study in computer-aided pedagogy in design education

My prior research studied how computers can assist design students in learning creative thinking skills in tertiary design education (Lau, 2006a). This study explored the possible ways of using ICT tools in facilitating design students' creative thinking processes. The research was divided into three areas consisting of 3F (3 Foci), 3L (3 Lesson Plans) and 3P (3 Phases). As figure 2 shows, Area One studied the 3 Foci, which consists of the reviews of various ICT tools, online educational platforms and offline educational software, and discussed the possible implementation of these resources in teaching creative thinking in design education as well as examining various educational models of creative thinking at tertiary level. In Area Two, three tailor-made lesson plans were designed based on the findings and implications of Area

One. The three lesson plans were (1) the conventional lesson plan which is typically adopted in local tertiary design education; (2) the ICT assisted lesson plan for individual students in learning creative thinking skills; the online image search engines and the software called *"Decision Explorer"* (software for making mind-maps) were used in this plan; and (3) the ICT assisted lesson plan for a small group of design students; both image search engines and discussion forum were employed in this lesson plan in Area TWO.

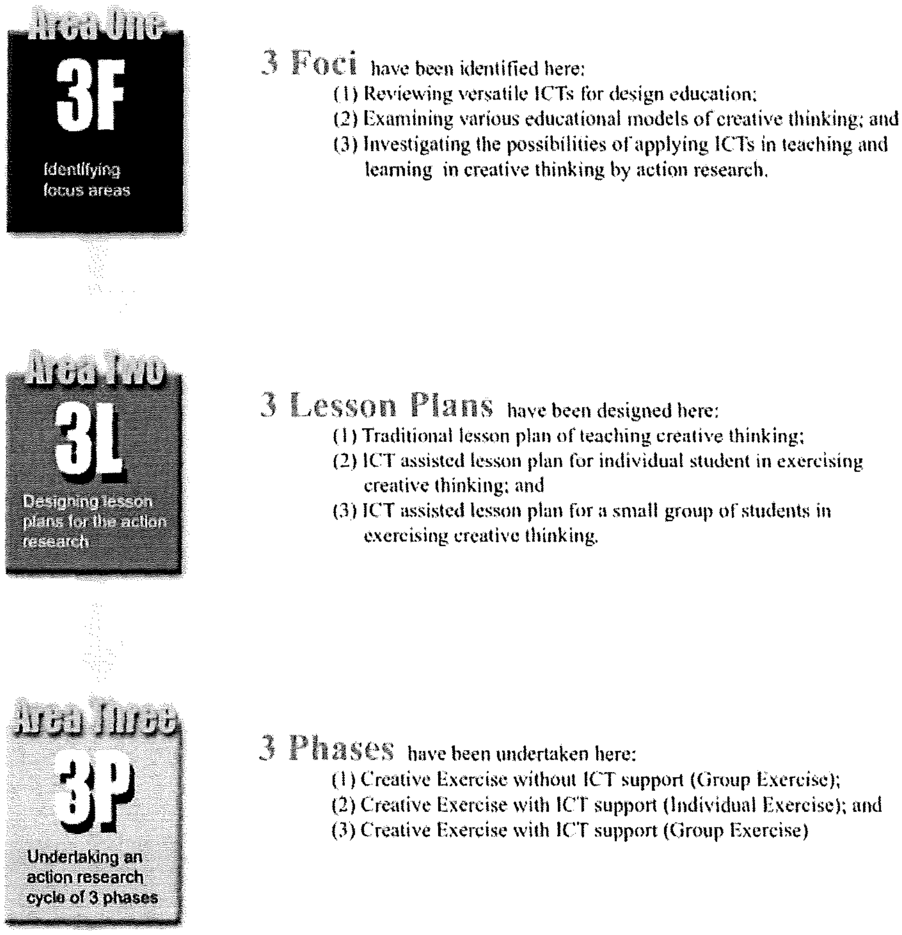

Figure 2: My prior study in computer-aided pedagogy in design education

In Area Three, the action research cycle was implemented in THREE different phases (See figure 3). Phase One studied the conventional pedagogies of teaching creative thinking skills and I found some possible ways of employing ICT tools for Phase Two. In the following two phases, Phase Two and Phase Three, I generated two computer-aided lesson plans for testing, and I found some advantages of using ICT in teaching and learning creative thinking in design education. This study provided me with a basic understanding of how computer and ICT tools could help design students in facilitating their creative thinking processes. The following findings are the advantages of applying ICT tools in teaching and learning creative thinking, which have been extracted from my prior research. ? Ref.

a. Flexibility in a digital environment: ICT provides a flexible learning environment for design students without limitation of time and space. *"Relaxing"* is one of the crucial elements in facilitating students' creative thinking processes. Thus, the digital platform offers sufficient time for students to obtain relaxation before or during the process of the creative exercise. In other words, students need not worry about how long they spend on each step of the exercise or even the deadline for completion. ICT helps autonomous learners to avoid expecting quick results during the creative process;

b. Stimulation in the digital environment: Computer assistance widens design students' horizons through digital media without any space constraint. Although students are situated in a small classroom or workshop, they can access the World virtually thought the Internet and various search engines.

This *library-linked* virtual world helps design students to obtain relevant materials for doing creative exercises as well as receiving stimulation during the creative thinking process from astonishing websites, images, pictures, interactive files, flashing objects and online games; and

c. Anonymity in the digital environment: *"Fear of criticism"* is one of the key obstacles to the creative thinking process. Design students are afraid of expressing their ideas to other group members due to the fear of being criticized. Computer assistance moderates this anxiety by providing a flexible virtual discussion platform. Students are able to post their rough ideas onto the platform without any identification of themselves. They can create new identities or avatars to represent themselves during the group discussion. Every participant is free to express his or her rough ideas without any hesitation.

The above findings have provided me with the underlying reasons for employing ICT in design education, and urge further studies of design students' learning experiences online, especially in shared virtual reality.

Phase One	*Phase Two*	*Phase Three*	
Duration	Approx. 2 1/2 hours	Approx. 1 1/2 hours	Approx. 2 hours
Mode	Group Exercise	Individual Exercise	Group Exercise
Number of Participants	6 full-time Design Students	5 Part-time Design Students	6 full-time Design Students
Computer Engine *Assistance*	Nil	+ Image Search Engine + Decision Explorer	+ Image Search + Discussion Forum
Remarks	+ It was a conventional process of creative exercise + Participants used ball pens, layout papers and some simple tools to complete the exercise	+ Participants were required to use Image Search Engine to assist themselves in creative thinking + Participants found a huge number of random images by using keyword search + Participants were required to use Decision Explorer to organize their creative ideas	+ Participants were required to use Image Search Engine to assist themselves in creative thinking. + Participants found a huge number of random images by using keyword search + Online discussion forum helped participants to share and exchange ideas + Participants were separated in different areas physically in order to prevent from face-to-face contact

Figure 3: An overview of implementing the action research study

Nonetheless, this piece of research has been employed to evaluate the existing pedagogy in design education in Hong Kong while exploring the major factors of implementing computer-aided lesson plans in a the real situation. This study aimed to bring *"change"* to conventional pedagogy in design education. This study was completed in 2003, and the findings were presented in the World Conference on Educational Multimedia (ED-MEDIA) in Orlando in 2006. As well as the aforesaid advantages of employing ICT in design education, I also found that the computer facilitated communication between students-to-students and students-to-teacher during the learning process and established a proactive learning environment for ideas sharing and exchange.

1.5 Summary of Chapter ONE: Background of the study

In Chapter ONE, I explained the underlying structure of SD 2000 and how this module interacts with design education in Hong Kong. I also explored the problems which this module has confronted under the ever-changing global market and reduction of credit by the educational reforms in Hong Kong. I suggested E-Learning and computer-aided pedagogy could be one of the solutions addressing these challenges if design educators are able to understand their students' learning experiences online and arrange appropriate teaching plans accordingly. Indeed, any types of new teaching and learning methods are possible under the rapid development of the Internet (Schank, 1994). On the other hand, I revealed the significant role of environmental factors in releasing the students' creative potential. The creative-friendly space is potentially able to offer socio-cultural stimulation and a heuristic learning atmosphere to facilitate students' creative thinking processes. As I stated, design students in Hong Kong have limited living and working space (See Section 2.3.3 Findings of Phase ONE (Part 2): The photo ethnographic research) therefore, I suggest that this could possibly hinder their creativity development. I presume that in shared virtual reality it is possible to establish a creative-friendly space for design students if I study how they are interacting with the virtual space. In addition, developing creative-friendly learning behavior in design students' is one of my major concerns in facilitating creativity training in SD. This could possibly be achieved by enhancing their intrinsic motivation, positive, forward thinking and self-determination as well as managing student emotions and intentionally removing obstacles to creativity. According to my prior research and study in ICT-supported creative thinking exercises (Lau, 2003; 2006a; 2006b), I reported that ICT has certain advantages, for instance the flexibility and anonymity that can facilitate the creative thinking process of design students in Hong Kong; I assume that the shared virtual reality, which is a hyperrealistic environment, could possibly enrich the teaching and learning experiences for both design educators and students in SD.

In order to illustrate the THREE major components involved in releasing design students' creativity and enhancing their learning experiences in creative thinking exercises, I have summarized the factors that I explored as a "*Creative Triangle*" which is shown in figure 4. This triangle is comprised of THREE components: (1) Designing Appropriate Creativity Training: Design educators have to design and arrange appropriate creativity training exercises deliberately for design students; (2) Developing Students' Creative-friendly Learning Behavior: Design educators ought to assist students in developing their positive learning behavior in creative thinking, for instance thinking interestingly, positively, and laterally; and (3) Establishing a Creative-friendly Environment: Design educators need to establish a proactive learning space with the support of creative climate and socio-cultural stimuli. As the figure shows, if design educators could create and manage these three circles effectively, the hidden triangle (which represents the hidden potentials of design students) appears simultaneously.

PICTURE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

However, the actual ways of establishing these components need further studies. I intend to research the ways in which the design students' learning experiences can be enriched and can be released under the interactions and collaborations within these components. In other words, a well-developed creativity training module is insufficient to release the students' creative potential due to the lack of the other two components. Moreover, I assume that the design students' learning experiences in creativity training are conditioned strongly by their learning behaviors and the space. Indeed, the findings of this research (See Chapter SEVEN) showed the environmental impact of the virtual space facilitated design students' creative thinking during the learning process. To be specific, the virtual reality and its impact provided students with a game-like learning experience and helped them to obtain creative-friendly learning behavior during the process. Nonetheless, the later chapters of this thesis will focus mainly on discussing these components of the *Creative Triangle* in order to study the design students' learning experiences in a shared virtual reality as well as the possibilities of employing virtual platforms in teaching and learning SD 2000.

Chapter TWO: The Research Planning

This chapter introduces my research planning and reports the findings and implications of my preliminary research in Phase ONE. I will present my research focus and research plan as well as addressing the ethical issues and limitations of my research. In the latter part of this chapter, I will report my preliminary data collection and analysis of Phase One (Part 1 and Part 2), which are the pilot quantitative research and the photo ethnographic research. Discussion of the findings and implications of Phase ONE will be provided in this chapter in order to give a brief understanding of the actual situations of students' perceptions of creativity and creative-friendly environments as well as the actual working and living environment of Hong Kong's design students.

2.1 The research significance and focus

My study attempted to deepen the understanding of the learning experiences of design students in undertaking design-thinking exercises in a shared virtual reality. I would like to identify the areas of an appropriate pedagogy for E-Learning and the use of a shared virtual environment for students in tertiary design education. Other questions, arising from this research are: (1) in what ways a virtual reality releases the creative potential of design students; (2) how a virtual reality affects the design students' learning experiences; and (3) how the computer plays a role as a learning partner in design education. Can virtual reality assist design students to learn design thinking skills effectively with the help of an appropriate pedagogy as well as reinforcing the nurturing of a creative climate in virtual reality? This research aims to: (1) look at design students' learning experiences in the module SD 2000 Design Thinking in a shared virtual reality; and (2) explore the implications of using shared virtual reality in design education.

2.1.1 The research questions

As mentioned In Chapter ONE, there are some important questions to be answered before studying students' virtual learning experiences in virtual reality. The FIVE major questions to be addressed are;

(1) Why do design educators need to use virtual learning environments for design education in Hong Kong, particularly in teaching and learning about design thinking?

(2) What are the design students' expectations of a creative learning environment for undertaking creative exercises? In particular, what do they expect of a computer-simulated creative learning environment?

(3) What is the definition of creativity in design education and how can design students' creativity or creative performances be measured?

(4) How can appropriate learning activities for creative thinking be arranged within a virtual learning environment?

(5) What are the major advantages and disadvantages of using a shared virtual reality in design education?

After the discussion of various studies of students' learning experiences in virtual reality, presented in Chapters FOUR and FIVE, TWO potential aspects of virtual reality can be identified, namely (1) hyperrealistic simulation in virtual reality; and (2) virtual communities for collaborative learning. This gives rise to the formulation of TWO directional hypotheses underpinning the design of a shared virtual reality. They are;

H 1 – Establishing a computer-simulated learning environment is a factor for developing students' design thinking skills.

H2 – Constructing a virtual community for hyperlearning is important in establishing collaborative learning among design students engaged in design thinking.

2.1.2 The research plan

My research plan was divided into **FIVE** phases (See figure 5)

Phase ONE: Preliminary research (Part 1 and Part 2) - A pilot quantitative study (Part 1) and a photo ethnographic study (Part 2) were carried out to explore the design students' understandings and perceptions of creativity, creative thinking exercises and environmental considerations as well as their actual working and living environments at home in Hong Kong which might affect their creative development. In the quantitative research (See Appendix A), a questionnaire with 20 behavioral and classified questions was designed to investigate the: (1) students' understanding of creativity; (2) students' obstacles to creativity; (3) students' opinions of designing creativity training exercises; and (4) students' ideas of establishing creative-friendly environment for conducting design-thinking exercises.

Meanwhile, in the photo ethnographic research, selected design students were given a camera and asked to capture images of their actual working and living environments. This research aimed at studying their working environments and seeing how these environments affect their learning experiences in design thinking. *Ethnography* usually relies on extended fieldwork with a certain lengthy amount of time in the field (Ireland, 2003), however, this photo ethnographic research was a pilot study under time constrains.

Phase TWO: Designing an appropriate lesson plan for research – This phase aimed at discussing the design of an appropriate lesson plan for conducting the module SD

2000 Design Thinking in a shared virtual reality which was based on the analysis and findings of Phase ONE;

Phase THREE: Establishing a shared virtual environment for conducting the module SD 2000 Design Thinking in virtual space - this phase aimed at designing and establishing a shared virtual environment for implementing the designed lesson plan for SD 2000. The shared virtual environment was built in a selected shared virtual learning reality called *ActiveWorld* ©, and a community of students' web blogs was also created in this phase.

Phase FOUR: Multimodal interaction research was conducted that studied students' learning experiences in a shared virtual reality - this phase aimed at implementing the designed lesson plan in the *ActiveWorld* ©, and employing the multimodal interaction research method to collect data in the areas of the: (1) student-environment interaction (including the virtual spaces and virtual objects); (2) students' emotional displays during the creative learning process (including behavior system of avatars); and (3) peer interaction among students (including text-based communication). A group of EIGHT design students was selected to participate in this phase. The researcher adopted the role of complete observer (Gold, 1958) for this qualitative observation during the research process. The Conversation Analysis (Psathas, 1995), Textual Analysis (Adolphs, 2006; Hughes, 2007) and Multimodal Interaction Analysis (Norris, 2002; 2004) were employed to analyze the participants' conversations and multimodal actions (See Chapter 6.1.1 for the ways of anaylsze multimodal interactions in Phase FOUR).

Phase FIVE: Post-lesson data collection - semi-structured post-lesson online interviews were carried out for all participants in order to collect their feedback and reflections regarding their online learning experiences in a selected shared virtual reality. In addition, students' virtual lablogs, by means of Web blogs, were collected to assess their creative achievement. The Textual Analysis (Adolphs, 2006; Hughes, 2007) was employed to analyze the online interviews and self-reflective journals.

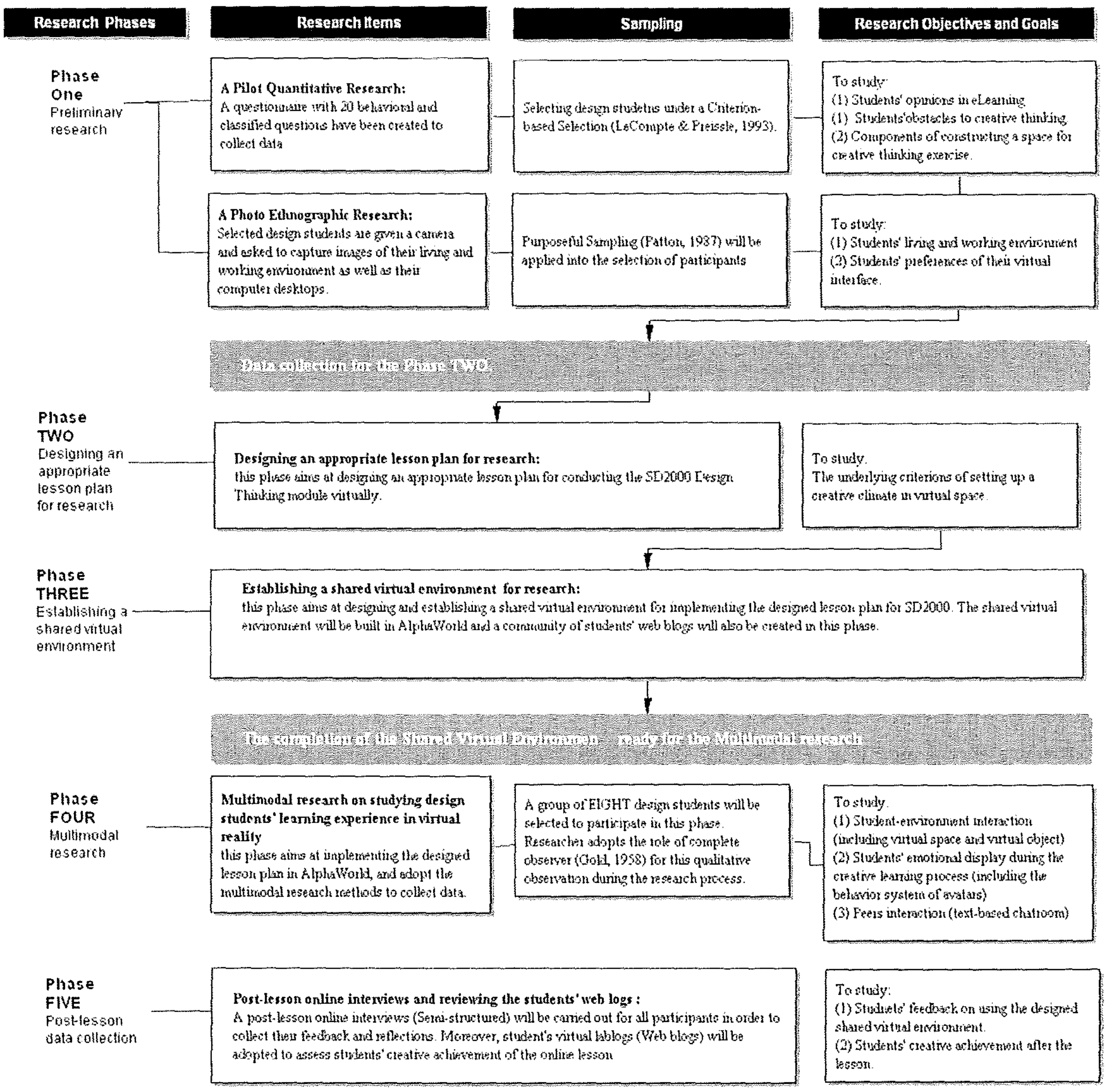

Figure 5: My research plan

2.1.3 The ethical issues of the research

The research design took into consideration the code of ethical guidelines which was set by the British Education Research Association (BERA) in 2004. The research report of this research has been accomplished with honesty, openness and respect for personal values and knowledge. In designing the questionnaires and other research means, I considered the nationality, cultural, religious, gender and other diverse factors that may cause difficulties in participants' contexts. The participants' privacy was also given high consideration and care was taken not violate this in any circumstances.

such as?

All participants were acquainted with the aims and objectives of this research by a clear explanation from the researcher before the commencement of each phase. Participants understood that the research was being conducted on a voluntary basis, and that they would not get any benefit from participating in the study. They were also assured that they were able to withdraw and stop participating in this research at any time they wished. They would not be penalized in any way if they withdrew and stopped participating in the study. There were no risks associated with participating in this research. TWO written consent forms (See Appendices B and C) were issued to every participant individually in order to seek their agreement to participate in the questionnaire completion, photo-ethnography, multimodal interaction research, online interviews and web blogs' assessment.

In addition, all participants were guaranteed anonymity and the confidentiality of their responses. Their interpersonal conversations, personal emotional displays and learning activities within the shared virtual reality were recorded without mentioning their names. In the final report, all names of participants have been eliminated and represented by other means, namely by coding them as design student 01 or 02 etc. The draft of the transcript and other multimodal recordings was circulated among all participants for verification in order to ensure their comments and ideas were documented and presented accurately.

The researcher's position of authority was another issue to be considered. Although the researcher is one of the faculty members in SD, HKPolyU, he is neither involved in the formal assessment of the said research module SD 2000 nor any further modules of the voluntary participants. Students were thus assured that their participation or performance in the research in all phases would have no effect on their assessment results in their academic subjects.

2.1.4 The limitations of the research

Since this research focused on a small number of core participants in tertiary design education in Hong Kong, the result is not considered to be a generalization of the area of study. The researcher acknowledges the potential effects of participants' different cultural and ideological backgrounds as well as psychological reactions towards the shared virtual reality and online platforms. Limitations exist in terms of generalizing participants' opinions and analyzing their bias in operating virtual platforms.

Regarding the validity of the research findings, the researcher paid attention to the availability of various digital records of participants' learning experiences in the shared virtual reality and verification of the transcript by online interviews that might have improved the validity of the final report.

It is inevitable that the results may have been influenced by the lecturer-student relationship between the researcher and participants. This relationship might have affected the participants' responses to questions and performances in the multimodal interaction research in Phase FOUR and Phase FIVE. The researcher was aware of these possible distortions and studied the observations and participants' responses carefully. All transcripts and notes have been kept by the researcher to support the analysis further and/or to serve as triangulation of certain pieces of information if necessary.

In addition, SD 2000 is delivered on a collaborative basis which involves another THREE faculty members. This might have had some effect on the content of the module and on the perception of the relevant theories and concepts which may have influenced how the participants expressed their opinions and ideas. To minimize any influence by the discrepancies in teaching and learning strategies in SD 2000 by different faculty members, a unique teaching plan was designed in Phase TWO and adopted in the research of Phase FOUR.

2.2 The research planning and methodology

In the following sections, I will present the planning of my research in Phase FOUR and Phase FIVE, which were the multimodal interaction research on studying students' learning experiences in the shared virtual reality and the post-lesson data collection of gathering students' feedback respectively. Emphasis is placed on: (1) reviewing my concerns about setting up a pilot lesson plan in a shared virtual reality for collecting data; (2) discussing the reasons for using multimodality discourse analysis in my research; (3) highlighting the criteria for selecting participants and identifying the group size for research; and (4) introducing the methods I used for data collection in each of the phases.

2.2.1 Setting up a pilot lesson plan in the virtual classroom

As I highlighted in Phase TWO of my research plan, a pilot lesson plan was designed for conducting SD 2000 in a shared virtual reality. Since SD 2000 is a complete subject with a total of 14 hours it was not possible to involve all lessons in my research. Therefore, a pilot lesson plan, which was extracted from SD 2000, was introduced in this research in Phase FOUR in order to collect data from the design students' learning experiences in the shared virtual reality. (See Chapter 3.3.2 and figure 12 for the details of the pilot lesson plan).

2.2.2 Using the multimodal interaction analysis and post-lesson interviews

The multimodality research method was formulated by Kress and Leeuwen (2001) in order to analyze the objects of visual culture. The original idea of multimodality came from Kress' theory of social semiotics that can be applied to analyze media, images, advertising and illustrations. Kress and Leeuwen (2001) expounded that the significations (meanings) of visual forms are determined by their inherent series of sign systems which consists of modality, affectivity, material basis, spatial placement and so forth. Kress and Leeuwen (2001) defined that the multimodal theory of communication is focused on TWO issues: (1) the adopted modes and media in semiotic communication; and (2) the implementation and practice of this adopted semiotic communication. In making sense of this multimodal communication, meaning is created by a multiplicity of semiotic resources and of diverse modes and media (Kress and Leeuwen, 2001).

Numerous channels, such as spoken words, intonation, facial expression, body gestures and eye gaze facilitate communication and interaction among people (Vilhjálmsson, 1997). Weisbrod (1965) described *looking* (gaze) as a way to coordinate group inaction, particularly supervising the progression of speeches. Additionally, Argyle and Cook (1976) pointed out that *eye gaze* during face-to-face conversation has THREE main functions: (1) seeking information; (2) sending signals; and (3) managing the process of conversation. Similarly, facial expression is essential in delivering and receiving information during conversation (speech channel) (Argyle and Cook 1976). During the conversation, the prominent points of speech are emphasized by the integration of these channels (Chovil 1992, Prevost 1996). Various studies have explored these functions of multimodal conversation, for instance in the verbal aspect (e.g. Schegloff, 1968; Schegloff and Sacks 1973; Adler, Iverson, 1974; Beall *et al.*, 2003), in eye gaze (e.g. Cary, 1978; Kendon 1990; Yee, Bailenson, Urbanek, Chang and Merget, 2007; Tampone, 2008) and body gesture (e.g. Kendon, 1990). Details of how I applied multimodal interaction analysis to analyze my research data were discussed in Chapter 6.1.

Because of the popularity of computer technology and digital culture, all different semiotic modes converge technically as the same medium of presentation under digitization (Addison and Burgess, 2000). Kress and Leeuwen (2001) elaborated that, because of digital technology, the single individual is able to manage all modes to execute the multimodal production independently. Certainly, virtual reality provides ways of tracking all movement within the space in order to analyze working patterns as well as ways of collecting data which facilitate the research design process (Borner, et. al., 2002). According to my research focus, I was looking at the learning experiences of design students in a shared virtual reality particularly in the creativity training subject SD 2000. Design students were asked to use avatars to represent themselves within the shared virtual reality, and these avatars could perform certain default emotional displays as well as body gestures. I was also looking at the students' interactions among students, facilitators, robots and the virtual environment. In this case, the multimodal interaction research method helped me to collect and analyze data from versatile perspectives, particularly in relation to how design students experience their learning process with digital presentation and representation.

Furthermore, a series of post-lesson interviews was conducted to collect qualitative data on students' feedback and comments on their learning experiences in the shared virtual reality.

Last but not least, for the multimodal interaction research in Phase FOUR and Phase FIVE, the techniques of the (1) Conversation Analysis (Psathas, 1995); (2) Textual Analysis (Adolphs, 2006; Hughes, 2007); and (3) Multimodal Interaction Analysis (Norris, 2002; 2004) were employed to analyze the participants' conversations and multimodal actions. The detailed explainations of how I apply the above methods in anaylsing my data in Phase Four and Phase Five was presented in Chapter 6.1.1 (Ways of anaylsing communicative modes and mediated actions).

2.2.3 Selecting participants and group size

In my research, Criterion-based Selection (LeCompte and Preissle, 1992) and Purposeful Sampling (Patton, 1987) were applied to the selection of participants who were under the same purpose of research focus in SD, HKPolyU. The selection of appropriate students participating in the study was very important and this definitely affected the quality of the results. The criteria for selecting appropriate informants were as follows:

- Asian design students in SD, HKPolyU;
- Asian design students who have had certain previous experiences in working with the creative and design thinking process;
- Students who have the ability to operate basic ICT tools and virtual platforms; and
- Equal distribution of genders in the group.

Participants, in all phases, were expected to be from similar cultural backgrounds and academic profiles. All participants were recruited voluntarily from different levels within the SD, HKPolyU, namely sub-degree, undergraduate and postgraduate. SD in HK HKPolyU PU is the only university which offers University Grants Committee (UGC) funded undergraduate and postgraduate courses in design study in Hong Kong. Therefore, SD is one of the best representatives in local tertiary design education.

For Phase ONE (Part 1 and Part 2), there were 18 respondents for the pilot quantitative research (Part 1) and 21 participants in the photo ethnographic research. Regarding the multimodal interaction research in Phase FOUR, 8 participants took part in a series of studies in Phase FOUR and Phase FIVE, such as participation in the shared virtual reality, online interviews and writing web blogs for assessment.

2.2.4 Methods for data collection

The data collection for all phases was based on a Scientific Method (American Association for the Advancement of Science, 1990) which is a dynamic process that includes empirical observations, generating and testing hypothesis as well as building and testing theories. . The emphasis was on observing front stage behavior (Goffman, 1959) rather than backstage behavior. THREE methods of data analysis were employed to analyze the findings of Phase FOUR and Phase FIVE: (1) Conversation Analysis (Psathas, 1995); (2) Textual Analysis (Adolphs, 2006; Hughes, 2007); and (3) Multimodal Interaction Analysis (Norris, 2002; 2004). The methods of Conversation Analysis and Textual Analysis were used to analyze the conversations among participants in Phase FOUR and the dialogues between interviewer and interviewee in Phase FIVE. The method of Multimodal Interaction Analysis was applied to study the multimodal interactions of participants by means of avatars in Phase FOUR.

2.3 The preliminary data collection and analysis for Phase One

Phase ONE of my research studied the design students' perceptions of creativity and creative-friendly environments, and their actual living and working spaces for doing creative activities in Hong Kong. The findings of this phase, which included a pilot quantitative research and a photo ethnographic research, provided me with the basic understanding of the design students' learning situations in Hong Kong and constructed the background for my study. In the following sections, emphasis is placed on: (1) presenting my aims and objectives of Phase ONE (Part 1 and Part 2); (2) reporting the findings from Part 1 and Part 2; and (3) the discussion of the findings of Phase ONE.

2.3.1 The aims and objectives of Phase ONE (Part 1 and Part 2)

An effective design thinking process depends highly on students' creativity and motivation. Understanding the nature of creativity, the obstacles to creativity and the significance of creativity training excises from the views of Hong Kong design students is essential to comprehend the creativity and design development of design education in Hong Kong. These sorts of issues were explored in this preliminary research of Part 1. On the other hand, design education is fundamentally influenced by environmental factors and stimulation, such as sight, sound, taste and touch (Green, 1974). Therefore, I also wanted to look at the design students' actual living and working spaces at home in order to find out the environmental impact on their creative development in Part 2. Nonetheless, Phase ONE (Part 1 and Part 2) research was NOT intended to find out the entire statistic data for quantitative analysis, but to understand the actual phenomenon of the students' perceptions of creativity and design thinking as well as their actual living and working environments in Hong Kong in order to probe the basic component of building a creative-friendly space for undertaking SD 2000. The results and findings of this phase, including Part 1 and Part 2, aim to provide the background of study for further phases. However, this research focus was on a small number of core participants in tertiary design education in Hong Kong, hence the result was not considered to be a generalization of my study area. This piece of pilot research was only for the purpose of providing a context for my study in creativity training for design students in Hong Kong. Therefore, the results of Part 1 and Part 2 are not complete or valuable in terms of validity and reliability. Nevertheless, although a small sample of design students was selected randomly, there was a high percentage of participation.

2.3.2 The findings of Phase ONE (Part 1): The pilot quantitative research

In this preliminary research (Part 1), a pilot quantitative investigation was carried out to study design students' understandings of creativity, creative thinking exercises and environmental impact. In this quantitative research, a questionnaire with 20 behavioral and classified questions was developed to investigate the: (1) students' understanding of creativity; (2) the obstacles to their creativity; (3) their opinions of designing creativity training exercises; and (4) their ideas of establishing creative-friendly environments for conducting creative exercises. Although a small sample of design students was selected randomly, there was a high participation rate (See

Appendix D). This preliminary quantitative research received 18 responses from various levels of design students in SD, including participants from postgraduate, undergraduate and sub degree programmes. The gender distribution of this research was 27.8% male and 72.2% female respondents in the mode of full-time study in SD and most of the participating students were from the visual communication discipline. Since this study focused on finding some background information about the students' learning expectations in relation to creativity, the respondents were required to have had certain years of experience in studying design subjects and creativity training courses. Luckily, 88.9% of the respondents came from at least second year of study in SD.

According to the aforesaid FOUR research foci of this pilot study, the first question I wanted to address is how design students' understand what creativity is. This is essential to study their beliefs and assumptions about creativity and design thinking before trying to design appropriate pedagogy as well as establishing a creative-friendly environment for them. In relation to the nature of creativity, 55.6% of respondents said they believe it is something about *craziness* while 66.7% of them agreed that it relates to *exploration*. Regarding the generation of creative solutions, 38.9% of the respondents said they believe creative solution has to be *newness* and *novelty*, while 33.3% of them agreed that the solution has to be *valuable*; 27.8% of respondents said creativity requires systematic and deliberate thinking process. It is interesting to note that only 11.1% of respondents agreed that creativity is natural behavior and they believe it can be achieved by workable effort. Taking the research question personally, only 27.8% of the respondents said they believed themselves to be *very creative* while 11.1% of them thought themselves to be less creative; 61.1%

considered themselves to be normal. This result indicated that even though the participating design students were studying in at least second year in design education, they still believed they were not very creative. They stated that creativity does not necessary exist inherently but it that can be improved or developed by some means, where? for instance, tertiary design education can develop students' systematic thinking and ways of creating valuable creative solutions.

The second question was trying to understand obstacles to creativity. The respondents considered that there are FIVE major obstacles to the creative thinking process: (1) 55.6% in personal motivation; (2) 55.6% in cultural and ideological factors; (3) 50% in lack of appropriate training exercises; (4) 33.3% in the constraints of physical environments; and (5) 44.4% in personal hesitation about raising their ideas within a group. Regarding this personal hesitation, some respondents' comments are interesting, as indicated by the following examples:

"If no one knows who you are, you can express your ideas freely, and you don't need to worry or bear responsibility for what you said".

"I don't have enough confidence about the idea I raised, and I am worrying that the idea seems to be naïve to others".

Obviously, design students are afraid of being criticized by other participants during the creative thinking process. Students lack confidence in raising their rough ideas due to this personal hesitation.

The third question aimed to collect the design students' opinions of how to design creativity training exercises. It is important to note that a high rate of 72.2% of respondents expressed the belief that creative thinking skills can be taught; and 55.6% agreed or strongly agreed that an appropriate design of creativity training exercise can help them to be more creative. Some respondents' comments are interesting, as indicated by the following examples:

"Creative thinking is a way to find out some abnormal relationship between different objects...it is important to learn that method to fuse both critical and horizontal thinking in order to foster creativity".

"Creative thinking is something about observation, experience, destruction, construction and development...it is not about creating something from nowhere. I think, those elements can be taught".

"I need more creative and real examples".

"Having more training exercises can help me think of more possibilities to solve problems".

From the above design students' opinions, it can be seen that they agreed strongly that creativity training can help them to release their creative potential. They said they believe an appropriate arrangement of creativity training exercises should be based on the integration of versatile thinking modes, such as critical thinking, logical thinking and lateral thinking. In addition to the content of creativity training exercises, time constraint is a common concern among participants, with 61.1% of respondents saying they prefer to be able to complete a creativity training exercise within 30 to 60 minutes.

The final focus of this preliminary research was to seek design students' ideas about establishing a creative-friendly environment for facilitating creative and design thinking processes. In the questionnaire (See Appendix A), two open-ended questions were designed to encourage meaningful answers by using the participant's own expectations. These were: Question 19, "Can physical space help you to remove your obstacles in the creative thinking process?" and Question 20, "What is your dream space for carrying out creative thinking exercises?" These two questions are similar in nature. I collected some interesting ideas from respondents, as exemplified below:

"...creativity comes from one's living environment and past experience".

"The environment should be tranquil and comfortable...the space contains many references and information...I can get any kind of data from media whenever I need...moreover, it is better to have a creative partner that I can exchange my idea to him/her".

"That space has comfortable chairs and soft music".

"Maybe like a club with sofas and CD players...soft lighting and provides soft drinks".

"A place which full of toys and my favorite objects...a place which has a wide floor without any chair and table...a place has posted various kinds of photographs...a place has a computer that I can search data on web while listen to different kinds of music".

"The environment must be quiet and spacious. If it is a room, it would be better to have more windows and white walls".

"The creative environment could be a café, of course not too crowded...The space provides me a relax feeling where I don't need to care about the tight deadlines".

"I prefer café, I like that relaxed atmosphere".

"It is a café where has many design books and magazines...people can sit there together having tea and snack while discussing creative ideas".

"A café has a big window. I can look at either cities or countryside through that window".

"I like to stay at home. I feel more relaxed and able to think of many ideas in this relaxed atmosphere at home".

"The more privacy that the space provides, the more freedom it can give for creative thinking...I can do and think anything freely inside that space".

To summarize the respondents' ideas of creating a creative-friendly environment, their ideal space should be: (1) comfortable and tranquil; (2) playful; (3) relaxing; (4) able to maintain privacy; and (5) equipped with formal and informal references. In addition, I was also concerned about the preferred mode of working from the students' perspective. I wanted to understand whether the students like to work alone or as a group in undertaking creative and design thinking processes. The results showed that 50% of respondents prefer to work alone while 44.4% of them prefer to work in a group. These figures disclosed a slight difference between these two modes of working. Regarding my main research question in my thesis, which was concerned with the computer-aided creative thinking exercises, it is interesting to note that only 5.6% of respondents mentioned working in hyperspace.

2.3.3 The findings of Phase ONE (Part 2): The photo ethnographic research

In this photo ethnographic research 21 design students were recruited on a voluntary basis and given cameras to capture their living and working environments at home. This research aimed at studying the design students' actual living and working environment and to determine how the space affects their learning experiences in creative and design thinking (See Appendix E). *Ethnography* relies on extended fieldwork with a lengthy amount of time in the field (Ireland, 2003), however, this purposeful photo ethnographic research was a pilot study under limited time constraints. Figure 6 presents TWO samples of the participants' living and working spaces.

PICTURE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

Despite the fact that the participants were all studying in SD, their backgrounds were quite varied in terms of geographic distribution, size and type of apartments, social and economic situation and family size. Although the participants came from diverse backgrounds, some commonalities were found in this photo ethnographic research. I found that the majority of the participants' private living spaces were less than fifty square feet, and their working areas within the spaces were even smaller. In order to make use of these tiny living and working spaces, the participants used computer roll-top desks, hanging racks and folding chairs. Despite the equipment, such as computers, monitors, printers and electronic devices, participants' photos also display many toys, photographs, postcards and decorative objects in their living and working spaces. These spaces are also full of stationery, sketch books, layouts and books.

This photo ethnographic research aimed at studying design students' working environments for creative tasks, the physical spaces of their *home studios*. In order to analyze and generalize the actual working space of the participants systematically, a thematic pie chart was created to give a visual representation of their private spaces in FOUR basic sections (See figure 7): (1) Household Commodities (HC): This section was intended to visualize students' overall living spaces including their common living commodities and furniture, such as bed, wardrobe and rack; (2) Design Equipment (DE): This section looked at design students' working equipment, such as computers, monitors, printers and electronic devices; (3) Environmental Stimulation (ES): Despite the necessary equipment and furniture within students' living spaces, there were so many personal belongings and interesting objects which provided environmental stimulation; and (4) Actual Working Space (AWS): This section indicates the design students' free space inside their home studios, that is how much physical space is left for them to manage creative activities autonomously. The reason for making these thematic pie charts was not to transform the participants' physical spaces into an accurate statistical representations, but to try to visualize the spaces by providing an easy and clear format for displays.

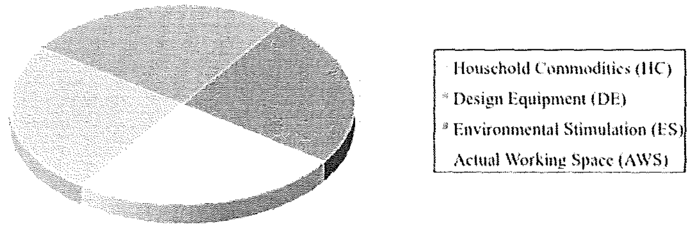

Figure 7: Schematic pie chart for indicating students' living and working spaces

This thematic pie chart provided me a schema to understand the actual situation instead of looking at each picture separately and subjectively. In figure 8, I have demonstrated two examples of how I analyzed and visualized the participants' situations into a thematic pie chart. Student A's space was occupied mainly by household commodities, such as the computer roll-top desk, small cabinet and folding chair; the design equipment, namely computer and monitor, shared a certain big proportion of his space. There was little space left for displaying his environmental stimulation as well as for actual working purposes. Student B's living and working space was slightly bigger than Student A's because her working area was situated beneath her bed. Student B had almost half of her total space occupied by household commodities, and about a quarter of the total space was shared by her design equipment. This left one quarter of the total space for environmental stimulation and for actual working purposes.

PICTURE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

With the help of this method of making thematic pie charts, it was easy to compare, contrast and generalize about the participants' situations for further analysis. After analyzing 21 pictures and transforming them into a series of thematic pie charts, a representative thematic pie chart (See figure 9) was generated to present the general living and working situation of the participants. I found the actual working space for all participants was very limited due to the big proportion of household commodities as well as the design equipment. Similarly, there was only a small section of space left for displaying environmental stimulation for participants.

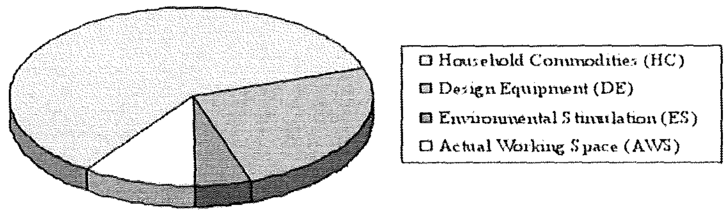

Figure 9: A representative thematic pie chart of design students' living and working spaces in Hong Kong

2.3.4 Discussion on the findings of Phase ONE (Part 1 and Part 2)

This section will discuss the preliminary quantitative research in Part 1. I found the participants' (design students) concepts of creativity are different in nature, and therefore their design thinking skills. It raised my concern to study the nature and definition of creativity in Chapter THREE: Creativity and Design Thinking. Besides, students also believe creativity can be improved by developing some cognitive abilities, such as systematic thinking and ways of creating valuable creative solutions. In other words, creativity is not a stand-alone ability but makes connections with other cognitive aspects. Based on this fact, the major issue for me in designing research activities in Phases Four and Five was not to measure the students' creativity, but to find out appropriate ways to enhance and release their creative potential. Another major finding from this preliminary research is that I realized the importance of removing obstacles to creativity. To release the students' creative potential effectively, one very important factor is consciously removing obstacles to creativity. Regarding the obstacles to students' creativity, the findings from the preliminary research were similar to what we have discussed in Chapter 1.3.6 Removing Students' Obstacles to Creativity. Insufficient time for relaxation and fear of criticism are some crucial factors which affect students' creative performances during the creative thinking process. As a result, they had become used to adopting a silent approach during the group discussions or brainstorming exercises. Moreover, some students had strong perceptions of the *right* answer, so they would spontaneously filter out their expected *wrong* answers during the creative thinking process. I assert that this habitual thinking limits the quantity of ideas that students could potentially make.

Additionally, Cave (1997a; 1997b) noted that individuals' creative performances are affected easily by their personal behaviors and attitudes. Therefore, students have to manage their learning attitudes by developing in themselves a non-hectic attitude. As a design educator and a facilitator for the group creative thinking exercises, my role is essential to help design students, particularly in Hong Kong, to be aware and to avoid the obstacles during their creative thinking process. Hallman (1967) highlighted the FOUR main obstacles to creative problem solving which involve teachers' participation: (1) pressure to conform: If teachers place too much emphasis on the standardized routines and inflexible rules of the problem-solving procedure, it hinders the students' creative talent; (2) ridicule of unusual ideas: If the teacher ridicules the students' unusual ideas, it could affect the students' feelings and sense of worth, and even make them defensive and compulsive; (3) excessive quest for success and the rewards it brings: If students are trying to meet the requirements and rewards which are expected by the teacher, then it distorts the students' view of reality and creative talent in the long run; and (4) intolerance of a playful attitude: Hallman stated that a creative person often engages in childlike and silly activities since innovation calls for playing around with ideas, fantasizing about concepts and believing in any crazy idea. It is an obstacle to creative thinking if teachers are not willing to tolerate students' nonsensical actions during the process. Besides, the teacher has to refrain from being too demanding for the quick production of results (Details of studying *creativity* is discussed in Chapter 3).

On the other hand, creativity itself cannot be taught by any means, but creative thinking techniques and procedures can. An appropriate design of creative thinking Claim exercises and process can have the benefit of releasing the students' creative potential. Undoubtedly, creativity training is one of the useful methods for improving individuals' creative performance (Ripple, 1989; Nickerson, 1999; Richards, 2006). In my quantitative research (Part 1), most of the students agreed strongly that well-arranged creativity training, including versatile thinking modes such as critical thinking and logical thinking, can help them to release their creative potential. Regarding the arrangement of an appropriate creativity training exercise for design students, the steps of the creative thinking process are essential to give the students a clear learning ladder; the steps of the creative thinking process are usually divided into a few stages which includes the stages of preparation, production, evaluation and implementation (e.g. Wallas, 1926; Stein, 1967; Hogarth, 1980). Another influential identification of the creative process is the model of Creative Problem Solving (CPS) initiated by Alex Osborn in 1952, followed by many amended versions in subsequent years (e.g. Noller, Parnes and Biondi, 1976; Isaksen and Treffinger, 1985; Isaksen and Dorval, 1993; Isaksen, Dorval and Treffinger, 2000). In the area of teaching and learning the creative thinking process, an appropriate learning model, for example the CPS model, facilitates the student's learning process on one hand, and maximizes possible ideas and solutions on the other. Students can arrange their thinking and working process systematically in order to generate workable solutions to problems. Additionally, there are thousands of creative thinking skills and procedures that can be applied in diverse situations and disciplines, such as foundation education, business, product development and advertising (Torrance. 1992; Michalko, 1998). Nevertheless, design educators have to select appropriate methods deliberately and consider the mix and match issues of combining various methods effectively into one taught module.

One of the significant areas of my research was looking at environmental stimulation on the creative thinking process. Environment plays a role in facilitating creativity enhancement by sparking creative ideas, encouraging the follow-up of creative ideas and evaluating and rewarding creative ideas (Sternberg and Lubart, 1995). In Phase ONE (Part 1), I generated students' opinions about establishing a creative-friendly space for undertaking creative and design thinking processes. An ideal environment for design students, a space for either individual or group participation, has to fulfill some basic criteria, such as: (1) comfortable and tranquil; (2) playful; (3) relaxing; (4) able to maintain privacy; and (5) equipped with formal and informal references. To a certain extent, a playful or game-like environment allows individuals to be free to explore, share and evaluate creative thoughts among participants (Wallach and Kogan, 1965). Likewise, a *design* environment should provide a mechanism to individuals in helping them to contextualize rich information and design activities (Norman, 1993). A creative space has to be tailor-made to help individuals develop new knowledge within (Myerson, 2003). Thus, it is essential to establish an appropriate design environment (Fischer, 1993). In Phase ONE (Part 2), which is the photo ethnographic research, a very brief impression of working spaces is that they were generally very small, tight and messy. With the help of the method of making a thematic pie chart, I analyzed 21 examples of students' situations and transformed them into a series of thematic pie charts; (See figure 4) was generated to present the general living and working situation of the participants. As figure 9 shows, the students' living and working spaces were occupied mainly by the household commodities and design equipment. In other words, there was little space left for allocation to environmental stimulation as well as for actual working purposes. As we discussed, environmental stimulation is important in triggering creative sparks and providing the full range of formal and informal references. The insufficient working spaces of design students in Hong Kong will possibly hinder the development of their learning experience in creativity training. Likewise, the limited working space obstructs their creative working process, which affects their creative performance eventually. For instance, students found difficulties in dealing with large-scale project presentations and handling various projects at the same time due to the limited working space. In this case, computer aids and virtual space could be a solution for Hong Kong design students to tackle their spatial problems. Moreover, the participating design students were familiar with various computer software and platforms since computer graphics was one of the main subjects in their study. However, only 5.6% of respondents indicated that they had considered working in hyperspace, which can be interpreted as insufficient computer support in facilitating the creative thinking process. In my early research, I found a lack of sufficient online learning materials, engines, and virtual platforms to help design students to develop their design thinking skills (Lau, 2003). Nonetheless, some remarkable advantages of using computer aids in creativity enhancement were found in my prior research (Lau, 2006a; 2006b): (1) providing *flexibility* to design students' creative thinking process as well as creating a relaxed atmosphere by eliminating the time and space constraints; and (2) stimulating students' creative thinking by providing rich information through astonishing websites, images, pictures and interactive files. Nonetheless, to establish a virtual space for facilitating design thinking for design students is neither focus on the system nor interface designs of the ubiquitous space as well as the enormous supports from ICT, it is actually the building of learning atmosphere, creating diverse simulation, providing peers and teacher supports as well as appropriate design of learning activities. A creative-friendly environment setting should be multidimensional, stimulating and interactive (Jacobs, 1961; 1969; 1984).

2.4 Summary of Chapter TWO: The research planning

In this Chapter, I have presented the research findings of Part 1 and Part 2 of Phase ONE. To summarize my findings, I discovered that design students who participated in this study have different concepts and ideas of what creativity and design thinking are. Therefore, further studies have to be undertaken in the areas of creativity, design thinking and design education. Moreover, I realized the importance of designing an appropriate pedagogy and creating a creative-friendly environment. These are some factors that could facilitate students' learning processes and remove the obstacles to their creativity successfully. Students' learning attitudes and learning behavior, for example fear and quietness, probably influence their learning process and hence warranted further study in the next phases of my research. One of the significant findings of Phase ONE was that the actual living and working spaces for design students are dreadful in Hong Kong. Students only have access to limited spaces for doing creative work as well as insufficient environmental simulation inside the spaces. In relation to the discussion about the importance of environmental simulation in Chapter ONE, these small and messy living and working spaces possibly affect students learning and design thinking processes. After all, the study of Phase ONE provided me a brief understanding of design students' learning intrinsic and extrinsic situations. The findings also provided me with reasons for employing ICT and virtual reality in helping design students to tackle their intrinsic problems (learning attitudes and learning behavior) and extrinsic problems (the limited space).

Before going to the next phases of my study, to explore the design students' learning experiences in shared virtual reality, literature reviews of various concepts and definitions are needed to clarify some conceptual frameworks for my study, for instance the definition of creativity and design thinking, the thinking process of human beings, the measurement of creativity and design solution as well as the relationship between creativity and design education. Chapter THREE is the first part of my literature review and discusses and explores the aforesaid issues.

Chapter THREE: Design Thinking and Creativity

This chapter THREE is the first part of the literature review of my paper which focuses on studying design thinking and creativity. As I explored some essential factors for developing an appropriate lesson plan and creating environmental stimulation to facilitate the design thinking process of design students in Hong Kong in the previous chapters, this chapter will discuss some underlying principles and theories of creativity, design thinking, measurement and the assessment of creative thoughts and the relationship between creativity training and design education. I am also looking into the factors necessary for the designing appropriate learning activity for creative thinking. Last but not least, a pilot lesson plan is suggested for conducting SD2000 in a shared virtual reality. Emphasis is placed on: (1) studying the nature of creativity by discussing various notions and perceptions defining human creativity historically; (2) probing design education and creativity training by reviewing the role of creativity training in design education; (3) arranging the learning activities for creative thinking; (4) suggesting a lesson plan for actual implementation; and (5) discussing the measurement of creative learning outcomes and performances in order to arrange an appropriate assessment method for conducting SD 2000 in a shared virtual reality.

3.1 Studying creativity

systematic?

A vast amount of literature on defining and evaluating creativity has been explored from the aspects of psychology, philosophy, cognitive science and even computer science. Hitherto, there is no common agreement on the definition of creativity among researchers. Then, what is creativity? Despite the explanation of human creativity from divine ancestry (Richards, 1990), probably the first documented reference goes back to the Greek philosopher Plato's "*Ion*" in 380 B.C. (Hamilton and Cairs, 1961); Plato mentioned that creative people are required to foster the development of society. Plato's idea revealed TWO fundamental concepts of *creativity*; (1) creativity is something can be applied and worked in society; and (2) creativity relates to social development. Various discussions and assertions have been carried out in the following centuries from diverse domains. Until the last century, discussions of creativity broadened to the areas of mathematics, engineering and natural sciences (e.g. Roe, 1952; Helson, 1983; Facaoaru, 1985). Researchers began to study human creativity in a scientific manner. In the early 1950s, psychologists started the study of human creativity in a broad sense which consisted of different levels of creative thoughts and behaviors (Ripple, 1989). However, psychologists and researchers did not pay very much attention to studying creativity as a unique scientific domain. Guilford (1950) was an influential researcher in the 1950s and 60s who addressed the importance of creativity research within human behavioral studies at the American Psychological Association (APA). Guilford (1950) highlighted the lack of creativity research, noting that only 186 articles in APA from the late 1920s to 1950s had mentioned the term *creativity*. This was only 0.02% of the total articles which had been published during the said period. Followed by Feist and Runc's (1993) indication, the figure had increased slightly to 0.1% by the 1980s. Another indication, from Sternberg and Lubart (1999), was that there was up to 0.5% increase from 1975 to 1994. These figures indicate that the scientific study of creativity was started very late in human research history.

However, studying human creativity scientifically does not give us a definition of what creativity is. Many researchers believe *creativity* is a product of high level intelligence that is beneficial to society (e.g. Guilford, 1959; Taylor, 1975b; Gardner, 1993a; Csikszentmihalyi, 1996; Albert and Runco, 1999; Gruber and Wallace, 1999). On the other hand, some researchers assume that creativity is an expressive activity of every individual that happens spontaneously. It is a kind of inherent ability which allows individuals to access and express their personalities with their particular cultural perspectives (e.g. Rogers, 1959; Gardner, 1993b; Starko, 1995; Baer, 1997; Kiely, 1998; Collins and Amabile, 1999; Hickey, 1999; Rejskind, 2000). Different from the above notions, Campbell (1960) introduced a unique concept of *"Flow"* which was an evolutionary approach to identifying human creativity. Csikszentmihalyi (1990) supported this idea of *"Flow"*, and continued his research in this area in subsequent years. Despite the arguments about the success of the concept *"Flow"* in defining creativity, it offered a new perspective on conducting creativity research. After all, during these decades of intensive creativity research, some researchers have been studying the areas of profiling intellectual capacities, personality characteristics, social arrangement, creative agendas and accomplishments of individuals (e.g. Guilford, 1959, 1975; Barron, 1969, 1999; Taylor, 1975; Albert and Runco, 1999; Sternberg and Lubart, 1999; Kyung, 2005; Richards, 2006; Yeh and Wu, 2006). Other researchers have aimed at understanding the fundamental nature and mechanism of human creative intelligence and how it works (e.g. Guilford, 1950; Sternberg, 1988; Martindale, 1999; Lubart, 2001; Kim, 2005; Preckel, Holling and Wiese, 2006). Additionally, some researchers seem to have been more practical and pragmatic; they were interested in studying the human creative mechanism in order to find out how to employ these mechanisms to generate more creative ideas (e.g. Oldham and Cummings, 1995; Darin, Glynn and Kazamjian, 1999; Ekvall and Ryhammer, 1999; Runco, 2004; DiLiello and Houghton, 2006; Eisler, 2007; Goerner, 2007; Loye, 2007). Other researchers (e.g. Richards, 2007a; 2007b; 2007c; Zausner, 2007) have emphasized how artistic exploration and self-expression enrich people's creative experiences within society.

It is notoriously difficult to define creativity as, it is unlike other human intelligences such as critical thinking, logical thinking and scientific reasoning for which there are resourceful assessment and measuring methods. In addition, *creativity* happens in all disciplines, from scientific explorations to artistic performances, that have various interpretations and diverse definitions. Therefore, defining creativity is a very complicated issue, which includes a whole complexity of meanings, such as artistic expression, talent, sensitivity and inspiration (De Bono, 1970). Boden (1993) also agreed that *creativity* cannot be explained, or even described adequately, due to the richly idiosyncratic complexity of human mind and experiences. Nonetheless, Boden stressed that creativity is not fundamentally mysterious or beyond scientific understanding, the diversity of definitions relate to the diverse personal thinking styles which are constructed by individuals' given space and domain. Creativity is not about making creative ideas randomly or idiosyncratically, but rather in making an original contribution of some meaningful innovations to the given space and domain (Richards, 2006).

After all, *creativity* cannot be defined easily due to its diversity in different domains and perspectives, for example creative ability in musical composing is totally different from generating creative solutions for business problems; similarly, creative design in architecture is different from fashion design. Therefore, this chapter is going to discuss *what creativity is* rather than *defining creativity.*

Plural meanings?

3.1.1 Is creativity peculiar to genius?

A lot of remarkable people in history have been treated as geniuses in diverse domains, namely Da Vinci, Beethoven and Einstein. Researchers (e.g. Galenson, 2005) believe geniuses come in a variety of forms, but generally consider them to be well-rounded people who are able to differentiate themselves from others through great *originality*. It is easy to understand that historical geniuses are able to create something *new* for society by their creative power. However, is creativity peculiar to ? genius? Hitherto, some people still believe creativity is a special gift exclusively given to a few creative persons. Whenever people see great creative persons, they assume that they are geniuses and that their abilities cannot be trained or learnt from anywhere, namely Mozart and Einstein. I wonder, is it really true? It means that only a few people are creative but most others are not creative at all? This idea is no longer viable if the arguments of contemporary research is accepted which I am going to discuss accordingly. Parnes (1972) tried to identify the nature of a creative person; he described that an individual has to behave creatively in setting and solving problems by making use of previous experiences in novel ways; the trait of a creative person is daring to fail frequently and acting as a pioneer who is looking for productivity in the long run. If Parnes was correct, this means that making creative use of prior experiences and daring to take risks are common traits of the creative person, while these characteristics can occur in any individual. In other words, there are no differences in thinking creatively between someone designated as such and any other person; creativity is a part of human intelligence and nature. Of course this explanation is certainly too simple to conclude the relationship between genius and a so-called "normal" person. Creativity can be defined as a psychological process. This definition can be traced back to the 1930s, from Vygotski's book titled *"Imagination and Creativity in Childhood (1995)"*, which expressed a view of the creative consciousness process. Vygotski (1995) carried out research on the creative process of human consciousness. He expressed the belief that all human beings, including children, are creative and that such creativity can be applied to arts, science and all kinds of knowledge. Jung (1964) reported that individuals have their own *archetypes* and that these models of human personality or behavior could trigger the creative process. Among many psychologists and researchers, Ripple (1989) highlighted the act of creativity as being in the realm of all mankind. He also gave a definition of creativity that does not preclude the existence of exceptional acts of creativity on the one side, and the versatile creative activities from everyday creative acts on the other (Sternberg, 1985a; 1985b; Runco and Bahleda, 1986; Ripple, 1989; Richards, 2006; 2007a; 2007c; Zausner, 2007).

In addition, Herrmann (1991) stated that everyone is inherently creative, what he called the *creative person.* Herrmann believes a *creative person* is able to perform *creative expression.* According to Hermann's explanation, this sort of expression can be divided into THREE levels. The first level is the *Already Creative,* which means that the creative person is frequently exercising his/her creative mind for pleasure and profit actively. The second level is those people who experience moments of creative brilliance but only occasionally; Herrmann called this situation *Sometime Creative.* The last level is talking about individuals who can be creative but have yet to tap into their potential (Herrmann, 1991). Similarly, Bruner (1996) summarized approaches to consciousness and learning in his book *"The Culture of Education".* Bruner believed that *humanity is creative*; every individual is able to communicate to each other by mastering and transforming his/her inner psychological process. In other words, individuals arrange symbolic tools consciously, namely signs, symbols and texts, to respond to other persons, societies and cultures. Edwards (2000) argued that creativity exists in every individual but in different levels, and that these inherent traits cannot be enhanced in any way. Ng (2001) agreed that creativity is a form of individualized behavior which involves the introduction of novel elements into an established domain. Indeed, individualized behavior takes many forms, from creating a scientific theory to a simple funny, everyday joke (Mumford, Mobley, Reiter-Palmon, Uhlman and Doares, 1991). It is possible that creativity could be considered as the essence of the creative act; creativity is not a gift but an attitude of humankind towards problems. Canaan (2003) stressed that creativity is inherently equally built in every individual since everyone has his/her own set of past experiences to make use of. Furthermore, Canaan explained that there are THREE major traits which can be found in a creative person: (1) ability to map new associations from unrelated elements; (2) willingness to chase and enjoy creating something even though you might reject it later on; and (3) tolerating ambiguous answers and solutions. It can be concluded that creativity is a form of novel action which is carried out by every individual in diverse domains. In other words, every human being is inherently creative since creativity is a part of humanity and human behavior.

3.1.2 Is creativity about making changes, surprises and differences?

Another assertion is that creativity is about making changes, surprises and differences Source? to normal answers or solutions. William James (1890) stated that creativity is a product of rich association while avoiding commonplace ideas at the same time. De Bono (1985) also commented that creativity is concerned with change, innovation, new ideas and new alternatives. I wonder if individuals need creativity because they assume that every task could be done in different ways. Does creativity bring change and innovation to individual routine? LaBerge and Rheingold (1991) pointed out the relationship between unconsciousness and creativity. They described creativity as being about the use of the imagination to produce some new things; of course creative things are diverse in different individuals in various domains. Nonetheless, researchers believe the essence of creativity is the combination of old ideas or concepts into new shapes as well seeing things with new perspectives (e.g. LaBerge and Rheingold, 1991; Herrmann, 1991; Cave, 1997a).

Furthermore, some researchers (e.g. Herrmann, 1991; Cave, 1997a; 1997b; Runco, 2006; Heller, 2007) have highlighted creativity as an ability to generate existing objects or theories and combine them in different ways for new purposes. Cave (1997b) declared that this concept is also applicable to arranging things which are interrelated; generating novel, useful ideas and solutions for problem solving. In other words, it is about creating *novelty* in order to bring changes to society and human life patterns (Aleinikov, 2002; Richards, 2007b). Michael Kirton, the author of Kirton Adaptor/innovator inventory (KAI), coined the term *"Innovator"* to describe the people who tend to change the system instead of adapting to it (Kirton, 1976; 1994). In terms of novelty, which means bringing the *new* to social contexts, Aleinikov (2002) classified this *"new"* into TWO different dimensions, which are *subjectively new* and *objectively new*. According to Aleinikov, the subjectively new is something new to a person or subject, while the objectively new is novel to all people within a social context. Aleinikov (2002) emphasized that *invention* alone is not enough, it is important to obtain a sense of *discovery* that deals with a new reality in a social context. This is because *discovery* involves finding a new object or phenomenon in nature. *Discovery* leads to plentiful inventions in actions, opportunities and, of course, creating new knowledge (Aleinikov, 2002). For instance, scientific discoveries are continuously creating new knowledge for mankind. Similarly, Polanyi (1998; 2003) agreed that *new* vision alone is not enough to create new knowledge, but it can only be done through the action of *discovery* that generates new knowledge for human beings. Furthermore, Canaan (2003) proposed that creativity is a *discovery* about finding the relationship between new information and past experiences, and making a combination to create new solutions or ideas. Despite Mumford, Blair and Marcy (2007) pointing out the complexity of knowledge structures in regards of inhibitory effects, Hunter and Ligon (2008) suggested the prompting use of knowledge, for instances schema or associational knowledge, can help individual to produce more high quality ideas. More specifically, the associational linkages could possibly trigger multiple ways of thinking in problem solving (Mumford, Blair and Marcy, 2007). Creativity, indeed, depends on the operation of relevant knowledge (Scott, Longergan and Mumford, 2005). If the above researchers are correct, creativity is highly related to individual prior experiences, and the ways of making linkages within. Additionally, other researchers (e.g. Boden, 1993; Runco, 2004) have professed that creativity is, by definition, surprising and unexpected. They believed that surprise and unpredictability are caused by a creative idea which must be counted into this combination. According to Boden (1993), creativity is a combination of value and unpredictability, however, this combination comes with constraints, which make creativity possible. Creativity stays in the midway of free association and being controlled (Brocking, 2006).

To summarize, creativity is not only regarded as bringing changes and differences to usual ideas and solutions, which could be considered as a subjectively new idea instead of the objectively new solution; but is also nurtured by individuals' previous experiences and how they combine and connect these experiences in order to make *new discovery*. Creativity is often discussed in terms of providing novel and useful ideas and products; in fact creativity is a kind of organizational innovation towards problems (Amabile, 1983; Zhou, 1988; Woodman, Sawyer and Griffin, 1993; Oldham and Cummings, 1995; Runco, 2004; 2006). Thus, in my study, I did not measure design students' creativity but rather focused on reviewing students' creative process as applied to problem solving, and seeing whether factors such as environmental stimulation and appropriate creativity training could possibly assist design students to make creative solutions for design problems.

3.1.3 Is creativity about richness of ideas?

Is creativity about richness of ideas? In other words, is a creative person able to generate a huge number of ideas towards problem solutions? De Bono (1970) expressed the belief that vertical thinking, regarded as a logical or systematic thinking process, is working for rightness; and lateral thinking considers the richness of ideas. Furthermore, De Bono (1970) expressed that creative thinking is a result of restructuring individuals' pattern systems by paying attention to the thoughts escaping from the restricting patterns, which is what he called "*lateral thinking*". This concept involves the skills of restructuring, escape and provocation. According to De Bono, lateral thinking skills help individuals to generate new ideas. Therefore, De Bono may be implying that creativity is about richness of ideas. Fitch (2002) pointed out that if an individual believes there is *no* single correct answer to a problem, this mindset is the basic concept of creativity. Fitch suggested that thinking of all possible ways to solve problems is the implementation of the human creative mind. In other words, the creative thinker needs as many possible ideas as he/she can possibly create in problem solving. Herrmann (1991) reminded us that *creativity* is a sense in generating an idea while manifesting it. According to Herrmann, the way to enhance individuals' creativity is to apply ideas in some forms with both experience and reaction. Hermann stressed that the application, which means the process of refinement, is essential to creativity because ideas can come in a second whereas the application needs to take a long time to be realized. Similarly, ideas can be obtained in a single flash but the application must involve a process of refinement. Herrmann (1991) underpinned that the application of refining creative ideas to problem solving is comparatively more important than *creativity* itself. This means that creative ideas that work in one domain don't necessarily work in other domains. The process of refinement involves adjusting the creative idea before implementing it in the target domain. This means that individuals are not only quantifying ideas but also need to consider deliberately the application and implementation of creative solutions in any particular discipline. Boden (1993; 1994; 2004) gave us a clear explanation of the relationship between creative ideas and domains. She highlighted that creative thinking involves the exploration and transformation of conceptual spaces; unpredictable experiences can trigger creativity by integrating it within a conceptual space. According to Boden (2004), the conceptual space is a sort of established style of thinking in different structures, dimensions, pathways and boundaries. In other words, an idea can be justified as *creative* in one particular conceptual space but may not be applicable to others; creative ideas work as possible solutions in one particular conceptual space but not in others. Besides, Boden (1993) also reminded us that the conceptual space facilitates individuals' creativity but hinders them at the same time. Therefore, Boden emphased that a conceptual space would have to be identified and mapped precisely along with explicit definitions of ways of exploring and changing the spaces. The mapping of a conceptual space involves both conscious and unconscious levels of representations and its structural features. Boden (1994; 2004) indicated that the more the individual is concerned about the representation of the structural features, the more power the individual could have to navigate and negotiate these conceptual spaces. It seems to me that once individuals are equipped with this mental map it enables them to explore and transform the conceptual spaces with their own imaginations.

After all, the richness of ideas is crucial to creativity, but individuals have to consider the implementation and refinement of ideas in a particular conceptual space. Creative ideas can possibly be generated by possibilities. To explain this idea simply, an individual has more possibilities to generate a creative solution to a problem if he/she has more possible rough ideas in hand. However, finding a creative solution is another issue. A creative solution does not mean an idea because finding a solution implies problem-solving skills which could only happen in a particular conceptual space. Thus, the appropriate design of creativity training and the effective allocation of environmental stimulation could be among the crucial factors for not only helping design students to obtain richness of ideas, but also making appropriate the creative solution of a problem. Therefore, I studied the said factors in this project by designing an appropriate creativity training syllabus and establishing environmental stimulation within virtual reality.

3.1.4 Is creativity driven by emotion?

I wonder whether creativity is driven by personal emotion, and how emotion affects the creative thinking process of an individual. Jung (1964) stated that a creative idea is a key to unlock the individual's hitherto unintelligible connections of facts in order to enable individuals to penetrate deeper into the mystery of life. According to Jung, *creativity* is a powerful resource of individuals' unconscious that are expressed in mythological, religious, artistic and cultural activities; that is, these are inherited patterns of emotional and mental behaviors on human beings which Jung called *"archetypes"* (Jung, 1964). Gardner (1993a) declared that creative people often use *feelings* from childhood for creative production. Harrison and Bramson (1984) agreed that thinking and feeling are interactive, and that the relationship between them is universal and cyclical. However, is it true that emotion is equal to feelings? Hillman (1962) stated that *emotion* is different from feeling, the latter being only a part of psychological function whereas emotion is the entire psyche activity. Damasio (1999) agreed that *feeling* is simply a private and mental experience of an emotion. Nonetheless, Vygotski (1995) pointed out that the creative consciousness process is linked to the relationship between emotion and intellectual thought, which he called *"imagination"*. This is the basis of every creative action, and essential to the existence of humanity and society. Certainly, emotion plays a role of gatekeeper in balancing the consciousness and unconscious minds of human beings (Waterworth, et al. 2003).

Regarding how emotion affects creativity, Cave (1997a) pointed out that an individual's emotions, particularly specific sets of values, meanings, beliefs and symbols, can obstruct creativity. Canaan (2003) argued that some kinds of emotions, for example *anxiety,* can however facilitate creativity. Canaan expressed the belief that the greater the anxiety during the creative process, the more creative energy can be constituted as stimulation. However, it has also been claimed that the abuse of anxiety results in paranoia, discouragement and fear (Canaan, 2003). After all, I argue that creativity is not a stand-alone ability but is connected to psychological reactions and other cognitive aspects of human consciousness. Therefore, I consider that students' emotion reaction during the creative thinking process can be stimulated in order to obtain more creative ideas. Additionally, creativity can be described as the result of some qualities of good thinking processes and it is definitively a part of human cognition (Klenz, 1987). Apparently, the cognitive characteristics of a creative individual include being equipped with metaphoric, flexible thinking, logical thinking skills in problem solving; novelty and high visualization skills in decision making; abilities to address problems and finding order in chaos (Sternberg and Lubart, 1999; Sternberg, 2001). Creative individuals are able to perceive and arrange fragments of reality and transform this to *reenter* reality (Vygotski, 1995). After all, I presume that the emotion of design students in the creative thinking process is essential because their emotional reactions will definitely affect the creative solution which they are generating. Current research (e.g. Horn and Salvendy, 2006) in product creativity for university students confirmed the important role of emotion in creative thinking process. The explanations of the emotional factors of creative individuals have been discussed in Chapter 1.3 The creative-friendly learning behavior for design thinking.

3.1.5 What is the nature of creative performance?

As I discussed earlier, creativity is related strongly to particular domains, and it is important to generate creative solutions instead of only making creative ideas. Arieti (1976) described the nature of creativity as a form of an exploratory transformation of the development of previously unknown conceptual space (a sort of thinking style which is made by an asset constraint that guides and limits the search for new ideas). In other words, the conceptual space is related to the individual's creative performance. However, what is the nature of creative performance? What sorts of mental skills are required? By synthesizing the earlier theories (e.g. Wallas, 1926; Dunker, 1945; Rogers, 1954; Campbell, 1960; Newell and Simon, 1972), Amabile (1996) underlined THREE components of creative performance: (1) Domain-relevant

Skills; (2) Creativity-relevant Processes; and (3) Task Motivation. According to Amabile, Domain-relevant Skill is the individuals' complete set of response possibilities which comprises some new responses that can be synthesized and judged against information; the Creativity-relevant Process is about how individuals can determine the best response by comparing previous responses within the domain; the Task Motivation is related to the personal motivation that triggers creative performances. In addition, Amabile (1996) highlighted that the Creativity-relevant Process is a sort of cognitive style which enables individuals to understand complexity during the problem-solving process by making use of knowledge of heuristics in generating ideas. Likewise, Partridge and Rowe (1994) explained that the nature of creativity can be divided into the (1) Input Creativity Model and (2) Output Creativity Model. The Input Creativity Model functions in interpreting information and creating abstract connections among concepts while the Output Creativity Model tackles the generation of novel or artistic output. Boden (1994) also supported the notion that creative performance can be classified according to the different mental skills which individuals have applied. Boden classified creative performances into (1) Combinational Creativity and (2) Exploratory-transformational Creativity. Combinational Creativity is a cognitive skill that puts previous concepts together in order to generate novel patterns, and Exploratory-transformational Creativity is the skill of exploring and transforming ideas. From the above discussion, I assume that creative performance can be understood as different cognitive skills and reactions; combination and making linkages among complex pieces of information within any particular domain is crucial to developing an individual's creativity as well as producing creative performance.

Despite the aforesaid cognitive skills of creativity, the creative thinking process might also facilitate an individual's creative performance. I suppose that a systematic and deliberate creative thinking process may enhance the individual's creative performance as well as enriching his/her creative solutions. In one of the notable models of a creative thinking process, Kneller (1965) identified the creative thinking process as having FIVE different stages: (1) First Insight: The formulation of a problem; (2) Preparation: The conscious attempt at solution; (3) Incubation: The subconscious development; (4) Illumination: The sudden emergence of an idea; and (5) Verification: The conscious development. Elton (1993) suggested that creativity can be thought of as a process of TWO stages, (1) Generation and (2) Evaluation. According to Elton, the role of evaluation is stressed over that of generation. Moreover, Hadamard (1954), a notable French mathematician, suggested that the process of creative thinking can be divided into FOUR stages: (1) Preparation, (2) Incubation, (3) Illumination and (4) Verification. The first three stages are very similar to the stage of *generation* as indicated by Elton (1993), and the latter one *verification* is considered as his idea of evaluation. Boden (1994; 2004) agreed that creativity comprises both generation and evaluation, which cannot be separated, in the thinking process. In other words, if an idea comes from the process of generation without evaluation, this idea only could be counted as a witty concept, but not a creative solution to a problem. Additionally, Cave (1997a) introduced the idea of the *"TWO Dimensions, THREE Aspects and THREE General Ways"* for facilitating the creative thinking process, which offers a constructive approach to teaching and learning in creative thinking. According to Cave, the TWO Dimensions are the (1) System and (2) Content; the System means a particular medium which allows the individual to manipulate the creative performance, namely painting or musical form; while the content is a conceptual description specifically regarded as manipulation, expression and depiction of the contents of some ideas. Creative performance involves *THREE Aspects*: (1) Creative Person, (2) Creative Process and (3) Criteria or Characteristics of Creative Product. Apparently, the personality traits of a Creative Person are crucial to facilitate his/her creative performance. An appropriate implementation of the creative thinking process may receive more attention when it is focused on the mechanisms of a creative act; the Criteria of creative performance are significant to the basis of any performance assessment and measuring tools in the real world. Last but not least, the THREE General Ways of achieving creative solutions are: (1) Serendipity, (2) Similarity, and (3) Meditation. Rather than classifying creative thinking process into diverse stages, Lauer and Pentak (2000) argued that the individual creative thinking process is very simple, mainly consisting of thinking, looking and doing. Lauer and Pentak disagreed with any classification of the creative process. They believed that thinking, looking and doing are not independent but overlapping, and are accomplished simultaneously. Nonetheless, the effectiveness of the individual's creative thinking process is sometimes measured by the creative solution, or production that he/she has created. Boden (2004) stated that the underlying principle of defining creativity, or creative performance, is dependent on the production of something which results in a novel and interesting solution. Elton (1993) agreed that the nature of the creative thinking process leads to the production of artifacts, which is essential to any proposed definition of creative performance. After all, I assume that a successful creative performance would be determined by the interwoven relationships between conceptual space, cognitive skills and creative thinking processes. In other words, the creative solution has to address problems in the particular domain by applying both cognitive thinking skills and a creative thinking process.

3.1.6 Creativity is something about...

Based on the above discussions, though I am not able to define what creativity is, the literature has revealed some crucial characteristics and assumptions about creativity and creative thinking. I understand that creativity is not peculiar to genius; every individual has an innate ability to create something. Creativity is not only about making changes, surprises and differences, it is an organized innovation addressing problems. Creativity certainly involves richness of ideas and solutions; however, an individual's ideas have to be examined through deliberate refinement stages and need to be applied under certain constraints, in particular conceptual space and domain. I realize that creativity is driven by emotion to a certain extent as well as connecting with other cognitive aspects of human psychological reactions. I presume that an individual's creativity and creative performance could be enhanced by undertaking a systematic and deliberate creative thinking process. Creativity is always wandering between being free and being controlled (Brocking, 2006). Truly, creativity is not a stand-alone intelligence but integrated and interacting with other human cognitive abilities. Take a successful example in science which is regarded as a highly creative discovery; James Watson and Francis Crick's discovery of the beautiful double helical geometry of DNA. Watson (1968) maintained the discovery of the structure of DNA was neither a logical deduction nor a calculation based on available evidence and experimental results; they applied divergent thinking and made a leap from nowhere. Another example, Albert Einstein, described his work as a combinatory play of gathering data, materials and perceptions in order to create something new and useful. This combinational thinking is indeed a synthesis (Florida, 2002). Synthesis is actually the sort of ordinary ability of every individual. Likewise, Boden (1994; 2004) pointed out that creativity can be drilled by some training of ordinary ability, for instance remembering, seeing, speaking, hearing, recognizing analogies and so forth. Although researchers assert that creativity is an integration of various cognitive abilities, one of the distinguished steps in the creative thinking process is *"incubation"*, which differs from other cognitive thinking processes. *Eureka!* It is a moment of seeing the new synthesis together with the help of verification and revision (Florida, 2002). Eureka happens suddenly in the stage of incubation. All in all, although a uniform definition of creativity and wisdom still does not exist (Ardelt, 2005; Birren and Svensson, 2005; Bluck and Gluck, 2005; Kunzmann and Baltes, 2005; Takahashi and Overton, 2005), some recent researchers have highlighted some essential propensities and traits of the higher creative person: (1) higher states of awareness and of purposes and meanings (e.g. Combs and Krippner, 2007; Richards, 2007b; Zausner, 2007); (2) thinking differently and ability to integrate their thinking (e.g. Runco, 2004; Richards 2006, 2007a); (3) openness (e.g. Kelly, 2005; Richards 2006); (4) endurance when tackling complex and difficult problems (e.g. Goerner, 2007); and (5) being fun, humor and playfulness (e.g. Michalko, 2006). In addition, Richards (2006; 2007a) also reminded that a creative person is always intensely involved in his/her works.

In summary, the major contribution of studying creativity in my project is not to define creativity accurately or measure people's creative ability to see whether they are geniuses or not, but rather to understand some basic assumptions of creativity in order to establish appropriate ways to enhance students' creative performances and possibly release their creative potentials.

3.2 Probing design education and creativity training

In the following sections, I discuss the relationships between design education and creativity training. I aim to clarify the importance of creativity training in the development of design education and the ways in which it can facilitate students' creative thinking. Therefore I have probed the historical development of design education as well as the importance of the design process in design education in the first and second parts. In the third and fourth parts, I study the role of creative thinking in design education and the issues of teaching creative thinking to design students.

3.2.1 A shift from craftsmanship training to intellectual development

Although art and craft subjects were introduced in the British technical and trade schools in the 1880s and 1890s respectively, these subject objectives focused on practical training for a career instead of conceptual development for students. A change started from 1890 although it only focused on craft education instead of design education. Salomon (1890) underlined a list of objectives for craft education which made him one of the pioneers in developing design education in that era. Salomon divided early craft education into (1) the formative focus and (2) the utilitarian focus. According to Salomon, the formative focus of craft education aims at developing students' independence, self-reliance, sense of forms and to develop touch in order to promote the development of the physical abilities in craftsmanship. The utilitarian focus is simply aiming at executing exact work and giving proficiency in the use of tools. Later, some craft teachers became engaged in developing the more intellectual method of using materials by focusing on exploring the applications of materials and tools. One of the early movements of curriculum reform in the 1960s was the Nuffield Foundation and School Councils in the United Kingdom. This movement involved the evaluation of the existing curriculum and reconsidered the role of craft education in schools. In the 1960s, a new subject domain was created which was called *Design Education* due to the multiple pressures put on the school curriculum that had forced schools to redefine the nature of work with materials. Arguments took place about the use of materials in creative problem solving. The traditional emphasis was on doing and thinking, as well as clarifying the concept of the design process (Eggleston, 1976).

Due to the efforts art and craft teachers put into exploring new knowledge of design education, teachers became able to demonstrate and analyze theoretical domains in art and design, such as creativity, initiative and adaptability. In addition to theoretical developments in design education, the new curriculum developed students' abilities in decision making through the exploration of the use of materials and integrations of first-hand experience and knowledge. UK?, QCA?

An influential project, called the *Design and Craft Education Project,* operating from 1968 to 1973 at the University of Keele, provided a framework for the later developments in design education, for instance the emphasis on drilling students in problem identification and problem-solving skills through the mastery of materials. It is important to note that the design subjects in this project were constructed by the combination of *intellectual* and *practical activities*. After this project, design education in Britain underwent a tremendous change, shifting the educational focus from practical skills to intellectual development. Many other British universities started similar projects in response to this project report, for instance the Art and Craft Education in the Goldsmiths' College (1969-72), the Art and Adolescent Project in Exeter University (1968-73), Project Technology in the Loughborough College of Education (1967-72) and Design Education Research at the Royal College of Art (1973-75). Design education was developed in the early 1970s, especially after Barnes published a book about design curriculum called *"Attitudes in Design Education"* in 1969. Many similar studies were published in the area of design education, namely Zanker's *"Design and Craft in Education"* in 1972, Aylward's *"Design Education in Schools"* in 1973 and Green's *"Design Education: Problem Solving and Visual Experience"* in 1974. Simultaneously, the National Association for Design Education in the United Kingdom was established as the first professional association for design education in the 1970s. In addition, this influence spread to other countries in western world, some to integrate theoretical knowledge with practical skills for functional purposes in the early twentieth century.

Despite the development of general design education in United Kingdom, professional design education, which aims at training professional designers, was developed in Europe and America from the 1930s. Some design educators, such as Moholy-Nagy, Klee and Kandinsky, were working on a combination of artistic exploration and practical function for formulating the foundation of design education. Eventually, the Bauhaus School was initially established in Germany in 1919 under these pioneers in professional design education (Buchanan, 1995). The contributions of the German Bauhaus School not only demonstrated the perfect combination of artistic exploration and practical functions in design education, but also provided references for pedagogical frameworks and curriculum structures for the later design schools. Because of World War II, the German Bauhaus School was closed in 1933 and moved to Chicago in the United States. One of the significant achievements happened in 1937 in Chicago, where Moholy-Nagy with the help of Charles W. Morris, who was a philosopher from the University of Chicago, developed a revolutionary curriculum in design education which enriched design students' sense and knowledge of art, science and technology (Findeli, 1991). Concurrently, Max Bill and his colleagues, based on the original principles of the Bauhaus, reestablished the Hochschule für Gestaltung Offenbach (HfG) in the 1960s which was generally accepted as the most influential design schools after World War II (Buchanan, 1995). All in all, according to the numerous revolutionary reforms in design education since 1880 including in the United Kingdom, Continental Europe and Northern America, the curriculum and pedagogical structures of design education had changed from crafts training, to education in art, science and technology, and towards professionalism. In the following sections, I will discuss the theoretical and intellectual parts of teaching and learning design education, namely the learning of the design process, creativity and design thinking.

3.2.2 Emphasizing the design process in design education

One of the influential design movements was developed by design educators such as Gropius, Klee and Kandinsky in the previously mentioned German Bauhaus School. The Bauhaus encouraged students to pay more attention to the *design process* instead of only focusing on the design outcome. The Bauhaus emphasized the concepts of simplicity and purity of forms as well as the properties of materials, within a sound development of design process. The Bauhaus' concepts and ways of teaching design became wide-spread in Continental Europe and North America, particularly in foundation design courses in art colleges. Although De Sausmarez (1964) argued that the Bauhaus' system was trapped in academicism and hindered the development of fundamental design by only focusing on a frighteningly consistent and entirely self-sufficient format, design education is no longer an art and craft training associated with lower intellectual development. Design education became a systematic educational approach for training professional designers in intellectual thinking and design skills. Consequently, after the 1970s, it evolved into a new era that emphasized the development of design processes as well as the students' conceptual development. Archer (1965) stressed that *Design* works for both spiritual and material needs, in allowing individuals to shape their environments by using knowledge and experience. Similarly, Wooff (1976) suggested that design education can be characterized in a more imaginative and cognitive way which does not simply focus on problem solving but also involves responses to emotions. Jones (1980) shifted his concern from studying design education to studying the design process. Jones pointed out that the function of design is to encourage individuals to make things in different ways. In other words, design education is a process of identifying the changing needs and of offering experience addressing these needs in an industrial society (Green, 1974).

Eggleston (1976) pinpointed some features of the "experiencing" design process which contributed to the later development within that arena: (1) experiencing the decision-making process by participating actively in developing new ideas as well as modifying old ones; (2) experiencing the interplay of knowledge and understanding by evaluating and comparing ideas and subjects; (3) experiencing the needs of the social context of human behavior by studying clients and societies; and (4) experiencing a meaningful way of using craftsmanship and other skills in design. Undoubtedly, design education is now working closely with the arts. Art plays an essential role in education by offering an introduction to aesthetic reaction in individuals' lives (Vygotski, 1926). Vygotski (1930) underlined the significances of *art* that helps individuals experience their lives from different and new perspectives. Furthermore, enriching versatile experiences are essential to both arts and design education. Green (1974) pointed out that a crucial barrier to creative education is a narrow, static view of culture, stating that students can only recognize creative cultural activities from their limited forms of experience. Additionally, Green (1974) noted that *design education* is concerned with the development of a critical mind in understanding human needs, and accumulating experiences in evaluating that adequacy. Green also suggested that *design education* is not going to impose *good taste*, because there is no such objective judgment about good or bad taste, whereas there are appropriate or inappropriate design solutions to problems. In this sense, an appropriate design solution, to some extent, is generated by a sound creative design process. Thus, *design education*, by means of teaching the design process, is indeed a problem-solving activity seeking for appropriate solutions. I assert that *design* is not a subjective judgment by designers' tastes at all, but a way of gathering information and feedback from all aspects in order to make appropriate design decisions (Lau and Lee, 2008). Fischer (1993) underlined that *design* is a conversation with the materials of design situations, and these situations need to *talk back*. This design process helps designers to understand the articulation which is relevant to the actual design

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outcomes (Fischer et. al, 1993). Thus, criticizing the structured systems and components is one of the ways that design works; this design process is tactical and well planned. It is important to train students in design process in design education.

I have already pointed out the importance of training students' design processes in design education. However, the problem is that diverse design disciplines have their domain specifics and exclusive design processes. Ericsson and Lehmann (1996) stated that all experts have their own domain specifics which shape the diversity of the working process. In contrast, Boruas and his associates (2001) argued that there are some similar mechanisms in conducting creative processes in diverse design domains. plural ? In other words, there are unclear standards among creative processes. Nonetheless, according to the book "*The Sciences of Artificial*" written by Herbert Simon in 1968, design education should be a core discipline for all liberally educated individuals instead of only for professionals (Simon, 1968). In this sense, presumably, there are common values in design education that could be relevant to other disciplines. I admit that the design process of various design domains are fundamentally similar but with different working mechanisms due to some factors, namely clients' expectations, customers' needs, production procedures and marketing strategies. One of the commonalities in design processes for all design disciplines, I deduce, is the creative thinking process and this should not be market-driven (Craft, 2006). No matter what kinds of design students are involved, they need an understanding of the creative-thinking process in the initial stage of design education.

3.2.3 The role of creative thinking in design education

Design can be defined as working out a solution for any specific problem in diverse contexts; every solution or strategy is indeed unique and provides room for creativity (Simon, 1981). Roberts (1989) declared that creative design should be both innovative and valuable. Numerous research studies of creative design have highlighted the significant role of design activities in relation to the development of creative thinking skills (e.g. Roberts, 1989; Kolodner, 2002; Lawson, 2006). For instance, Kolodner (2002) studied the relationship between science and design activity, focusing particularly on the creative thinking process in order to facilitate design education. Lawson (2006) explained that *design* is a creative process that creates novelty for people to experience. If Lawson's idea is correct, that means the *originality* of creative exploration is the ultimate goal of all kinds of design activities. However, if all sorts of design activities involve the creative thinking process, then can the originality of design outcomes be evaluated by reviewing the creative thinking process? Regarding this inquiry, Boden (2004) explained that *creativity* can be classified into the categories of H-Creativity (Historical Creativity) and P-Creativity (Psychological Creativity). H-Creativity results in new and novel ideas, whereas P-Creativity is relatively less important to human beings but personally satisfactory. In other words, H-Creativity is something about designing and creating original solutions. Actually, numerous original and creative examples are found in design history which are regarded as classics; these examples can be treated as original designs with timeless quality (Boden, 2004).

Further to the main idea of creating original designs in design education, from my teaching experience, design students are eager to study the *classical* design cases during their design processes. However, I wonder whether studying classical design cases hinders students' exploration of novel concepts. This is because students feel more comfortable in their creative thinking processes by referring to some successful models and samples. Kneller (1965) highlighted the dilemma of creativity, that individuals have to create novel concepts on one hand, and study the prior, familiar, innovative solutions on the other. Dreyfus (2003) disputes the value of giving good examples to students. He claimed that such examples will reduce the students' motivation to explore other possibilities during the design thinking process. Therefore, it seems to me that if design students are too concentrated on researching prior successful cases, they may be over-influenced by these examples, eventually hindering their creative thinking process in seeking for something new and novel. Nonetheless, Kneller (1965) suggested that prior experience acts as a springboard that fosters creative thinking. Likewise, Laxton (1969) pinpointed the importance of a prior reservoir of experience in the process of teaching and learning creative thinking. His study was based on the work completed by children in his design school in the 1960s. Laxton implemented a THREE Stages model of design education in order to identify and develop the children's abilities of initiating and expressing ideas based on their reservoirs of knowledge. In design study, Jones (1980) reminded us that designers need to doubt, to set up, and to observe the past results of a controlled experiment scientifically before they can solve problems confidently as well as predict the future needs of society. Hertzberher (1991) agreed that gaining knowledge and experience is essential to enhance students' creativity in design studies. He believed that the more design students experience and absorb in their lives, the more ideas they can create.

In conclusion, creative thinking is nurtured by prior internal and external experiences of design students. In other words, design students make use of their personal experiences and prior successful cases to form a knowledge base for exploring creative ideas while evaluating them. Lawson (2006) also stressed that the essence of *design education* is in offering a delicate balance between guiding students to establish their reservoirs of experience and fostering students' creative thinking processes for originality and novelty. It has been noted that creative thinking plays a crucial role, not only in design education, but also in generic education because with it students can experience, discover and construct their lives (Bateson, 1999).

3.2.4 Teaching creative thinking in design education

Early research by Simberg and Shannon (1959) suggested that *creativity* can be taught. Their study tried to compare two different groups, the trained group and untrained group, in producing quantity and quality of creative ideas. According to the research by Simberg and Shannon, an obvious result was that the trained group provided suggestions of both quantity and quality that the counter group did not. If Simberg and Shannon were correct, then what are the models and approaches for training individuals' creative thinking? The models and approaches of creativity training were established initially by Osborn (1953) and Torrance (1972). Based on their notions, versatile ways of training creativity have been proposed and developed in subsequent years (e.g. Jausovec, 1994; Butler and Kline, 1998; Butler and Thomas, 1999; Bull, Montgomery and Balloche, 1995; Smith, 1998; Nickerson, 1999; Baumgartner, 2002). In addition, I agree with some researchers' counter ideas that questioned the effectiveness of providing creativity training for enhancing students' creativity (e.g. Cropley, 1997; Storm and Storm, 2002; Fogg, 2003); they suggest creativity training might not be a solution, or even an attempt, to develop students' creative capacities. Nonetheless, these training exercises at least are able to help students to release their creative potential by employing various creative thinking approaches and skills in their learning process. In addition, creative thinking is a decision-making process in thinking of certain ways of doing certain things (Sternberg and Lubart, 1995; Sternberg, 2003). Sternberg suggested that students could develop FIVE underlying learning behaviors exclusively for creativity training exercises: (1) redefining problems which mean not accepting the way the problems are presented; (2) being willing to take intellectual risks towards problems; (3) removing obstacles that means not being afraid of being criticized by others; (4) persuading people to value one's creative ideas; and (5) believing that everyone truly has the potential to produce creative ideas. After all, creativity training exercises are not actually concerned with developing students' creativity but with equipping their diverse intelligences and abilities, namely problem identification, critical thinking, curiosity and risk taking, in which ultimately students are helped to generate creative ideas and solutions to problems.

In addition to the models and approaches of creativity training, lecturers also play a crucial role in enhancing students' creative thinking abilities. Hickey (1999) expounded that a creative teacher needs to provide safe climates for developing students' creative abilities, for instance in developing individuality and independence, and allowing students to feel free to take risks. Moreover, nowadays design lecturers are no longer knowledge distributors for students but rather they play the role of facilitators during teaching and learning activities. This role of the design lecturer is particularly important in conducting creativity training exercises. Historically, Piaget (1973) suggested that a creative teacher has to help students to discover and develop their knowledge in order to facilitate creativity. Green (1974) critiqued traditional design education where he suggested design lecturers are the only body of knowledge. Green argued that it is difficult for design lecturers to keep abreast of the rapid development of social changes, versatile theories and technical information. Therefore, the design teachers' role is indeed to facilitate the learning experiences between teachers and students in discovering and experiencing new knowledge and experiences simultaneously. Moreover, Dreyfus (2003) pointed out that the lecturer is always a model for students to imitate; thus teachers play an essential role in monitoring students' emotions and concentrating on the learning situation. Therefore, I agreed that design lecturers have to be highly aware of their weaknesses and develop their strengths in creative thinking in order to form a learning model for students. Furthermore, design teachers need to help students to recognize and act upon their capabilities and establish an appropriate learning atmosphere, which is based on mutual regard and respect. Through the appropriate learning atmosphere and activity, it helps students to stretch their personal issues to universal themes, forces and offer deeper meaning (Richards, 2006; 2007b) as well as developing students' their spirituality (Richards, 2007b) and the evolution of consciousness (Combs and Krippner, 2007). Apparently, creative teachers play an essential role in preparing creative teaching strategies (e.g. Garrison and Anderson, 2003; Fisher and William, 2004). Additionally, I suggest it is also essential for design teachers to establish a creative learning atmosphere to simulate their students' motivation. This learning atmosphere might also be able to encourage design students to reflect on their ideas freely and make collaborations actively. Obviously, design students' motivation and collaboration are important factors in the teaching and learning of creativity training exercises.

3.2.5 Design thinking is managing creative thinking and design planning

Sir Barnes Neville Wallis, an English inventor who created the bouncing bomb, stated that there has always been a *problem* first before a creative solution can develop (Whitfield, 1975). The Spanish architect Santiago Calatrava specified that the designer needs a very precise problem to work with (Lawson, 1994a). Likewise, architect Herman Hertzberger (1991) stressed that if the creative solution is not addressed to actual problems or needs, which means this solution is not creative, it is indeed only a *fake* creativity. Green (1974) described all design decisions as generated by a cyclical problem-solving process that involves: (1) the identification of a problem; and (2) examination of a proposed solution. Green also argued that design solutions are created by neither accident nor attitude of taste. The efficient design solutions rely upon the deliberate analysis and considerations of human need (Green, 1974). Lawson (1994b) asserted that *creative thinking* in design is not a matter of being original, or even necessary, but indeed is a problem-solving process. Apparently, the process of problem identification is a crucial step in design thinking, since design practice is working for problem solving. However, what is the problem? And what are the characteristics of problems in the design domains? In the following sections, I will discuss the importance and specific role of *problem* in design education.

What is a problem? Thorndike (1931) defined that a *problem* is raised because an organism wants something, but the actions and methods of obtaining it are not obvious. Apparently, this simple explanation is not enough to explain what the *actual problem* is, for that I need a detailed definition since teaching design thinking is, to a large extent, teaching ways of problem solving. Researchers tend to identify problems in design domains into THREE main types (e.g. Churchman, 1967; Newell, Shaw and Simon, 1963; Rittel, 1972; Simon, 1973; Gick, 1986; Rowe, 1987): (1) Well-defined problems; (2) Ill-defined problems; (3) Wicked problems. Well-defined problems are some difficulties which require a solution that address an obvious end or goal; the solution only needs a provision of appropriate means (Newell, Shaw, and Simon, 1967). Actually, the well-defined problems can be solved easily by knowledgeable or experienced experts without any further information (Rittel, 1972). On the contrary, unlike some clear and constructed problems, ill-defined problems lack obvious ends and goals, and the means of solution are unrevealed at the beginning of the problem-solving process (Newell, Shaw, and Simon, 1967). Some researchers named this poorly defined problem as ill-structured (e.g. Gick, 1986; Simon, 1973). Similarly, many ill-defined problems in design domains are called wicked problems (Churchman 1967; Rittel, 1972). Rowe (1987) described wicked problem as having no explicit basis for the termination of problem-solving activity, the problem needs continual reformulation because there are many additional questions and problems raised during the problem-solving process.

Both ill-defined and wicked problems need further problem definition and redefinition within the problem-solving process; some problems are very common in design domains. In other words, designers and design students often tackle these problems instead of well-defined problems in their creative work. Jones (1980) made an ironic remark that if a problem in a design domain can be solved by a mathematical procedure, then this problem can also be answered by a computer without human intervention. Undoubtedly, arts and design have no fixed correct solutions, and the creative acts are open to diverse interpretations and applications. De Bono (1970) agreed that ways of problem solving in design are different from others because the problems require more creativity. Problems in arts and design fields indeed are varying in specifics and complexity (Lauer and Pentak, 2000). For instance in industrial design, Rhea (2003) specified that the early stages of product design development are routinely mixed with some vague information, rough ideas, nebulous trends and crude user requirement; these stages are, therefore, commonly treated as a fuzzy end looking like a cloud raining on a funnel, Rhea (2003) called these stages "*Fuzzy Front End*". According to Rhea, the problems in this *Fuzzy Front End* need deliberate problem identification and re-identification; these problems are certainly ill-defined and wicked.

Design students usually deal with ill-defined and wicked problems in their design projects (Wales, Nardi and Stager, 1993). Therefore, it is essential in design education to teach ways of problem identification. Similarly, De Bono (1970) alluded to the *problem* as underlying material for creative thinking; he urged that *problem materials* generate alternatives, especially in design and innovation practices. Schön (1983) also highlighted the significant role of problem framing in creativity training. Lauer and

Pentak (2000) indicated that the identification of problems is indeed an essential part of problem solving for designers; designers have to think deliberately about the choices and determine the best selection based on clarified design problems. Therefore, design students need efficient methods to identify and connect their creative thoughts by referring to the defined problem area. One of the effective methods of problem identification is the *Empty Quadrants* (Rhea, 2003) approach. This approach aims at searching the problem areas in order to identify opportunities and create innovative ideas. Rhea (2003) stressed that the advantage of identifying problems in the design domains is that designers can generate possibilities beyond the normal scope. A creative person can indeed tackle complex and difficult problems (Goerner, 2007). Therefore, I put forward an assertion that design education, especially the creativity training, is a process of which consists of processes of creative thinking (seeking creative solution) and design planning (identifying and analyzing problems and references). Therefore, an appropriate learning activity in creativity training might need to help design students to obtain the *unpredictability* through the integration and interaction of creative thinking and design planning process. Indeed, various research (e.g. Hasirci, 2005; Hasirci and Demirkan, 2007) have proved the highest correlation between creativity and the design process.

3.3 Designing an appropriate learning activity for SD2000 in a shared virtual reality

Dewey (1929) described design practices as an employment of individuals' integrative thinking instead of specialization, and design as a new form of liberal art with integrated abilities and skills; that is an *art* of production (Dewey, 1956; Groupius, 1962). In subsequent decades, various research studies have been conducted on the design and design thinking processes of professional designers or design-related professions (e.g. Alexander, 1964; Archer, 1963-1964; De Bono, 1970; Roy, 1993; Candy and Edmonds, 1994; 1995; 1996; Cross and Cross, 1996; Candy, 1998); some researchers (e.g. Bower, Clark, Lesgold, and Winzenz, 1969; Lawson, 1980; Brainerd, Kingma and Howe, 1986; Christians and Dorst, 1992; Lloyd, Lawson and Scott, 1995; Demirkan, 2005; Yokochi and Okada, 2005) developed their methodologies of the design thinking process for professional designers. Others (e.g. Rosch, 1973; Rosch and Mervis, 1975; Rosch, Mervis, Gray, Johnson, and Boyes-Braem, 1976; Barsalou, 1983; 1986) studied the concept development. Overall, researchers have generally agreed that the design thinking process of the professional designer is crucial in achieving design objectives as well as obtaining design solutions (e.g. Nagai and Noguchi, 2002). Strategic design solution requires an application of various modes of thinking simultaneously and a systematic arrangement especially for design education. Thus, below is a review of the various creativity training methods in order to design an appropriate lesson plan for SD 2000. Emphasis is placed on: (1) discussing how to arrange learning activities for creative thinking; the significant steps of creativity training will be identified in order to propose an appropriate learning procedure for undertaking the SD 2000; and (2) suggesting a pilot lesson plan for conducting SD 2000. In addition, this chapter also aims at designing an appropriate lesson plan for conducting SD 2000 in a shared virtual reality. Thus, one of the crucial steps of the lesson plan will be selected for the multimodal interaction research in Phase FOUR and Phase FIVE.

3.3.1 Arranging appropriate learning activities for creative thinking

Creative thinking is a process of thinking instead of only having an idea pop up suddenly from nowhere. In order to obtain workable creative solutions addressing various design problems, design students might also need to realize the process and procedure of creating thinking. One of the early researchers in studying creativity, Wallas (1926), classified the creative process into FOUR distinct stages: (1) Preparation: The first distinct stage which identifies the problem and all relevant data; (2) Incubation: A significant stage that isolates the problem by allowing individuals to sink into their unconscious minds; (3) Illumination: A stage of insight – Wallas suggested that ideas, solutions and/or new relationships will emerge suddenly in this stage; and (4) Verification: Individuals have to ponder the possibilities of executing their insights to a doable solution. A similar method of classification comes from Stein (1967). He identified the creative process in THREE stages: (1) Hypothesis Formation, which relates to the problem identification; (2) Hypothesis Testing, which is a stage of exploring possibilities towards solving problems; and (3) Communication, which is regarded as a stage of proposing possible execution for problem solving. Hogarth (1980) agreed with the above identified stages for the creative thinking process. He described that the creative thinking process is comprised of preparation, production, evaluation, and implementation. Some similar cases of identification can also be found in the work of other researchers (e.g. Hadamard, 1954; Kneller 1965; Okuda, Runco and Berger, 1991; Elton, 1993; Mumford, Supinski, Baughman, Costanza and Threlfall, 1997; Ward, Finke and Smith, 1999; Lubart, 2001), who have all expressed the belief that the creative thinking process consists of diverse tiers of operation, namely problem finding, conceptual combination and idea generation. Nonetheless, one of the influential identifications of the creative process is the model of Creative Problem Solving (CPS). This was originally created by Alex Osborn in the 1950s and was based on Wallas' 1926 Stage Model. The prototype of CPS identified the creative process into SEVEN stages (Osborn, 1952). The details of the first CPS model are as follows.

The Model of Creative Problem Solving		
1	Orientation	Pointing up the problem
2	Preparation	Gathering pertinent data
3	Analysis	Breaking down the relevant material
4	Hypothesis	Pilling up to invite illumination
5	Incubation	Letting up to invite illumination
6	Synthesis	Putting the pieces together
7	Verification	Judging the resultant ideas

Figure 10: The Model of CPS (Sources: Alex Osborn's Applied imagination – First edition, 1952)

According to Osborn's initial CPS model, shown in figure 10, Osborn extended the creative process into seven stages instead of three or four stages as had been done in other studies. Osborn (1952) emphasized TWO stages in his CPS model – the first stage of *Orientatio*n which is the tier of problem identification, and the sixth stage of *Synthesis* that requests the individual to put pieces together by making sense of data and ideas. Ten years later, Osborn (1963) revised his original CPS model, and summarized it into THREE comprehensive stages: (1) *Fact Finding*; (2) *Idea Finding*;

and (3) *Solution Finding*. According to his idea, first, the Fact Finding stage asks the individual to identify the problem accurately by researching all relevant references and background information. This is indeed the stage of *preparation*. Second, the Idea Finding stage is similar to the stage of *incubation* (Wallas, 1926), aiming at exploring possible ideas for problem solving. This stage is the vital process of the CPS model. Finally, the stage of Solution Finding requires intentional analysis and evaluation of the proposed ideas or solutions. This refers to the development of the CPS model. There have been so many modifications and developments to the CPS model in recent decades (e.g. Noller, Parnes and Biondi, 1976; Parnes, 1981; Eberle and Standish, 1985; Isaksen and Treffinger, 1985; Isaksen and Dorval, 1993; Isaksen, Dorval and Treffinger, 2000). Despite some arguments against the CPS model that it lacks a clear explanation of the model's rationale (e.g. Isakson and Dorval, 1993; Isaksen, Treffinger and Dorval, 1997; Treffinger, 2000), the study of problem-solving preferences in relation to CPS models helps researchers to understand the relationship between the creative individual and the creative process. Isaksen and Treffinger (2004) pointed out that if individuals can understand and apply the CPS model in their personal authentic and valid ways, they can solve problems effectively. In summary, after more than fifty years of development in the CPS model as well as studying the creative thinking process, researchers have tended to agree that *creative thinking* is: (1) a process which includes different stages; (2) aiming for solving problem; (3) working with deductive and inductive thinking skills; and (4) containing a stage of incubation that seeks for *Eureka*.

A deliberate design and arrangement of creative learning activities within the learning space is crucial to help design students to release their creative potential. I have compared the various stages of some notable descriptions of the creative thinking process from diverse researchers in figure 11, and generated a proposed learning process of creativity that can be identified into FOUR stages: (1) the Preparation Stage, in which students have to build up their knowledge by gathering versatile information in this stage; (2) the Incubation Stage which is the accent of the entire learning process which involves the use of various creative thinking skills that allows students to explore possible solutions to address problems; (3) the Evaluation Stage that allows students to look at their explorations and creative thoughts deliberately in order to determine the most appropriate solution from hundreds of possibilities, and gives them the opportunity to examine their selected solution in (4) the Implementation Stage. In addition, however many creative ideas are explored after this creative thinking process, if the determined idea does not solve the problem properly, we cannot treat this idea as a creative solution but only a creative thought. Then students have to go back to the prior stages in order to seek for new ideas again.

	Identification of Creative Thinking Process				Proposed Learning Process for Creativity
Stage	Wallas (1926)	Stein (1967)	Hogarth (1980)	CPS model (1952-2000)	
1	Preparation	Hypothesis Formation	Preparation	Fact-finding	Preparation
2	Incubation	Hypothesis Testing	Production	Idea-finding	Incubation
3	Illumination	Communication	Evaluation	Solution finding	Evaluation
4	Verification		Implementation		Implementation

Figure 11: Creative thinking process and learning process for creativity

In the previous chapters I have discussed the importance of designing a deliberate learning activity to develop students' creativity with the help of computer technology. These proposed stages of the creative thinking process provide an underlying principle for making an appropriate pedagogy to teach SD 2000 virtually.

3.3.2 Designing a pilot lesson plan for conducting SD 2000 in a shared virtual reality

In the following sections, I would like to sum up the findings and describe the pilot lesson plan that was developed for conducting SD 2000 in a shared virtual reality. Figure 12 shows the design and arrangement of my pilot lesson plan with ICT and VR support. This pilot lesson plan was divided into FOUR main stages. First, stage ONE is the *Preparation Phase* which focused mainly on problem identification, research and problem analysis. Design students were required to identify the wicked problem, research on relevant information and materials, and analyze the references and factors of the problem for a creative task. The problem identification could be worked out with the assistance of ICT, namely Inspiration (www.inspiration.com) and other digital mapping tools. In the areas of research and analysis, students could adopt the tremendous resources of the Internet, Intranet, World Wide Web, images libraries, search engines, and electronic libraries. Second, stage TWO was the *Incubation Phase* which aimed at idea development and allowed the students to employ various creativity training methods in seeking creative solutions. In this stage, the shared virtual reality, for example the *ActiveWorld* ©, could be applied to facilitate students' creative and learning progress. They could possibly build up a virtual learning community among themselves for collaborative learning and group work as well as making use of the environmental stimulation within the virtual platform. Third, in stage THREE, which was the *Evaluation Phase*, design students were expected to evaluate and assess their proposed ideas and solutions by collecting diverse feedback and opinions not only from design educators and schoolmates, but also professional designers and potential clients. Digital communication tools, namely online chat room, emails, discussion forum and web blogs were used to facilitate the progress of collecting relevant feedback for further ideas development. Last but not least, stage FOUR aimed at testing ideas and solutions by actually implementing them with potential clients. This stage was called the *Implementation Phase*.

	Stage	Proposed Lesson Plan for SD 2000	Learning Activities	Proposed ICT/VR Supports
	1	Preparation	• Problem identification	• ICT supported mapping tools (e.g. Inspiration)
			• Research and analysis	• e.g. Internet, Web images and eLibrary
Research area for the Phase FOUR and Phase FIVE	2	Incubation	• Idea development by employing various creativity training methods for creative thinking	• *ActiveWorld*© introduced to study the students' learning experiences in the shared virtual reality. • Environmental stimulation • Creating virtual learning community
	3	Evaluation	• Idea evaluation and assessment	• Using digital communication tools, such as emails and web blogs to collect opinions and feedback from diverse channels namely teachers, schoolmates, professional designers and potential clients.
	4	Implementation	• Testing idea or solutions	• Not Applicable

Figure 12: Proposed pilot lesson plan for conducting SD 2000 with ICT and VR supports (the shaped area of the table was my research focus for Phase FOUR and Phase FIVE)*

Undoubtedly, ICT could be used to facilitate the teaching and learning of creative thinking for design students in stages 1 and 3 by employing existing information infrastructures, namely mapping systems and the Internet. Particularly in stage 3, the collection of feedback and opinions from various channels, design students were familiar with almost all communication systems in the virtual world since these digital tools are adopted frequently in their working process and daily lives. However, the virtual learning experience in stage 2, the stage of Incubation, is still under exploration in design education in Hong Kong. Thus, my research focus was to look at the learning experiences of design students in a shared virtual reality, particularly in the process of creative thinking and idea development. Therefore, the designed multimodal interaction research (See Section 2.2.1) did not cover stages ONE, THREE and FOUR of the proposed lesson plan, although I admit that these stages are also important in studying design students' learning experiences. The shaped row in figure 15, which is stage TWO of *Incubation*, was my focus area in this research. A brainstorming exercise was selected to carry out a creativity training exercise in the designed shared virtual reality (*ActiveWorld*©) for a group of EIGHT design students. This brainstorming exercise asked the participants to explore 101 ways to squeeze a lemon in order to design a creative lemon juicer eventually. For the details of this designed brainstorming exercise in the virtual reality could refer to Chapter 5.3.

In this research, I studied the design students' learning experiences in undertaking this *Incubation Phase* of the design process by looking at their creative thinking processes, collaborative learning within the virtual community, environmental stimulation and the emotional displays of their avatars in digital forms of communication. Nonetheless, I assumed that the deliberate design of a computer-aided lesson plan was necessary to carry out a successful learning activity in teaching and learning creative thinking in virtual space. However, only teaching creativity training methods is not enough to release or develop students' creative potential (Boden, 1993; Goldstein and Ford, 2001). Design educators have to establish a creative-friendly learning environment proactively by constantly removing obstacles to creativity and providing environmental stimulation for facilitating students' learning process as well as helping them to develop their creative-friendly learning behaviors (See Chapter ONE). All in all, the result of this research proved the importance of providing students' with a clear guideline and designed lesson plan during their creative learning process. Participants in Phase FOUR performed a high quality of organization skills during the learning process by referring to the learning materials and lesson plan (See Chapter 6.2.1). It is important to know that the entire virtual lesson in Phase FOUR was conducted without the teacher's instruction. l.c.

3.4 Measuring design students' creative learning outcomes and performances

Some researchers (e.g. Dacey, 1989; Lawson, 2006) have highlighted the importance of studying creativity measurement that can help design educators to design appropriate curricula and syllabi as well as to develop relevant learning materials and activities for creativity training. However, it is difficult to standardize various creativity measurement tools due to the diverse assertions. Some (e.g. Galton, 1869; 1879; Guilford, 1950; 1956; Guilford and Christensen, 1973; Wallach, 1985) were looking at assessing individuals' divergent thinking skill, and others (e.g. Kitto, Lok and Rudowicz, 1994; Helson, 1999) tended to use cognitive and mental tests for assessing creative potential. Similarly, some researchers (e.g. Osborn, 1963; Parnes and Noller, 1972; Kirton, 1976; 1994; Runco, 1986; 1990; Basadur, Graen and Wakabayashi, 1990; Isaksen, Pucciom and Treffinger, 1993; Mogar, 1997; Puccio, 1999; Yeh and Wu, 2006) were looking at studying individuals' creativity through measuring their problem solving skill, and others (e.g. Mednick, 1962; Wallach and Kogan, 1965; Guilford, 1976; Hocevar, 1979; Meeker, 1985; Torrance and Safter, 1999) focused on designing creativity tests. Nevertheless, using various creativity tests to assess students' creativity is controversial, and has been criticized by many researchers (e.g. Wallach, 1976; Baer, 1993a; 1993b; 1994a; 1994b; 1998; Carroll, 1993; Alder, 2002; Kim, 2005; Kyung, 2005; Reuter, et al., 2005; Preckel, Holling and Wiese, 2006; Silvia, 2008). From other perspectives, some researchers (e.g. Jackson and Messick, 1965; Taylor, 1975; Besemer and O' Quin, 1987; De Bono, 1992; Hennessey, 1994; Csikszentmihalyi, 1996; Cropley, 1999; Sternberg, 1999; Cropley, 2001; Aleinikov, 2002; Kim, 2005; Kline, 2005) were looking at measuring individuals' creative outcomes; some similar research (e.g. Cropley, 1972; 2001;

Milgram and Hong, 1999; Plucker, 1999) studied creative achievements. However, only a few studies (e.g. McCall, Fischer and Morch, 1990; Lawson, 2006) looked at creativity measurement in design education. Likewise, there has been a little research hitherto conducted in studying professional designers and their creative performances (e.g. Lawson, 1994b; Candy and Edmonds, 1996). Thus, design education bodies have been calling continuously for assessment approaches in higher education, such as performance-based assessment, portfolio assessment and authentic assessment (Anderson, 1998). Particularly in art and design studies in higher education, students' creative achievements in design subjects are very difficult to assess due to the diversity of design domains, content specifics and the subjectivity of aesthetic judgment. In my university, the major assessment methods for SD are: (1) Process Folio: All design students have to submit their personal process folios and/or project reports in order to demonstrate visual evidence for their learning process; and (2) Peer Group Assessment: A proportion of credit grade, for some compulsory design subjects, reflects students' learning outcomes by peer group assessment. For instance lecturers collect students' comments on their peers' work during the critiques (Definitive Programme Document, 2005-07). Another approach for peer assessment is the Token Allocation Scheme (assessment method for global learning and project-based learning) introduced by Professor Rimmington (Rimmington, et al., 2003). This scheme asks students to provide an allocation of marks/tokens to other groups as an assessment of their contribution to creative ideas and solutions in every scored unit. Although I wonder about the accuracy of this scheme due to the subjectivity, immaturity and bias of students' judgments, it is able to facilitate sharing and collaboration among students during creative thinking and evaluation processes.

The assessment of the Process Folio of design subjects in SD (module SD 2000 Design Thinking) is one hundred percent based on coursework. Design students have to submit a *Lablog* for revision and marking. The Lablog is a combination of (1) a laboratory notebook; and (2) a navigation logbook which includes all exercises given in the classes. Lablog is a journey of exploration and experimentation that contains students' records of observations, experiments, lecture and seminar notes and self explorations as well as records of successes, failures, frustrations, despair, joy and imaginative leaps. In SD, the submitted lablogs are reviewed by the teaching team and peer groups for comments. The grading and comments are based on a *Criterion-referenced Assessment Rubric* (CRAR) which is shown in figure 13. Design students' lablogs are assessed by FOUR main indicators equally: (1) Experiments (Learning by doing); (2) Versatility of Thinking (Ability to solve problems by using different styles of thinking); (3) Independent Learning (Self-motivation in furthering knowledge, skills and interests); and (4) Critical Reflection (ability to evaluate own process of learning to make improvements). There are FIVE levels of students' achievement: Outstanding / Excellent / Very Good / Good, Wholly Satisfactory / Satisfactory, Barely Adequate / Weak and Fail. Based on the reference of this CRAR, lecturers and students can easily distinguish the achievement of lablogs. For instance, if students are able to exhibit courage and leave their comfort zones and test existing boundaries in the category of experiments, they may obtain an outstanding grade of A+ or A.

Assessment Criteria	Outstanding / Excellent		Very Good / Good		Wholly Satisfactory / Satisfactory		Barely Adequate / Weak		Fail
	A+	A	B+	B	C+	C	D+	D	F
1. Experiments (Learning by doing) 25%	Exhibited courage to leave comfort zones and test existing boundaries, conventions and rules for unknown possibilities.		Demonstrated openness to experiment with new approaches and challenge conventions.		Experimented with a number of different approaches, techniques & materials to solve problems but did not go beyond conventions.		Some attempts to experiment, but the approaches, techniques & materials used are limited and lacked diversity.		No or little evidence of attempted experiment.
2. Versatility of thinking (Ability to solve problems by using different styles of thinking) 25%	A high level of flexibility to generate diverse ideas by thinking analytically and laterally.		Generated ideas of a diverse nature by thinking analytically and laterally.		Generated some ideas to solve problems but most are based on a similar style of thinking.		Only a few ideas generated with barely any diversity in style of thinking.		No or little evidence of diversity in style of thinking.
3. Independent learning (Self-motivation in furthering knowledge, skills and interests) 25%	Furthering knowledge through analysis and interpretation of issues discussed, using information from a range of sources.		Compared and contrasted information from various sources with own interpretation relating to issues discussed.		Some discussion of issues raised in class, drawing on a few sources of information.		Only little discussion of issues raised in class, drawing on few sources of information.		No or little discussion of issues raised in class.
4. Critical reflection (Ability to evaluate own process of learning to make improvements) 25%	Analyzed and critically reflected upon own learning experience, and found new paths for further development.		Discussed own learning experience with evidence of a critical approach.		Gave a discussion of learning experience, but the account was generally descriptive without critical or alternative comments.		Some attempts to discuss own learning experience, which remains descriptive and superficial.		Simply recorded the activities done in class without reflection.

Figure 13: Assessment criteria of SD 2000 Design Thinking (Definitive Programme Document)

Before 2005, SD used to apply the model of Non-referenced Assumption (NFA) to assess design students' creative performances in SD 2000. NFA measures the students' characteristics so that they can be compared to each other with reference to diverse characteristics (Nicholls, 1994; Taylor, 1994). Since 2005, SD started to adopt

Criterion-referenced Assessment (CRA) to assess students' learning outcomes in SD2000 Design Thinking. This is because the CRA model provides criteria and standards for sharing understanding among students. The advantage of the CRA is that it is a standard model to tell students directly what, and how well, they have learned without comparing them to other schoolmates (Keller, 1968; Bloom et al., 1971). Some researchers believe an appropriate assessment approach ought to create an interactive system for teachers and students (e.g. Dunkin and Biddle, 1974; Biggs, 1999). In SD, lecturers and design students are given a criterion-referenced assessment rubric such as the one shown above, before the module starts. Both sides fully understand the criteria of the module and the expected outcomes of students' creative performances, and these *visible* criteria, which are listed in the rubric, are able to help students to apply, create feedback and make judgments in their learning processes (Sadler, 1998). In addition, the peer assessment of lablogs gives students a chance to discuss and evaluate their projects practically without any influence on the final grade (Carlson, et al., 2000). After all, the model of the Criterion-referenced Assessment Rubric (CRAR), which has been employed continuously in assessing design students in SD since 2006, was employed to evaluate the design students' creative performance in Phase FOUR and Phase FIVE. The students' creative performance, to a certain extent, could possibly reveal their learning experiences in virtual reality.

3.5 Summary of Chapter THREE: Design thinking and creativity

In this chapter, I have developed the first part of my literature review which focuses on design thinking and creativity. I have discussed the nature, definition and characteristics of creativity, even though I am not able to provide a precise definition of what creativity is. I assert that the people's creativity certainly has richness of ideas and innovations that could possibly be developed by various creativity training models. Likewise, I presume that the creativity and creative performance of design students could be enhanced by undertaking systematic and deliberate creative thinking processes. I discovered that creativity is not a stand-alone intelligence, but it integrates and interacts with other human cognitive abilities. Therefore, it is important to design an appropriate creativity training model to help design students to enhance their abilities in creative thinking and combinational thinking (Florida, 2002). Actually, referring to the creative triangle I proposed in figure 4 in the first chapter, creativity training is one of the crucial components in releasing the students' creative potential. Moreover, I realized that creativity is driven by emotion as well as connecting with other cognitive aspects of human psychological reactions. In other words, design students' personalities and emotions might affect their creative performances. Similarly, it is also essential to develop students' creative-friendly learning behavior which I had discussed in Chapter ONE (See figure 4). Furthermore, environmental stimulation is one of the factors in developing students' creative thinking skills. In this research, I looked at the environmental impact of virtual reality by studying the virtual learning experiences of design students.

The second part of this chapter reviewed the connection between design education and creativity training. I found that the creative thinking is believed to play a crucial role in design education. Teaching *design thinking* is indeed educating design students to manage creative thinking and design planning. Design thinking is a process which involves *free* creative exploration and *scientific* procedure of planning. This process is formed by the instability of the *subject matter* in design practices in which the subject matter is: (1) not fixed; (2) explored constantly; (3) evolving; and (4) the scope of products and servicing areas are expanding (Buchanan, 1995). Therefore, designers are working with the matter of choices, and design is indeed a determinate activity of discovery (Buchanan, 1995). If this process of design thinking is aiming at eventual discoveries, the same as other major scientific breakthroughs, design students have to balance abilities of both creative thinking and design planning in a systematic, deliberate and scientific manner.

In the third part of this chapter, I proposed a learning process of creativity training after the analysis of diverse creativity training methods. The proposed process can be identified as (1) the Preparation Stage, (2) the Incubation Stage, (3) the Evaluation Stage and (4) the Implementation Stage. I assert that strategic design solution requires a systematic arrangement of learning activity especially for design education. In this research, my intention was to study whether the virtual reality technologies can help design students in enriching their learning experiences during their creative thinking process. As discussed, the deliberate arrangement of learning activities for creative thinking skills facilitates students' learning experiences during the process. Thus, a computer-aided pilot lesson plan was developed for the incubation stage. Participants in Phase FOUR were asked to explore 101 ways to squeeze a lemon in order

why this particular task?

eventually to design a creative lemon juicer (See Chapter 5.3). The results showed that the entire learning process was effective and well structured and the students showed a high quality of organization skill during the process (See Chapter 6.2.1).

The final part of this chapter discussed how to assess design students' creative outcomes in their learning process, in Phase Four and Phase Five. A Criterion-referenced Assessment Rubric has been suggested to assess the students' performance in SD 2000 as well as employing this rubric to measure their creative achievement in virtual reality.

Chapter FOUR: Virtual Technologies and Design Education

After the discussion of the nature of creativity, measurement and design education, I would like to shift my focus from studying the areas of creativity and design education to analyzing the employment of virtual technologies in design education and creativity development. This chapter is the second part of my literature review, which provides me with a holistic picture of how virtual technologies can be applied to design education particularly in facilitating creative thinking. Emphasis is placed on discussing (1) the development of using technology in education; (2) the possibility of using the computer as a learning partner in design education; (3) how to foster the individual's thinking and creativity through the use of hypermedia; (4) whether the computer can be used as a creative thinking partner (5) the gender differences in using virtual technologies in education; and (6) the use of virtual reality and multi-users domains in education.

4.1 The use of technology in design education and creativity development

Students are switching their reading habits from conventional and tangible materials, such as newspapers, books, magazines, printed items and notes, to the electronic and intangible materials in the information age. Educational websites and homepages are becoming more and more important and popular in conveying messages and information due to their inherent characteristics in displaying and arranging quantitative information virtually. Information and data can be stored and retrieved easily by only pressing a button with hypertext linkages. In view of the educational context, digitizing information and data for easy collection and storage saves physical space as well as the convenience of updating and retrieving information saving time and manpower. One of the advantages of using educational websites is the multiplicity of communication; students can share and communicate with each other by the convergence of all digital media and platforms.

Wood (1999) believed that almost all websites can potentially be adopted as Internet pedagogy, even the crassest homepages. Apparently, the Internet has transformed the traditional educational pedagogies at all levels. Because of these tremendous changes, educators need to find out any appropriate ways of delivering effective pedagogy with this powerful vehicle. Internet-based education could be one of the best possible directions for future development in all kind of educational disciplines. This is because the infinite bandwidth empowers the signal-carrying capacity and virtual communication that reach the techno-utopianism (Gilder, 2000; Florida, 2002). Of course, the Internet facilitates all disciplines in diverse levels. The usages of the Internet in business environment will be different from educational platforms. Therefore, educators are responsible to shape and transform the advantages of using the Internet to the actual educational implementation. In view of web-based learning environments, Harasim and his associates (1995) classified existing online learning approaches into SEVEN categories: (1) Electronic Lectures: A presentation of online instructional materials; (2) Ask-and-Expert: A question-and-answer communication model for the interaction between a group of students and an expert; (3) Mentorship: an online mentor and apprentice interaction platform; (4) Tutor Support: an interface which enhances face-to-face interaction between tutors and students; (5) Access to Network Resources: a library-linked database which contains versatile information and knowledge for students; (6) Informal Peer Interaction: an informal communication network for peer sharing and information exchanges; and (7) Structured Group Activity: an online curriculum-based group learning activity. Based on Harasim's classification, these seven categories of applying web-based learning could possibly facilitate all types of educational purposes in all levels, including design education. Therefore, I would like to study the relationships between information technology and education based on the above approaches in order to find out some clues and possible ways of employing digital environments, particularly in the shared virtual reality, in creativity training in the following sections.

4.1.1 The development of using technology in education

In 1922, Thomas Edison foresaw that our education system would be changed totally by applying the motion picture in teaching and learning. More than twenty years later in 1946, William Levenson, who was the director of the Radio Station of the Cleveland Public School, highlighted that the educational system was under a revolution because of the portable radio receivers that were installed in the conventional classroom (Levenson, 1946). Psychologist Skinner (1960) introduced his "*Teaching Machines*" in the late 1950s and 1960s, which brought tremendous modifications to traditional teaching methods. Apparently, the popularity of using computers in educational approaches since the 1980s brought enormous possibilities to education. Dreyfus and Dreyfus (1986) described *two uses* of computers in education, as overseers of drills and as tutors of learning. The idea of Computer Aided Instruction (CAI) can be used as a tutor, of the successful cases being the LOGO project which has applied the designed computer language and environment as tutee (Dreyfus and Dreyfus, 1986). Additionally, in view of design education, Green (1974) stated that *design* aims at developing students' value judgments by means of deliberate analysis and consideration of human needs in the 1980s. According to Green, *technology* is able to provide new complex forms and values that lead design students to understand the tremendous changing world as well as demanding critical responses to their social environments. Obviously, one of the significant steps of applying technology in education was the invention of the World Wide Web (WWW). WWW can possibly work as a tool that can enhance collaborative learning intrinsically in diverse perspectives due to its inherent characteristics. Tim Berners-Lee, the inventor of the WWW, created a set of agreed protocols and standards for users to store their documents on Web servers anywhere in the world. Moreover, the WWW is a two-way process in which users not only read web pages, but also can actively create, amend and link new pages (Berners-Lee and Fischetti, 1999). The interactivity of the WWW enables facilitation of any type of educational activities. One of the earlier comments from Dreyfus and Dreyfus (1986) was that the individual can actually learn useful things whenever interacting with the computer; the computer is able to help individuals to apply what they have learnt to real situations by doing diverse experiments. Nonetheless, the most essential focus is to understand the learning processes of individuals, and identify clearly different types of skills before using technology in education (Dreyfus and Dreyfus, 1986). In addition, Dreyfus and Dreyfus believed that the computer will possibly be developed to understand the students' strengths and weaknesses during their learning processes in order to provide tailor-made instruction, advice and hints, and pose problems, appropriate learning speed and proper pedagogical order. Furthermore, another significant feature of the computer is the hypermedia technology which facilitates different forms of human communication virtually, such as synchronized and asynchronized communications. Cotton and Oliver (2000) underlined FIVE significant characteristics of using hypermedia for communication: (1) it takes advantage of gathering powerful functions of computers and other telecommunication technologies; (2) it offers an interactive platform which allows individuals to make active contributions; (3) it is a very interesting medium which has a non-linear form with no beginning, middle or end; (4) it allows combinations and chemical reactions by employing multiple media together; and (5) it is a hybrid medium that leads individuals to experience the medium and create experiences at the same time. After all, these characteristics of hypermedia are able to provide possibilities for developing any kind of computer-aided educational activities including the creativity training.

weaknesses + limitations?

4.1.2 Computers as a learning partner in design education

Dewey (1956) described *technology* as an art of experimental thinking. *Technology* is an all-pervasive aspect of the human being in daily life (Green, 1999). The Conseil Européen pour la Recherche Nucléaire (CERN) (In English: European Organization for Nuclear Research) created the World Wide Web (WWW) in the 1990s, and web-based learning was applied quickly into educational areas and became one of the promising education tools (Cailliau, 1995; Brooks, 1997; Sloane, 1997). In fact, after the popularity of the personal computer since the 1980s, more and more people have been able to experience and have used their personal computers in their own ways. In the 1990s, the computer emerged as an expressive medium with the help of color screens, powerful graphics displays and CD-ROMs (Turkle, 1995). Besides, software for digital graphic design and image retouching became a crucial tool in helping artists and designers in creation and artistic expression since 1990. With the assistance of computer technology, artists and designers can share their creative achievements with other individuals whilst appreciating other creative artifacts through virtual platforms and the Internet. Kroll (1995) stated that the computer is popular in art and design development and has completely changed the understanding of the artist-viewer relationship and interaction. *Art* is no longer a passive experience; viewers can be involved in art exploration with the assistance of computers (Kroll, 1995). Digital art and design creative software are not only assisting professional designers and artists to complete their creative work, but also helping the layman to make art pieces easily. An example from a collaborative artwork project called the *Listening Post*, which is designed by a New York artist and a research statistician, was built by generating thousands of people typing away in chat rooms, online forums and search engines, and transforming the data into a symphony of sounds that pulse in time with the flow of data (Andrejevic, 2000). This project made use of the interactions among participants to compose unpredictable musical patterns. Andrejevic (2000) explained that the *Listening Post* project was a representative of digital aesthetics by underlining several characteristic elements of the hyper medium, for instance, the interactivity, ability of digitization and transformation, and open-ended format. Apparently, computer technology, especially the Internet, gives opportunities to individuals to produce creative and expressive art pieces, namely paintings, poems and amateur magazines easily (Gauntlett, 2000). In view of education, especially creativity education, Schank and Cleary (1995) have introduced their concept of *Engines for Education* in their hyper-book. Some examples of these learning engines can be found inside their studies, for instance demo software called *Broadcast News*, which makes the learning process become a fun activity by presenting a good demonstration of *Leaning by Doing* to students. In this engine, students are able to organize their news-shows with some disparate elements of the program. The *Broadcast News* has applied FOUR learning approaches to the digital platform, which are (1) learning by doing, (2) incidental learning, (3) learning by exploring and (4) case-based teaching. Other cases from Schank's engines include an engine called *Yello* that works for creating social simulation to students. The engine provides a virtual educational environment that helps students to understand some business problems and obtain hands-on experiences which are similar to the actual business world. Nonetheless, though the above cases, namely the *Broadcast News* and the *Yello,* are not related to any design subjects in design education, these engines require students to solve problems by using their creativity and imagination. Such concepts could possibly be applied to teaching and learning creative and design thinking in design education because creativity training is indeed a part of the problem-solving process.

As I discussed earlier in Chapter THREE, design thinking is managing creative thinking and design planning. Here I could see the possibilities of using the hypermedia platform of computers to facilitate the problem-solving process of design students, however, how is it possible to facilitate the creative thinking and imagination of design students? Andrejevic (2000) stated that cyberspace is an imaginative environment because this space is not constrained by the laws of physics. Andrejevic (2000) listed two interesting assumptions about using cyberspace to create environmental stimulation in facilitating creative thinking: (1) if a sculptor wants to create a virtual sculpture, he can ignore the laws of gravity in building it in cyberspace; and (2) a composer could possibly create a song that is impossible for a human to sing in cyberspace. Andrejevic (2000) explained that the cyberspace is *an externalization of fantasy* which only happens in the human mind. In other words, the cyberspace is a place for people to *realize* their fantasies and explore their creativity and imagination.

4.1.3 Using hypermedia to foster individuals' thinking and creativity

In July 1945, Vannevar Bush published an influential essay called *"As We May Think"* in the Atlantic Monthly, which elaborated the birth of hypermedia and how this new medium contrasts the rigid and hierarchical systems of information retrieving and storing in conventional human thought. Bush (1945) simply pointed out the way in which hypermedia works totally differently from how human mind does.

"It operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts, in accordance with some intricate Web of traits carried by the cells of the brain...trails that are not frequently followed are prone to fade, items are not fully permanent, memory is transitory.....yet the speed of action, the intricacy of trails, the detail of mental pictures, is awe-inspiring beyond all else in nature" (Bush, 1945: Atlantic Monthly).

Bush (1945) introduced the system called the *Memex* in 1945, which was a new vision of a personal memory system. The *Memex* allows individuals to store, construct and retrieve trails of their associations. By creating these associations, the *Memex* works as a permanent tool of recording for creative researchers (Cotton and Oliver, 2000). Various experiments and studies have been carried out in the development of hypermedia in subsequent years. For instance Douglas Englebart, who is a pioneer of designing office automation, namely mouse and multi-window screens, developed the *Augmentation System* in the early 1960s in order to enhance individuals' abilities to augment human intelligence. According to Englebart, the *Augmentation System* involves knowledge of procedures, human custom, languages and methods, and all training skills. Likewise, Ted Nelson, who coined the term "*hypermedia*" in 1965, introduced a very ambitious project called the *Xanadu* which tried to collect and link together with the total sum of human knowledge. This system, as a hypermedia tool, allows individuals to study, compare, recombine and re-use the accumulated knowledge of mankind. In 1991, Tim Berners-Lee developed the World Wide Web project in order to foster the knowledge exchange and collaborative working within a matrix. Additionally, a very interesting discovery has come from Nicholas Negroponte's Semantic Compression. Negroponte believed that human beings can apply the multisensory capabilities of the hypermedia to express and compress huge amounts of information and ideas (Cotton and Oliver, 2000). In view of the ways of using virtual communication nowadays, some behavioral icons in the systems of MSN or Skype, individuals can apply a smiling or crying icon to present their complicated feelings and opinions in a simple action. If Negroponte is right, the concept of multisensory in hypermedia could be a way to develop computer-aided education in a more sophisticated level by applying these emotional displays to facilitate virtual communication among computers, students and educators.

After all, Cotton and Oliver (2000) classified all sorts of research in hypermedia into FIVE major directions: (1) to find out effective ways to map the linked ideas and information in meaningful connections; (2) to provide multisensory simulation to creative thinkers in various thinking exercises; (3) to use multiple media to express ideas addressing problems; (4) to develop forms of using the Semantic Compression in order to simplify any complex systems; and (5) to foster collaborative activities for working and thinking effectively and creatively. In addition to the aforesaid characteristics of research focuses in hypermedia, one of the key factors of developing hypermedia is helping individuals to think effectively and creatively (Cotton and Oliver, 2000). This was the main concern in my research, and I set out to find out any possible way of using hypermedia to release students' creative potential.

4.1.4 Computers as a creative thinking partner

I ask an interesting question in the era of information age, particularly in the area of fostering E-Learning in design subjects (Lau, 2003; 2006a; 2006b): Does computer and information technology facilitate students' creative thinking processes? If it is possible, in what ways can the computer help? What is the role of the computer in conducting the creativity training process? To address these questions, Edwards (2000) believed the computer does help an individual to explore general principles of creativity in a broad sense, and technology is able to assist individuals to become creative in society. Machrone (1994) explained one of the functions of using technology and the computer which could facilitate *creativity* in the workplace by demonstrating a graphical organization, a mind-map or graphical representation of ideas, to help individuals to structure their thinking and thought processes. Machrone noted that, with the help of these graphical organizations, individuals are able to find out links and relationships between their concepts and ideas in order to seek creative solutions (Machrone, 1994). Similarly, Boden (1994) pointed out that computers are able to facilitate the combinational creativity by putting all prior concepts and ideas to form certain patterns. In other words, computers and information technologies play a role as an effective tool for constructing creative solutions for ill-defined problems; either tangible or intangible mind mapping facilitates individuals' creative thinking processes by providing a clear and systematic schema against interwoven difficulties. As I discussed the importance of identifying problem materials for creative thinking process in previous chapters, I assert that the computer does help design students to identify wicked problems by mapping attributes and visualizing their thinking processes. A practical case can be found in the research of Proctor (1991), in which he demonstrated the significant function of using computers to enhance individuals' creativity by applying a computer program called "*Brain*" in producing creative thought. Proctor's hypothesis is that computers can help individuals to destroy thought patterns in solving problems along the process of generating new insights. In his report, Proctor (1991) concluded that creative insights can be generated by gathering linked concepts and ideas into a schema. Proctor strongly supported that the use of computers in creative thinking is to make use of pictures and images as a problem-solving tool.

In addition to the concepts of using the computer as an organizer for mapping individuals' creative thoughts, Huber (1990) underlined the use of computer facilitated project-based creativity in many ways. For instance the electronic communication facilitates communication effectively and inexpensively without limitations of time and space; the computer provides recording and index systems for communication in a more reliable and cheaper way; and the computer manages the accessibility of participants in electronic networks. Relevant practices can be found in the computer-based instruction in a creativity training program (Clements, 1991), which combines modeling, coaching and feedback systems in order to teach young children how to apply analogies and metaphors in solving problems (Castillo, 1988). Henderson and Venkatraman (1994) agreed that the computer is able to facilitate individuals' collaboration in disseminating project members geographically due to the function of distributing quantity of data and information easily and effectively. Moreover, individuals' psychological readiness in collaborative creative works can be facilitated through the sharing within this organizational arena, namely the individuals' self-esteem, mutual respect among members, sense of commitment and organization identification (Orr, 1989). Individuals' motivation can also be reinforced through this organizational citizenship (Bateman and Organ, 1983).

Dewett (2003) explained that both time and collaboration factors are some important components of developing individuals' creativity in the organizational arena; collaboration provides new perspectives and knowledge to individuals while time is the key to understand how a project is developing. Dewett (2003) suggested that technology could play an essential role for facilitating individuals' creative processes by offering an organizational learning mode during the progress especially in large-scale project-based work. Apart from that, the computer allows individuals to share their beliefs, values and norms quickly and effectively among group members (Dewett, 2003). I argue that the creative-thinking process needs certain formal and informal knowledge for students to acquire and explore in Chapter THREE. In this case, a common way of using the computer is working as a database because it stores information and knowledge which allows students to access them in anytime and anywhere. Apparently, the computer not only allows students to retrieve their prior information and knowledge conveniently, but also helps students to search for and absorb new knowledge related to the actual problem. Computer works for knowledge codification indeed (Tushman, 1977). Huber (1990) agreed that the computer is able to codify knowledge because the human memory is imperfect and can easily make mistakes; Huber admitted that the computer facilitates individuals to store and retrieve quantities of data in a quicker and inexpensive manner. Additionally, the computer is a labor-saving device that obviously frees people from complex and boring tasks (Edwards, 2000). In this sense, individuals can focus on the essential parts of the creative thinking process, such as problem identification and incubation, instead of dealing with simple calculative analysis, memory and data storage.

Based on the above discussion, the computer seems to play a very positive and functional role in assisting students' creative thinking processes. However, Feldhusen and Clinkenbeard (1986) gave a reminder that different computer-aided creativity training programs obtain diverse results and performances due to the diverse applications and technologies that are employed. McLaren (1993) argued that the computer is not able to facilitate moral guidance in the use of human creativity. McLaren pointed out that since society is enjoying the advantages of using computers in all aspects, people are not willing to realize the side-effects of using technology, and this is what McLaren called *The Dark Side of Creativity* (McLaren, 1993). According to McLaren, the computer hinders the development and exploration of emotional factors and human touch within the creative thinking process. Nonetheless, computer technology is only a tool that society can apply to shape the environment, which has neither positive nor negative effects (Papert, 1990). Papert (1990) took a positive view on using the computer for developing individuals' creativity. He pinpointed that people have to think about how to explore the opportunities which computers and technologies can offer instead of worrying about their side-effects on human beings. Despite the argument about the side-effects of using computers and technologies, the computer indeed works as a learning partner of creativity thinking activities for design students by means of playing neither an instructive role nor guidance during the thinking process, but assisting students in visualizing their thoughts by schema, releasing simple tasks and routines, and fostering effective communication among group members.

4.1.5 The gender differences in using virtual technologies in education

Gender differences in the usability of computers, the Internet and virtual applications have been a controversial topic since the personal computer has become popular at home. In general, the male is expected to use the Internet and computer facilities more than the female does (e.g. Chen, 1986; Levine and Donitsa-Schmidt, 1995; Graphics, Visualization, and Usability Center [GVU], 1998; Cyberdialogue, 1998; Chuang, Hwang and Tsai, 2008). Researchers (e.g. Kirckpatrick and Cuban, 1998; Chuang, Hwang and Tsai, 2008) believed that female has a comparatively lower technological competence level than the male does, particularly in using computers and the Internet. Young (2000) discovered that males spend more time in using computers at home when compared with females. Furthermore, some researchers (e.g. Schumacher and

Morahan-Martin, 2001; Colley and Comber, 2003; Volman, Van Eck, Heemskerk and Kuiper, 2005) stated that females lack of confidence in working with technology might cause computer anxiety (Jackson et. al., 2001; Brunner and Bennett, 2002; Cooper and Weaver, 2003). Nonetheless, some researchers have presented evidence that there is no biological incompatibility of females in operating computers and technology (Schofield, 1995; Edwards, Coddington and Caterina, 1997). There were no significant differences found between genders in accessing the computer at home in spite of the ownership of personal computers (Young, 2000). Likewise, although males play computer games more often (Brunner, Bennett and Honey, 1998; Cassell, 2002) and take more technology subjects (Nachmias, Mioduser and Shemlah, 2001; Pinkard, 2005) in school than females do, females use email and other personal communication devices more often than males do (Schumacher and Morahan-Martin, 2001; Volman, et al., 2005).

Regarding the connectivity of online and distance learning, an early research study by Hoai-An (1993) stated that there has been an inequality in genders in E-Learning since female comprises only between 10-15 percent of the online population. Almost ten years later, SØLVBERG (2002) organized a study of gender differences in home computer usage in rural schools in Norway. This study consisted of 152 students with a female to male ratio of about 60 percent to 40 percent. The results suggested that the purchase of home computers had been increasing tremendously and there was no apparent gender difference in accessibility. Many other investigations also demonstrated that males and females had equal achievement scores and attitudes in computer classes, the usability of computers as well as experiences with computers (e.g. Arch and Cummins, 1989; Colley et al., 1994; Rozell and Gardner, 1999). Atan

(2002) and her associates conducted gender-related research on IT accessibility in Malaysia. Their study revealed no gender difference in the utilization of computer technology. Positively speaking, the mode of distance learning through ICT reduces the gender gap in terms of computer availability and accessibility, and actually facilitates the distance learning activities (Atan, et. al, 2002). The gender gap in the use of and knowledge about ICT has diminished (Cooper, 2006). Likewise, some researchers (e.g. Aysersman, 1996; Brunner and Bennett, 2002; Cooper and Weaver, 2003) argued that the issues of gender stereotypes have less influence over computer experience and anxiety. Additionally, evidence shows that gender difference in attitude and advanced operation skills have been reducing because of the popularity of home computers and the employment of computer aids in the school curriculum (Miller, Schweingruber and Brandenburg, 2001; Schumacher and Morahan-Martin, 2001; Cooper, 2006).

It is important to note that a case study exploring how technology affected gender differences in science performance demonstrated that proper pedagogical practices and social organization in technology could help to promote gender inclusive experience and performances (Mayer-Smith et. al., 2000). Subsequent researchers (e.g. Van den Akker, 2003; Oudshoorn, Rommes, and Stienstra, 2004; Heemskerk, Brink, Volman, and Ten Dam, 2005; Heemskerk, Ten Dam, Volman and Admiraal, 2009) suggested that educational approaches should embed gender scripts (Oudshoorn, Seatnan, and Lie, 2002) in order to enhance positive attitudes toward technology and learning effects. Some (e.g. Cooper, 2006; Li and Kirkup, 2007) have even argued that educational software is often, unintentionally, designed for the interest of males. It is essential to consider gender differences while designing any educational approach using virtual platforms. Research findings (e.g. Cooper and Weaver, 2003; Volman, Van Eck, Heemskerk and Kuiper, 2005; Heemskerk, Volman, Admiraal, and Ten Dam, 2008) showed that females appreciated clear instructions and interesting subjects more than males did, whereas males appreciated images, choices and competition more than females did. Moreover, other researchers (e.g. Brunner, Bennett and Honey, 1998; De Jean, Upitis, Koch and Young, 1999; Fiore, 1999; Agosto, 2001; Heemskerk, Volman, Admiraal and Ten Dam, 2008) have claimed that females prefer collaboration and to work in groups in virtual platforms. Current research (e.g. Chuang, Hwang and Tsai, 2008) has indicated that males have better adaptability to Internet-based learning than females do, particularly in the process of discussion and when making critical judgments.

After all, gender issues in teaching and learning design thinking in a shared virtual reality was one of my concerns in this study. According to my research planning, described in Chapter TWO, an equal distribution of genders was essential to enable gender differences in E-Learning to be identified, as well as to gain insights about the role of gender in conducting design thinking exercises. The results of this research showed no significant differences between male and female students in operating the system and avatars in the shared virtual reality, except for the case of one male student <03> who reported his anxiety about using the computer during the process (See chapter 6.2.3). The shared virtual reality is fundamentally different from other web-based learning platforms. It requires students with little operational skills to handle the movements of avatars and participate in group discussions. This user-friendly platform provides students with a "what-they-see-is-what-they-get" function, which facilitates their learning with technology. However, this research found that the artificial gender distinctions in the shared virtual reality can potentially influence students' learning experience (See chapter 6.2.3), which is one of the essential areas for studying gender differences in virtual reality for further exploration. Nonetheless, it must be admitted that this study only explored an aspect of gender issues in shared virtual reality, and further studies from diverse perspectives are needed. For example, it is interesting to find out that IBM (2007) has announced official guidelines regarding appropriate avatar conduct. Jackson, Zhao, Witt, Fitzgerald and von Eye (2009) are studying gender differences in moral behavior in virtual worlds. In relation to creativity training in virtual reality, current research (e.g. Brizendine, 2006; Abraham, 2007) has indicated that there is no gender difference in cyberspace, and that the actual gender of the participant will not impede the progress. My research findings also support that there are only artificial gender distinctions in cyberspace and show no significant influences on their learning experiences.

4.2 The use of virtual reality in education

In the above sections we discussed the use of various technologies in design education, and I stated that the computer could be utilized by students as a "learning partner" as well as by educators to foster students' creative thinking, for example with the use of hypermedia. In the following section, I would like to advance my idea from the use of computers and information technologies to in the use of virtual reality. The emphasis will be on (1) defining the use of virtual reality in education; and (2) studying the use of virtual reality and multi-user domains in education.

4.2.1 Defining the use of virtual reality in education

Peter Weibal, who is an artist, curator and theoretician, made use of the term "virtual" early in the 1960s but, in fact, the term "virtual" was already being used in art history in the 1920s (Arnheim, 2007). Sutherland coined the term, "virtual reality" as early as 1963. He also designed the prototype head mounted display (HMD) for rendering visual stimuli. His work was followed by other researchers (e.g. Heim, 1998; Strangman and Hall, 2003) who simply defined virtual reality as a technology. Fitzgerald and Riva (2001) pointed out that the fundamental nature of virtual reality is a computer-synthesized, three-dimensional graphical environment with visual and auditory output devices. With these systems, users can experience immersive virtual environments as if they were actually there. Graves and Kupsh (1994) suggested earlier about the use of multimedia presentations can give students valuable experiences that simulate real-world learning through giving them opportunities to guide their own learning. Therefore, the student-computer interface is one crucial factor in developing a rich computer-mediated world and providing rich information in any virtual platform (Draper, 1999). In other words, in a highly interactive virtual environment, participants are able to change the visual and spatial sense of the space autonomously in order to create multisensory and highly interactive experiences (Grau, 2004; 2007). Therefore, *images* are now advancing into a completely new arena in which everyone is living within this matrix of artificial images (Grau, 2007). This artificial visualization is indeed shaping the future digital world (The Image and Meaning Initiative, 2001). Furthermore, interactivity is one of the key components in providing the sense of immersion in virtual reality. Sastry and Boyd (1998) stressed that the participants' feeling of presence, particularly within real world applications, is determined by the level of interactivity. In other words, participants are able to interact with other people, objects and environments spontaneously. Further details of the use of virtual reality in education will be discussed in Section 4.2.2.

Some writers (e.g. Steuer, 1992; Lombard and Ditton, 1997; Heeter, 2000; Burnett and Marshall, 2003) have defined interactivity as being a characteristic of any medium in which the user can influence the form and content of the mediated presentation or experience. Johnson and Levine (2008) explained that the fundamental nature of virtual reality allows participants to interact with other participants, objects and spaces in order to influence the subsequent course of events. According to Johnson and Levine, the current virtual environments, which are attracting masses of users, allow participants to build friendships, communities, societies and even cultures that enrich their experiences, just like in the real world. Furthermore, virtual reality not only establishes highly social environments for participants, it also provides richly expressive environments in which the participants become immersed, by applying multi-sensory simulations such as sound and visual cues, hypperealic perspectives, high levels of interactivity and rich textures (Johnson and Levine, 2008).

More and more research on defining virtual reality (e.g. Steuer, 1992; Seidel and Chatelier, 1997; Riva, 2000; Fitzgerald and Riva, 2001) is considering virtual reality as a human experience. In other words, it is a unique experience between the participant and the virtual environment. For instance, Seidel (1997) defined virtual reality as a multi-dimensional human experience which can be generated totally or partially by computer; In line with the comments about the importance of *presence* in the section above, Fitzgerald and Riva (2001) pointed out the fundamental nature of virtual reality is a computer-synthesized, three-dimensional graphical environment with visual and auditory output devices. With these systems, users can experience an immersive virtual environment as if they were actually there. Exploring the understanding of virtual reality further, Slater (1999) highlighted the concept of *presence* as crucial. He emphasized that this concept should include THREE aspects, namely (1) the sense of being there in the environment depicted by the virtual environment; (2) the extent to which the virtual environment becomes the dominant one, for example when participants respond to events in the virtual environment rather than in the real world; and (3) the extent to which participants, after the virtual environment experience, remember it as a place they have visited rather than just as images generated by a computer (Slater, 1999:p.550-561). However, some researchers (e.g. Rizzo and Buckwalter, 1997; Riva, 1998; Gaggioli, 2001) have argued that the participant's experiences in virtual reality are limited when compared with real-world situations. This is because real-world experiences have sensory richness. Thus, as

Gaggioli (2001) reminded us, the application of virtual reality has limitations when it comes to the generalization of research results. Similarly, interpersonal interaction is one of the key components of simulations in virtual environments. For example, most of the multiplayer simulated virtual environments only offer players a basic level of personal reactions (Thorsen, 2006). From a broader point of view, different from creating simulations in pure science domains, Thorsen (2006) highlighted that the problem of communication in the simulation environment for the social sciences is that participants are frequently using verbal rather than numerical communication methods during the process. Moreover, tracking the participant's gaze (frustum) in virtual reality is a big problem. Gaze is one of the key factors for effective communication in real-world face-to-face practices (Yee, Bailenson, Urbanek, Chang and Merget, 2007; Tampone, 2008). A possible method, which may not be a solution, is the application of the Cave Automated Virtual Environment (CAVE) technology, which is a system providing visual information in virtual environments (Blascovich and Bailenson, 2006). This CAVE system allows participants to change their gaze directions at will. Despite the use of CAVE, researchers (e.g. Loomis, Blascovich, and Reall, 1999; Blascovich and Bailenson, 2006) proposed the use of a small light-emitting diode (LED) device to track their movements and gaze directions in a more cost-effective manner.

From the point of view of educational research, the virtual reality system has a huge capacity to measure and record naturalistic behavior within simulated scenarios (Gaggioli, 2001). The highly flexible and programmable nature of virtual reality systems enable researchers to collect, measure and present a wide variety of controlled stimuli and responses made by the subject (Riva, 1999). Therefore, a huge number of educational research studies on the uses of virtual reality have been carried out in many forms and for many purposes (e.g. Ali, 2002; Monahan, McArdle and Bertolotto, 2008). For example, Monahan, McArdle and Bertolotto (2008) applied the virtual reality and multimedia systems as a communication tool to support collaboration among students; The Florida Virtual School project was designed to develop students' skills and to provide them with learning resources for a lifelong learning process through the construction of learning communities (Friend and Johnston, 2005). Another similar project, funded by the U.S. Department of Education Technology Innovation Challenge Grant, is The Virtual High School (Pape, Adams and Ribeiro, 2005). This project has shown that one of the key factors in developing a virtual learning community is giving a balance of authority and responsibility for students' learning. Additionally, researchers (e.g. Lotens and Riemersma, 1997) have agreed that one of the powerful uses of the virtual environment in training and education is to simulate large scale exercises cheaply and effectively For instance control training, battlefield simulation, disaster control training are dangerous to the participants. Moreover, the virtual environment enables the participant to experience some learning contexts that are impossible or difficult to experience in real life (Mantovani, 2001). Mantovani (2001) indicated that another potential application of the virtual environment in learning is that it allows disabled people to participate in various experiments or learning environments easily. Undoubtedly, when we compare traditional web-based and multimedia technologies in education, virtual environment technologies are more functional and effective for various aspects of training and education. However, Lotens and Riemersma (1997) argued that the perceptual quality of the presentation system in the current state of virtual environment technology is very limited, especially in the communication of haptic, force and vestibular information.

Nonetheless, as suggested by many researchers (e.g. Bruner, 1966; Roussos, 1999; Winn, 1993; Standsfield, Sobel, Prasad and Tapia, 2000), virtual reality has the potential to modify and enhancing students' learning experiences by giving them a rich, interactive and immersive learning environment as well as supporting experiential learning. One of the effective ways of applying virtual reality in education is to create a unique experience for students. This makes students' learning become a personal experience during the learning process. Hereby, a tailor-made shared virtual learning environment has been established particularly for providing design students' a unique personal experience during the learning process in this research (See Chapter 5.2). The result showed that design students were excited about doing design thinking exercises in a virtual open area as well as inside a virtual café (See Chapter 7.2).

4.2.2 Applying virtual reality and multi-users domains in education

One of the early developments of virtual reality, or cyberspace technology, was based on the hypothesis and research of Head-Mounted Displays (HMDs), conducted by Sutherland and his colleagues at Lincoln Laboratory, Massachusetts Institute of Technology (MIT) in 1966. The HMDs aims at providing users with an illusion of seeing virtual three-dimensional objects by moving their heads and changing perspectives (Sutherland, 1968). According to Sutherland, this three-dimensionality takes place whilst the virtual objects on screen display have almost the same movement as real objects if the spectators turn their sights. Rheingold (1992) gave a clear explanation of this by introducing his ideas of immersion and navigation, Rheingold elucidated that the use of stereoscopy, gaze-tracking and other related computer technologies can create an illusion of *immersing* a computer-generated scene, and also spectators can *navigate* inside this computer environment liberally with the support of computer technologies. In the early stage of the development of the HMDs, the first virtual object was a *cube* with approximately two inches height which was developed by the system TX-2 in 1967; another virtual object was a skeletal perspective view of cyclothexane (Rheingold, 1992). It is interesting to note that some virtual objects provided an *unfamiliar* perspective to spectators since these objects were floating in the air by screen display. Further development in the University of Utah from the late 1960s to the early 1970s was the construction of the first batch of systems for developing virtual reality, some of which were invented by Sutherland and his colleagues in the early stages in Massachusetts Institute of Technology (MIT), for instance, the clipping divider, matrix multiplier, vector generator, headset, head position sensor, and general purpose computer (Rheingold, 1992). Followed by John Warnock, a graduate student of the University of Utah who founded the Adobe Corporation later, Warnock created an algorithm in computer programming which is based on Sutherland's clipper divider. Another significant breakthrough was the electronic prosthetic called *Utah Arm*, which combined various advantages of VR technologies and cyberspace interface to operate remote robots (Rheingold, 1992). Despite the academic research in universities, America's National Aeronautics and Space Administration (NASA) created a model VR laboratory in 1988. Meanwhile, a prototype of a cyberspace replica of the city of Seattle was introduced by the participants in the annual conference of the Association for Computing Machinery in 1990 (Rheingold, 1992).

In 1985, the first online multi-users environment was established by the Commodore 64 through the network service of the Quantum Computer Service (the former American Online system). This virtual environment allows approximately 500 participants to interact with others by using graphical representations of bodies and objects, or call *avatars*. Despite the fact that the initial Multi-Users Domains (MUDs) and Multi-Object Oriented (MOOs) are mainly operated under a text-based platform, the latest MUDs and MOOs only use text for conversation while users are using three-dimensional avatars to represent themselves with a highly photorealistic virtual environment. Some of the successful systems include the CyberGate designed by the Black Sun Corporation (www.blacksun.com), the Moondo developed the by Intel Corporation (http://www.intel.com/iaweb/moondo/) and the LogiMoo which is a virtual world for group-work run over the Internet. In view of building educational MUDs and MOOs, an experimental virtual environment called the *CyberCampus* (www.is.ntts.com) was developed by the NTT Software Corporation based in San Francisco. The CyberCampus provides simple three-dimensional worlds with graphics, live sound and limited videos which facilitate the interaction of multi users by means of avatars.

Apparently, the virtual reality environment is changing the relationships between mankind and technology as well as man-machine interactions in order to create new modes of human interactions and relationships (Riel, 1999). Riel said that the virtual environment for educational purposes could be classified into the Distributed Virtual

Environments (DVE) and the Shared Virtual Environments (SVE). The underlying concept of DVE is using an online environment which allows users to shift their visual and auditory perspectives, and all participants are supposed to be separated geographically but taking part in real-time interactions. Similarly, the Distributed Interactive Virtual Environment (DIVE) (http://www.sics.se/dce/dive/), which was launched by the Swedish Institute of Computer Science, is a system fostering learning collaboration within the virtual environment. One of the earlier and influential virtual learning environments for multi-users is the *ActiveWorld* © system, also called the *Virtual Reality Multi-User Dungeon* (VRMUD) (www.activeworlds.com/worlds/alphaworld/), which facilitates virtual collaboration on the Internet. The *ActiveWorld* © has developed tremendously in terms of its size and target population since 1995. The system now contains about 60 million virtual objects including buildings, models and other virtual commodities. Additionally, the Collaborative VE-systems (CVEs), which is an extension of the Distributed Virtual Environments (DVEs), has been established recently to facilitate the integrated collaboration of participants, and support the co-operative application by combining participants and their information in a common display space (Bouras, Philopoulos and Tsiatsos, 2001). The Learning Virtual Environments (LVE) is a sort of CVEs which not only facilitates collaborative tasks and training, but also provides synchronous and asynchronous learning tasks (Bouras, Philopoulos and Tsiatsos, 2001). One of the special features of the LVE is that this system allows avatar (participant's graphical representation) to perform extra behaviors in the virtual world, namely emotional expression.

In view of the navigation in the virtual environments (VEs), it virtually provides space with objects that enhance participants' memory of places (read-world information navigation) while being integrated with the advanced online functions, such as quick cross referencing, fast searches and sorting (Bouras, Philopoulos and Tsiatsos, 2001). Nonetheless, highly autonomous VEs rely upon participants' immersion in the computer interface (Biocca, 1997; Cassell and Vilhjálmsson, 1999; Taylor, 1999). The Immersive Virtual Environments (IVEs) is a virtual platform which allows participants to be immersed visually in a virtual world. Some high-end equipment is being employed to create a more realistic experience, such as the Head Mounted Display, ImmerseDesk and CAVE (Bouras, Philopoulos and Tsiatsos, 2001). However, Bouras et al (2001) criticized that IVEs only focus on creating immersion experience for participants, but ignore the fact that the main issue of educational virtual reality is to provide interactivity in learning. Bouras et al. suggested that the desktop virtual reality is more appropriate for conducting educational activities due to the adoptability of hardware and software. A good example is the Virtual European School Project (Bouras et al. 1999; VSE) and some other projects that have attempted to develop system platforms to facilitate the communication and sharing among distributed workgroups, for instance the Computer Supported Collaborative Work (CSCW) (Vilhjálmsson, 1997). Nonetheless, some early researchers (e.g. Jonassen, Mayes and MacAleese, 1993; Koschmann, 1996) have declared that the Shared Virtual Environment (SVE) ought to enhance the collaborative learning among peers groups, and this system should facilitate both teachers and students in sharing their creative solutions and become aware of multiple points of views. Moreover, the platforms should also allow students to learn from their peers as well as their teachers.

4.3 Summary of Chapter FOUR: Virtual technologies and design education

This chapter has discussed and explored the relationships, opportunities and implementations of virtual technologies and design education by reviewing the various virtual technologies as well as research and practices in applying such technologies in education. In the first half of this chapter, I reviewed the development of technology use in education and explored how computers can be worked as a creative thinking partner for design students. I stated that it is possible to use a hypermedia platform to facilitate the problem-solving processes of design students and to help them to identify wicked problems by mapping problem attributes. In view of student's learning experiences during the creative thinking exercise, the computer can facilitate project-based creativity in many ways, such as enabling effective communication without limitations of time and space and fostering collaborative learning among students. In the second half of this chapter, I developed the argument, based on the literature, that the study of virtual reality and multi-users domains could enhance collaborative learning among students during the creative thinking progress. Moreover, it is one of the important findings from the literature, that the use of virtual reality in education can possibly provide students with a unique learning experience. More specifically, applying virtual reality in education makes students' learning a personal experience. Based on this assumption, I would like to establish a tailor-made shared virtual environment for conducting the SD2000 design thinking exercises. The design of this shared virtual environment is based on the findings of my Phase ONE research (See Chapter 2.3). The details of the establishment of this shared virtual environment will be discussed in Chapter 5.2.

In conclusion, virtual technology seems to be valuable in enhancing learning experiences, and it is an exciting learning partner for design students during their creative thinking processes, particularly by offering interactivity and simulations to enhance collaborative learning. However, a common misunderstanding about the *interactivity* in virtual space is the belief that learners can click buttons to navigate autonomously through computer interfaces. Seitzinger (2006) pointed out that in interactive learning, learners can participate actively in developing the course elements and learning environment and arranging their own learning processes and materials. Likewise, Youngblut (1998) completed an extended review of applications of virtual reality in facilitating educational purposes. He reported that only 2 percent of virtual reality applications support multiple users and almost all them provide limited types of interaction among participants. These issues should be addressed before implementing Phases FOUR and FIVE of the research. Therefore, Chapter FIVE will focus on studies of diverse virtual learning experiences, with the aim of finding out the advantages, methodologies and pitfalls of applying shared virtual reality to provide unique learning experiences.

Chapter FIVE: Studying Learning Experiences in Virtual Environments

This chapter is the third part of my literature review, and mainly emphasizes students' learning experiences in virtual environments. The first half of this chapter will discuss the importance of students' learning experiences in virtual space. TWO potential aspects of virtual reality will be identified in this chapter, namely (1) hyperrealistic simulation in virtual reality; and (2) virtual communities for collaborative learning. More specifically, TWO directional hypotheses underpinning the design of a shared virtual reality will be introduced here. They are:

H1 – Establishing a computer-simulated learning environment is a factor for developing students' design thinking skills; and

H2 – Constructing a virtual community for hyperlearning is important in establishing collaborative learning among design students engaged in design thinking.

In addition, a tailor-made shared virtual environment and its guided learning materials will be introduced in the later part of this chapter.

5.1 Studying virtual learning experiences

As explained in Chapter FOUR, the application of computer technologies in education does not simply involve developing a huge informative portal which allows students to browse autonomously, neither does it involve uploading all digitized teaching and learning materials online for easy access. It is a completely new arena of educational approach which supports students' learning in novel ways. This new approach needs widespread research to explore the possibilities of using virtual technologies to enhance students' learning experiences. In fact, Computer-Based Learning (CBL) and Computer-Assisted Learning (CAL) have been important concepts in developing innovative learning tools since the 1970s (Newhagen, 1996; National Research Council, 1999). Similarly, the use of virtual reality in education is no longer focusing on teaching simple tasks, but moving forward to deliver complex knowledge and skills such as abstract reasoning and management of complex information spaces (Salzman, Dede, Loftin and Chen, 1999). As McLellan (1994) stated, the computer is a powerful cognitive technology for creating unlimited possibilities to facilitate students' cognitive development, for instance communication and creative problem solving. In this case, students can obtain a range of higher-order learning experiences by solving series of difficult and cross-curricula problems during the learning progress (Hackett, Davies and Tibble, 2005). Indeed, many researchers (e.g. Sykes and Reid, 1990; Jiang and Potter, 1994; Kelly, 1997) have pointed out that virtual simulation programs allow students to concentrate on the targeted learning objectives and to encounter abstract concepts directly by removing students' barriers of language and symbols translation as well as freeing them from data recording and translation. This helps to scaffold and individualize the students' learning processes.

However, as Gaggioli (2001) reminded us, effort should be made to bridge the behavior science and computing technologies, in terms of methodological and technical problems, before actually implementing experimental psychological research, or related educational research, in virtual reality. Nonetheless, applying any virtual technologies in education creates a new type of learning experience for students during their learning process. Understanding students' learning experiences in virtual environments is key knowledge required for educators to apply such technologies effectively to enhance learning. Johnson and Levine (2008) stated that *learning experiences* are essential in refining students' understanding in subject learning, and this understanding can generate new experiences simultaneously. In other words, it is inherently a part of any learning cycle, and each new learning cycle creates new experiences (Johnson and Levine, 2008). In this sense, educators are therefore always looking for new, innovative ways to improve the learning experiences of their students. The technology is now present for the students to interact easily with a varied and complex electronic environment (Johnson, 1994), particularly, the visual and spatial sensory of the autonomous virtual space provided participants with multisensory and interactive experiences (Grau, 2003; 2004; 2007).

Apparently, various virtual learning environments have the potential to empower students' learning experiences (e.g. Osberg, 1992; Draper, 1999; Mantovani, 2001). However, Mantovani (2001) reminded us that many challenges from technological, theoretical, economical and cultural aspects need further investigation in order to integrate virtual environments and educational contexts. Bowman et al. (1999) argued that learning experience is only a part of students' learning processes and their understanding of the subject, providing them with peripheral information and background knowledge, encouraging reflection and sharing before the learning activity start are equally important. Similarly, Chaudhury and Chew (2000) reminded us to pay attention to the differences between Western and Asian academic systems in applying virtual technologies in curricula. Different student's expectations of the benefits of virtual learning may also differ significantly, as may their acceptance of the new learning method and their learning experiences. Nonetheless, student's learning processes become easier when the knowledge context is structured (Mantovani, 2001). In other words, educators should deliberately arrange learning objectives, activities and materials in such a way as to enhance students' learning experiences. Moreover, McGuire (1996) pointed out the importance of an active process in students' learning experiences. He recommended *"An ongoing process of making sense out of new information – by creating their own version of reality instead of simply receiving the author's view"* (McGuire, 1996: p.257). Therefore, students have to take an active role in shaping their own world for learning inside virtual environments. Similarly, Salzman et al (1999) reminded us that the interaction experience is affected by the features of the virtual environment and the student's individual learning styles. This interaction experience eventually affects the student's learning experiences. In addition, Salzman et al (1999) stated that educators should enable students to be a part of a phenomenon in order to experience it directly inside the virtual environment.

to what ?

To enhance students' learning experiences, virtual reality and hypermedia technologies have been applied to an enormous number of training activities (e.g. Hays and Vincenzi, 2000), military and NASA projects (e.g. Null and Jenkins, 1993; Cook, 1994; Knerr et al., 1994; Lampton et al., 1994), entertainment industries (e.g.

Gradecki, 1994; Brill, 1999), and other popular press (e.g. Rheingold, 1992; Kalansky, 1993; Burdea and Coiffet, 1994). Despite some attempts to virtualize lecture theatre and laboratory environments (e.g. Newton, 1997; Havice, 1998), many researchers have studied the differences between traditional learning and teaching approaches and the new approaches with hypermedia and virtual technologies. For example, Dary and Richards (1999) compared traditional and hypermedia approaches to teaching psychology in higher education and found that students generally preferred the use of hypermedia. The Virtual High School Project (Pape, Adams and Ribeiro, 2005) designed diverse assessment methods in order to meet every individual student's needs and learning styles by using virtual technologies. In Hay and Vincenzi's (2000) research, which applied virtual reality technologies in training systems, the virtual reality technologies were found to be effective for both introductory and refresher training. However, they admitted that this result could not fully reflect the effectiveness of virtual reality in training since a training system is far more than just using technologies. Nonetheless, some researchers (e.g. Richard and Mueller, 1990; Liu et al., 2002; November, 2008; Wilen-Daugenti, 2009) studied the computer literacy and experiences of students who were using E-Learning platforms and the Internet. They believed that computer literacy is a core skill for distributed learning. Looking at students' experiences in shared virtual environments, these researchers found that a simulated environment allows students to move and communicate easily and little skill is required to handle the system.

Regarding the use of shared virtual reality and multi-user domains (See Section 4.2.2) to enhance students' learning experiences, one of the earlier studies was informal research in MUDs with adults in 1993-4 (Bruckman and Resnick, 1995). Research suggested consistently that virtual reality is able to enhance students' learning experiences during the learning process. For example, Monahan, McArdle and Bertolotto (2008) developed the Collaborative Learning Environment with Virtual Reality (CLEV-R) to study students' E-learning experiences. The results showed that the students' learning experiences were enhanced through the uses of virtual reality and multimedia communications. Calongne's (2008) research also found virtual reality to be successful in enhancing students' learning experiences through the immersive and stimulated environment that virtual technologies have created. Calonge pointed out that virtual reality enriches students' learning experiences by creating a sense of presence within online lectures and classes, using avatars to represent the class participants and applying the hyperrestic 3-D environment in the learning process. Recently, Kuksa (2009) conducted an examination of the role of multimedia in the areas of theatre design and education, particularly emphasizing the theory and practice of theatre studies. Kuksa's findings showed that the current developments of E-learning, student-centred research and personalization of knowledge delivery are requiring traditionally passive learners to transform into active and creative participants in learning experiences. I am not sure that virtual reality can enhance students' learning experiences in the specific area of teaching and learning creative thinking skills. However, researchers (e.g. Kotulak, 1996; Hackett, Davies and Tibble, 2005) have started to conduct human brain research to study how new technologies can affect learners' learning and in what way academic institutions are able to manage and deliver learning effectively via technologies.

The main focus of this thesis is students' virtual learning experiences in doing creative thinking exercises. Although limited research has been done in this area, some prior attempts (e.g. Berlin and White, 1986; Michael, 2001) have been useful in deepening my understanding. According to Miller's (1987; 1999) identification, there are TWO main approaches to stimulating creativity within a group: (1) linear approaches and (2) intuitive approaches. Linear approaches help a team to clarify its problem as well as generating creative ideas by using one or more techniques, for example, attribute listing, morphological synthesis, force-field analysis, mind mapping, idea checklists, and brainstorming. While the intuitive approaches help the team to achieve an inner state of calmness for generating creative solutions, the whole process seems unstructured, for example, imagery, analogical thinking, drawing, and meditation. In response to this issue, some creativity software has been developed to facilitate students' creativity in virtual space, including (1) Idea generators: (Brainstorming Toolbox, IdeaFisher™, ThoughtPath ™, Creative Whack Pack ® Online; (2) Idea Outliners: Inspiration ®, MindManager ® ; (3) Idea Processors, Axon Idea Processor, Idea Generator Plus. Using these, Michael (2001) conducted a study using computer-simulated activities to facilitate students' product creativity. In his research, he compared TWO groups of students, one using a virtual environment and the other a traditional hands-on activity in product creativity. Michael applied the Creative Product Semantic Scale (CPSS) to measure students' product creativity. There were no significant differences in product creativity between these two groups. Some researchers (e.g. Edmonds, et al, 1995; Nemiro, 2004) stressed that any creativity technique or software program can only work as a tool to facilitate the creative thinking process. In other words, no techniques or software can create ideas or decisions spontaneously.

Despite the positive findings about the effectiveness of virtual environments, the evidence is not always promising. For example, Havice's (1998) research showed that a control group of students taught through a traditional approach obtained a better result than students taught by integrated media. Marchionini (1988) reminded educators that it is important to help students from becoming lost, or feeling lost, in the learning process within hypermedia and virtual space. Rintala (1998) criticized that many academic institutions in higher education only adopted hypermedia and virtual technologies in their courses within deliberate considerations. He suggested that hypermedia should be worked as an "experiment" instead of a solution to education. Besides, some institutions believe that using virtual technologies in education can reduce the budget for delivering course materials. However this is not always the case. In Issroff and Eisenstadt's (1997) virtual summer school project, they admitted that the project was successful in many aspects, but it was more costly than using real-world practice. Despite the use of virtual learning environments, Salzman et al. (1999) suggested that some core factors in students' learning processes should be considered, for instance the concepts or skills to be learned, student's personal learning styles, the learning experience and the interaction experience. The teacher's role in virtual space is also a factor in enhancing students' learning experiences. Friend and Johnston (2005) stated that a good online teacher should work as a guide, motivator and a listener during the students' learning processes. Likewise, other research (e.g. Garrison and Anderson, 2003; Garrison and Cleveland-Innes, 2005; Bonk and Graham, 2006) places a strong emphasis on the teacher's role in preparing appropriate instructions in virtual learning. Additionally, some researchers (e.g. Pape et al., 2005; Johnson and Levine, 2008) suggested that the teacher could work as a designer and be highly involved in the entire course development and design processes in virtual learning. Nonetheless, the possible advantages of virtual reality are not only that it provides virtual learning experiences for students, but also that it offers a viable alternative in education (Spicer and Stratford, 2001). Before I summarize the virtual learning experiences based on the literature reviews, three other areas are essential for discussion, they are the impact of (1) hyperrealistic simulation in virtual environment for educational purposes; (2) immersive virtual environment for students; and (3) virtual learning community. After completing the above topics, a summary will be provided in Chapter 5.4.

5.1.1 Hyperrealistic simulation in virtual environment for educational purposes

A simple definition of computer simulation is "a computer-generated version of real-world objects and processes in text-driven formats, 2-D presentation or 3-D multimedia formats" (Strangman and Hall, 2003). The Guide to Simulations and Games for Education and Training (Horn, 1997) defined *simulation* as a way to represent reality, particularly the essence of the interaction in physical or social systems. A further explanation from Horn (1997) is that simulations need to replicate these crucial components of real world practice in better ways. Yair, Mintz and Litvak stated that simulation, particularly in virtual reality, *"bridges the gap between the concrete world of nature and the abstract world of concepts and models"* (Yair, Mintz and Litvak, 2001: p.294). Shanken (2007) defined *simulation* as a representation of the originals with shared attributes. Nevertheless, simulation is not simply replication of real world reality, it is a model of a system (Pearce, 1997). It is a simulation of real-world conditions to provide participants with not only hyperrealistic virtual environments, but also the social systems and their shared attributes. Therefore, the context in simulation should be real enough to facilitate participants to collect, retrieve and transfer information to real-world practice (Thorsen, 2006).

In view of using hyperrealistic simulation in academic research and education, early researchers (e.g. Brown, Collins and Daguid, 1989; Brown and Campione, 1990; Lave and Wenger, 1991) believe virtual reality gives students a chance to learn within a simulation of real world practices. This learning experience makes students' learning more meaningful and effective. In subsequent years, researchers have looked at how to apply educational simulations into developing educational theories and practices, for example using role-playing as a simulation (e.g. Van Ments, 1999; Root-Bernstein and Root-Bernstein, 1999; Stoerger, 2008), using stories as a basis for simulation (e.g. Schank, 1995) and using simulations as a pedagogical method (e.g. Joyce, Weil and Calhoun, 2000; Hoyt, Blascovich and Swinth, 2003; Crush, 2008; Johnson and Levine, 2008). However, some researchers (Reif and Larkin, 1991: Frederiksen and White, 1992; Salzman et al., 1999; Omale, Hung, Luetkehans and Cooke-Plagwitz, 2009) have cautioned that it is very difficult to simulate real-life experiences because they are constructed by abstract phenomena, mental models and metaphors. Moreover, in an early study Kaser (1996) argued that there were no significant differences based on instructional strategy in computer-assisted simulated environments. His critical comments are valuable because he did conduct empirical research on the application of computer-assisted simulation in teaching and learning with business students at the post-secondary level, particularly looking at students' learning experiences in a virtual environment. The subsequent research (e.g. de Frietas, 2006; Johnson and Levine, 2008; Omale, Hung, Luetkehans and Cooke-

Plagwitz, 2009) also highlighted the difficulties of constructively connecting educational strategy to virtual technologies. Likewise, in the social sciences, the situational simulations method has often been used to study the behaviors and attitudes of individuals or organizations in diverse situations (Alessi and Trollip, 2001; Rizzo et al., 2002; Gaggioli et al., 2003). Alessi and Trollip (2001) admitted that it is difficult to conduct effective situational simulations for educational research because of the complexity of human and organizational behavior.

Nonetheless, other researchers (e.g. Kalay, 2004; Brown and Thomas, 2006; Stoerger, 2008; Wagner, 2008) have taken a positive view of hyperrealistic simulated environments. For example, some (e.g. Grabinger, 1996; Jonassen and Hernandez-Serrano, 2002; Winn, 2002) have suggested that computer-generated simulations can be used as a learning guide for students to interact and tackle ill-structured problems. Strangman and Hall (2003) stated that simulations created by virtual reality technologies are able to provide a unique experience to students as well as helping them to explore a broad range of objects, environments and phenomena in cyberspace. Reilly (2008) stated that some simulated virtual environments, for example virtual laboratories, have potential to facilitate students' deep learning experiences. Blascovich and Bailenson (2006) listed TWO possible advantages of applying immersive virtual reality technology in simulation-based educational research: (1) the facilitation of exact replications of research in the behavioral sciences and social psychological; and (2) the provision of a research platform for some research that was previously impossible or extremely difficult to control and arrange, for instance making it possible for participants to change their social identity, sex, race and ethnicity for the research. Wagner (2008) stated that the simulated virtual environment is able to shift student's learning behavior. Likewise, Omale, Hung, Luetkehans and Cooke-Plagwitz (2009) believed that simulated virtual space could enhance student's overall learning experiences. Based on the above discussion, simulated virtual environment is potentially useful for enhancing students learning experience.

5.1.2 Developing immersive virtual environment for students

Various researchers have focused on immersion in virtual reality. Many (e.g. Winn, 1993; Psotka, 1996; Salzman et al, 1999; Chaudhury and Chew, 2000; Green and Bavelier, 2003; de Frietas, 2006; Johnson and Levine, 2008; Stoerger, 2008) have suggested that immersive virtual reality has the potential to be a learning environment. In particular, Salzman et al. (1999) stated that immersion is a possible way to help students to build a mental model for social simulation of learning activities. Researchers (e.g. Jones, Morales and Knezek, 2005; Barab, Thomas, Dodge, Carteaux and Hakan, 2005) underlined that an immersive virtual environment could provide students with a playful learning experiences and active learning process, and this playful virtual environment is able to motivate students in their learning process (Steinkuehler, 2004; Squire, 2005; Van, 2007). The immersive experience in virtual spaces could be used to carry out any educational activities effectively (Johnson and Levine, 2008). However, what is immersion? And how can it be applied to enhance students' learning experiences? Immersion can be explained as an intense feeling of self-location within the virtual environment (e.g. Cronin, 1997; Adams, 2004). In other words, participants perceive themselves as existing within the immersive virtual environment psychologically (Blascovich and Bailenson, 2006). This psychological situation is similar to that presented by the movie "The Matrix". Blascovich and Bailenson (2006) took a phenomenological perspective to define the immersive virtual environment, explaining that this environment should be established on the basis of organized information, which is organized through the combination of diverse sensory channels such as vision, audition, touch, olfaction and taste. Blascovich and Bailenson also elaborated that the participants who are situated within this immersive environment should not be able to be aware of or consciously understand where the organized information comes from. The level of immersion within the virtual environment is determined by the interactivity among participants, sensory information and the environment, and this level of immersion is essential to generalize participants' virtual experiences (Blascovich and Bailenson, 2006). The virtual platform is indeed an interactive forum and/or society (Koster, 2007).

In view of using immersive environment in education, the context, application and practice of immersive learning approach can be traced back to the earliest days of civilization, for example the apprenticeship is a long-used educational approach used to immerse students in a rich learning environment (Johnson and Levine, 2008). According to Johnson and Levine, some approaches like role-playing scenarios, case studies and simulation learning are very important tools for conducting immersive learning approaches. When it comes to creating immersive learning experiences in virtual reality, the first problem is that it is very difficult to make connections between learning and application in virtual reality, particularly about immersion (de Frietas, 2006). Johnson and Levine (2008) argued that using immersive experiences in virtual reality not only reduces the cost and makes the training process secure, but also allows for the application of attributes such as scale, texture and sound in the virtual environments to design new sorts of learning approaches. Nonetheless, researchers (e.g. Rodriguez, 2001; de Frietas, 2006; Johnson and Levine, 2008) believe that an immersive experience in virtual reality is effective and efficient in helping students to have better learning experiences during the learning process. More specifically, some researchers (e.g. McCormick, 1995; Wickens and Baker, 1995; Green and Bavelier, 2003; Stoerger, 2008) found that the virtual immersive experience helped students to interact with spatial and visual representations which might thus improve their learning performance. Other researchers (e.g. Nugent, 1982; Psotka, 1996; Brown and Thomas, 2006; Wagner, 2008) stated that the multisensory cues within an immersive virtual environment could potentially deepen students' learning. Indeed, any features of virtual environment potentially influence students' learning processes, experiences and outcomes (Salzman et al, 1999).

However, some early researchers (e.g. Milgram, 1963; Baumrind, 1964; Haney, Banks and Zimbardo, 1973) made negative comments about the use of virtual immersive experience in education. For instance, Milgram (1963) conducted a controversial project which used immersive virtual teaching laboratories to study student's obedience. In that project, some participants were assigned the roles of teacher and instructors. The project failed because these participants lacked the necessary knowledge and skill, and there were some severe criticisms of Milgram's work (e.g. Baumrind, 1964). Moreover, an immersive virtual prison project was conducted by Zimbardo and colleagues (Haney, Banks and Zimbardo, 1973) in the basement of Jordon Hall at Stanford University to investigate the inmate-staff interactions. Students were assigned randomly to the roles of guards and prisoners. This project proved to be a dangerous immersive simulation. Even some current research (e.g. Lim, Nonis and Hedberg, 2006) criticized the virtual simulation is distracting students' concentration during the learning process. Despite that, not all projects have failed in the early stage of development the use of immersive virtual reality, Latane and Darley (1969) used virtual environments to study pro-social behavior. One of their established immersive virtual environments was a room filling with smoke. The study helped them to understand the processes of creating potential danger to bystanders. More achievements have been obtained from various studies in the subsequent decades. For example, Schroeder (1995) conducted three research projects, the West Denton High School in Newcastle, the Human-Computer Interface Technology Laboratory's summer school in Seattle and the Shepard School for children with special needs in Nottingham. These projects looked at the uses of virtual reality in education. Schroeder found that a variety of virtual reality applications, such as entertainment games and virtual learning systems, provided an immersive and highly interactivity learning environment for the students. Another project, the Project ScienceSpace, tried to define, use and evaluate how immersive virtual reality could facilitate complex and abstract learning and teaching concepts (Salzman et al., 1999). Similarly, Bitner et al (1999) found that the use of immersive virtual environments, for instance virtual field trips, enhanced students' competency in solving real-world problems. Spicer and Stratford (2001) conducted a study of immersive experiences to further the idea of the virtual field trip. This project allowed university students to experience a field trip virtually. The results showed that students enjoyed the valuable learning experiences within the virtual environment. Nevertheless, the students commented that virtual field trips should not replace real field trip experiences. Therefore, Spicer and Stratford (2001) proposed that the virtual field trip could be used for preparing for or revising after a real field trip.

Currently, one of the key concepts of immersive virtual reality is *Second Life*. In fact, readers can easily mix up the concept of *Second Life* and the popular online virtual platform called "SecondLife ©" (SecondLife, 2005). The concept of *Second Life* refers to a kind of advanced immersive virtual reality which not only helps participants to feel that they are there, but also to feel like having another life with an exclusive appearance, identity, personality and lifestyle. The latter is only one of the representatives of these advanced immersive virtual environments. Sherry Turkle (1995) explained that the computer had created a *Second Life* for users by reconstructing their identities virtually. Likewise, Meecham and Sheldon (2000) stated that Internet users are creating their digital alter egos to inhabit simulated environments in cyberspace. They believe that the Internet is increasingly making a sense of *Second Life* possible, particularly through the use of avatars. This is because users actually "exist" in these online chat environments. Actually, the development of Second Life's platforms can be traced back to the early 1970s, when programmers developed the Multi User Domains (MUDs) and the MUD Object Oriented (MOO), which were the original types of real-time discussion groups over computer networks, using some software like Mosaic and riding bareback (See Section 4.2.2). In fact, some popular computer games are transforming from MUDs games to providing second life experiences to players. Some examples of these are, SimCity (http://simcitysocieties.ea.com), Sid Meier's Civilization (http://www.civilization.com), Roller Coaster Tycoon (http://www.atari.com), The Sims (http://thesims.ea.com/), The Oregon Trail (http://www.isu.edu), the Quest Atlantis (http://atlantis.crlt.indiana.edu) and ActiveWorlds (http://www.activeworlds.com). Quest Atlantis and ActiveWorlds are two of the popular educational and entertaining shared virtual environments suitable for any educational approaches (Barab, Thomas, Dodge, Carteaux and Hakan, 2005; Qian, 2008). In the field of education, some examples of using SecondLife © in university have included the MSc course in clinical management at Coventry University and MSc in E-learning course at the University of Edinburgh. Moreover, the New Media Consortium (NMC) designed and constructed the NMC campus in SecondLife © in 2006 (http://sl.nmc.org). This project offered a wide variety of experiences and events to participants in order to facilitate their operations and navigations within the space (Johnson and Levine, 2008). In addition to university education, many companies, including Sony and Time Warner, BigFish Games, Microsoft, Benchmark Capital, Vickers Financial Group and Trinity Ventures, have invested in SecondLife and other similar virtual worlds recently to develop customer-service training and team-building exercises (Tampone, 2008). Using immersive virtual reality for education and training is extending to the fields of economics (Castronova, 2006) and legal issues (e.g. Lastowka and Hunter, 2003; Balkin and Noveck, 2005).

The current trend of developing virtual technologies for learning is the 3-Dmultiuser Virtual Environments (3-D MUVEs), which focuses on promoting social presence and collaborative community (e.g. Dalgarno, 2002; Barab, Thomas, Dodge, Carteaux and Hakan, 2005; Jones, Morales and Knezek, 2005; Nelson, 2007; Berge, 2008). The 3-D MUVEs is indeed a networked virtual reality which promotes social interaction by providing highly collaborative, immersive learning environments (Dickey, 2005; Jones, Morales and Knezek, 2005). Researchers (e.g. Barab, Thomas, Dodge, Carteaux and Hakan, 2005; Jones, Morales and Knezek, 2005) have highlighted that 3-D MUVEs has inherently embedded some interesting learning approaches namely role-playing games, computer games, multiuser virtual communication as well as a hyperrealistic virtual environment. In this case, the use of immersive virtual reality seems to have promise in enhancing students' learning experiences as discussed above, in particular to support active and playful learning processes (Brown and Thomas, 2006; Jones, Morales and Knezek, 2005; Barab, Thomas, Dodge, Carteaux and Hakan, 2005; Johnson and Levine, 2008). Current research on the virtual learning experience (e.g. Wagner, 2008) has found that students presented interesting work and demonstrated considerable learning which went beyond their instructors' expectations. However, some counter research (e.g Dalgarno, 2002; Gee, 2003; Lim, Nonis and Hedberg, 2006) criticized the immersive virtual reality for failing to enhance students' learning because they were distracted during the online learning process. One of the reasons for this is that students may be too excited when exploring the hyperrealistic virtual space (Lim, Nonis and Hedberg, 2006). Of course some students might also find it difficult to work in a virtual world because of its complexity and technological challenges (Gee, 2003). Therefore, current researchers (e.g. de Frietas, 2006; Johnson and Levine, 2008; Omale, Hung, Luetkehans and Cooke-Plagwitz, 2009) have called for further studies on virtual reality in order to enhance students' overall learning experiences. Johnson and Levine (2008) reminded educators that virtual learning experience should be designed by someone who comprehends and appreciates the virtual platforms. It is never easy to made constructive connections between virtual applications and learning activities (de Frietas, 2006).

One of the key concepts in utilising an immersive simulated virtual environment during the learning process is the idea of Frames of Reference (FORs). This uses spatial metaphors to enhance the meaningfulness of data in order to offer participants some qualitative insights (Erickson, 1993). Indeed, many psychological research studies (e.g. Thorndike and Hayes-Roth, 1982; Presson, DeLange and Hazelrigg, 1989; Ellis, Tharp, Grunwald and Smith, 1991: Barfield, Rosenberg and Furness, 1995; Darken and Sibert, 1995; McCormick, Wicken, Banks and Yeh, 1998) have found that the spatial learning, visualization and navigation of FORs have had remarkable influences on students' learning. Current research (e.g. Bernatchez and Robert, 2007) has found that FORs has a significant impact on user experiences in virtual reality. All in all, deliberately designing the learning environment in virtual space is crucial to enhancing students' learning experiences. Thus, the first directional hypothesis underpinning the design of a shared virtual reality for this thesis is introduced: H1 – Establishing a computer-simulated learning environment is a factor for developing students' design thinking skills.

5.1.3 Constructing a virtual learning community to enhance learning experiences

Despite the discussion about providing students with immersive virtual learning experiences by using hypperealistic simulation and high levels of interactivity, some researchers (e.g. Grave, 1992; Kellogg, 1999) highlighted the importance of creating 'learning communities' in the 1990s. Kellogg (1999) emphasized the curricular structure for learning communities in higher education, while Grave (1992) stressed the kinds of human sociality, such as high levels of cooperation and collaboration among students and teachers, that are more significant. According to Grave, a community is an inherently cooperative and cohesive group of people with common goals, values and lifestyles. Reeves and Nass (1996) stated that individuals respond to social activities automatically and unconsciously via media, so it is not necessary to teach students to participate in any social group. They stated that *"Humans are experts on social relationships, and they are experts on how the physical world works. Rules on using media as tools, on the contrary, are often arbitrary and must be learned. When media conform to social and natural rules, however, no instruction is necessary"* (Reeves and Nass, 1996: p9). In addition, sociologist Ray Oldenburg (1997) described a place, between home and work, that is a "third place" that allows a person to interact with others to form a community. On the topic of creating community in virtual environments, there have been many researchers (e.g. Kollock and Smith, 1999; Wellman and Gulia, 1999; Bonk and Wisher, 2000; Kim, 2000; Preece, 2000; Preece and Maloney-Krichmar, 2003) who have proposed definitions of "virtual community" since this term was coined by Rheingold in 1993. Based on their definitions, virtual community can be defined as a sufficient number of people creating networks of personal relations in cyberspace. Researchers on the virtual learning community (e.g. Lave and Wenger, 1991; Wenger, 1998; Omale, Hung, Luetkehans and Cooke-Plagwitz, 2009) have stated that learning is not only about the learner's cognitive change, but about sharing a set of practices or expertise in a social group. Virtual community plays an important role in fostering social sharing among students. This is because the virtual technology helps the student to interact easily with diverse and complex electronic environments (Johnson, 1994). Recently, Johnson and Levine (2008) used Maslow's Hierarchy of Needs (Maslow, 1943) to explain the concept of learning community in virtual reality, claiming that the ability to form friendships and relationships among students is linked to the Love/Belonging level of Maslow's (1943) Pyramid. However, it is very difficult to identify a general theory of collaborative learning within a community in virtual reality. Although the constructivist approach offers one valid and reliable basis for a theory of learning in virtual reality (Winn, 1993; Fraser, 1994; Fraser, 1998; Gabbard, 2000), the social interaction in a virtual community is far more complex than what humans use to communicate in the physical world. As Herring (2004) has reminded us, when people are interacting online this is not necessarily a form of community. The term "community" is more complex than it seems. The skill of social interaction is crucial for anyone who connects to cyberspace where there are many-to-many interactions across a wide range of disciplines and forms (Afonso, 2006). Some researchers (e.g. Genov, 1997; Afonso, 2006) have been concerned about the human identity in communities. For example, Genov (1997) considered that modern individuals obtain multiple identities in various organizations and communities. Indeed, it is very difficult to identify human identity since it is totally related to subjectivity and these identities change in different social categories and groups (Afonso, 2006). The term "community" gets even more complex with individuals' changing identities.

Moreover, encouraging trust and strengthening ties among members are among the key factors in developing learning communities (Graves, 1992). Nemiro (2004) stated that trust is built under positive and ongoing experiences, since it is a belief in another's expertise. In relation to the virtual community, Nemiro (2004) particularly highlighted trust as a crucial challenge in any team working in a virtual platform since participants might not have met each other before. Furthermore, Kling and Courtright (2004) pointed out the importance of people's participation in face-to-face conservation in the formation of sustainable trust. Kling and Courtright reminded us that appearances lead to stereotyping. In other words, people develop trust by simply looking at others' participation in real-world practices. Current research (e.g. Kelly and Daughtry, 2008) supported that a trustful learning environment facilitates students' creativity. However, this sustainable trust is relatively difficult to develop in virtual conversations, regardless of whether they are text-based or in virtual reality. The concept of community is inherently abstract, especially in virtual community (Herring, 2004). Hence, it is not necessary to compare face-to-face community with online community (Jones, 1995).

In relation to the main focus of this thesis, which is exploring the students' experiences while doing virtual creative thinking exercises, Nemiro (2004) stated that creativity can be facilitated by an appropriate creative climate for virtual teamwork. To establish this creative climate, educators should provide solid connections at both task and interpersonal levels among students. (The discussion of creative climate for creative thinking has been explored in Section 1.2.3). To be more explicit, goal clarity and trust are essential in building these connections (O'Hara-Devereaus and Johansen, 1994; Lipnack and Stamps, 1997; Nemiro, 2004). In this case, the support and networking among peer group members are essential to deepen students' understanding and, simultaneously, to accelerate their learning (Hackett, Davies and Tibble, 2005). A high level of creativity and strategies for problem solving can be generated and transferred by collaborative learning (Hackett, Davies and Tibble, 2005). According to Jonassen's conception of a Constructivist Learning Environment (Jonassen, 1999), there are FOUR tools required to develop a learning environment for social construction and problem-based learning: (1) cognitive tools, such as visualization tools, to enhance student cognitive processing; (2) static and dynamic knowledge modeling tools to create simulations of real-world situations; (3) performance support and information gathering tools to increase student productivity in difficult tasks; and (4) conversation and collaboration tools to provide a method or environment for collaborative and social construction. The above tools provided me with a clue for design an appropriate virtual learning environment for design thinking as well as for forming my second hypothesis for this thesis. In addition, students, especially at a younger age, need more opportunities to tackle higher-order learning activities and problem-solving tasks (Hackett, Davies and Tibble, 2005).

Despite the criticism from Bruckman (1998) that the educational technologies are far from being enough to transform the fundamental nature of education, numbers of researchers (e.g. Vygotski, 1978; Newman et al, 1989; Lave and Wegner, 1991) have explored the social nature of learning, as well as computer-supported collaborative learning (e.g. Koschmann, 1996). An example of a constructionist learning environment is the MOOSE Crossing, which is a text-based virtual reality for children ages eight to thirteen to construct personally meaningful projects (Bruckman, 1998). According to Bruckman, MOOSE Crossing creates natural opportunities for casual and social interaction among participants to build social relationships as well as emotional and technical support. Other researchers (e.g. Bowers, 2000; Kibby and Costello, 2001; Naper, 2001) pointed out that the participants in computer-mediated groups are interacting more and more via multimodal interfaces such as virtual environments, weblogs and online videoconferencing in order to create a "feeling" of being inside a community. In addition, the theory of Community of Practice (CoP) is also relevant in fostering social collaboration within any community including virtual community (this theory is about designing a proper environment to support learning and teaching (e.g. Lave and Wenger, 1991; Wenger, 1998). The CoP researchers believe that learning involves a social group sharing a set of practices instead of a cognitive change happening only in the single learner. Similarly, Afonso (2006) stressed that learning described as networked learning, is no longer the exclusive domain of academic institutions. According to Afonso, the core factors in learning are about the social construction of knowledge and collaborative learning within a learning community. Additionally, Weller (2007) underlined the significant role of peer learning in a community of practice approach, since this learning approach is treated as a social construct which depends largely on the interactions among peers.

Indeed, any new kinds of learning experiences are possible if given the support of online communities (Bruckman, 1998). In particular, the virtual community fosters collaboration among students by providing a common simulated environment for sharing various experiences (Mantovani, 2001). However, educators should make virtual communities meaningful instead of purely metaphorical (Herring, 2004). Some current research (e.g. Omale, Hung, Luetkehans and Cooke-Plagwitz, 2009) has even argued that virtual reality, especially 3-D technology, did not entirely construct students' social experience within virtual environment. Therefore, it is necessary for educators to study and enhance students' learning experiences through new and innovative educational approaches in virtual reality instead of only providing students a virtual environment without pedagogic arrangement. After all, to enhance students' experiences through collaborative learning within a community is essential in constructing a virtual learning environment. Therefore, the second directional hypothesis underpinning the design of a shared virtual reality for this thesis arises from this theory: H2 – Constructing a virtual community for hyperlearning is important in order in establishing collaborative learning among design students engaged in design thinking.

5.2 Establishing a virtual environment for enhancing design students' learning experiences

Some writers (e.g. Salzman et al., 1999; de Frietas, 2006; Johnson and Levine, 2008) have stated that it is important to design an appropriate virtual learning environment to implement virtual learning, for example, careful arrangements of 3-D immersion, frames of reference, and multisensory cues as well as deliberate consideration of the nature of different learning tasks and needs. In particular, visualization can be a powerful learning tool for students' cognitive development (Rieber, 1995; Green and Bavelier, 2003; Stoerger, 2008). In this research, I looked at the design students' learning experiences in creativity training in a shared virtual reality. I used the *ActiveWorld©* (AWs) (See figure 14) for my study in Phase Four and Phase Five. The AWs is an online shared virtual learning environment which allows participants to interact with others within a three-dimensional on-screen display. The reason for choosing AWs as the instrument for my research is that it is one of the biggest educational virtual platforms, with educational partners of over 250 universities and schools worldwide. AWs has over TWO million participants globally, separated into two different categories - Citizens and Tourists. The citizens are permanent members of this virtual environment who are allowed to build their own structures and objects, and even create their own worlds; the tourists are indeed visitors, who can visit some worlds and participate in some interactive activities and conversations under certain limitations. In view of the structure of AWs, it has THREE components: (1) the world - all spaces inside, which are usually displayed by green plain; (2) the people - participants who are represented by avatars; and the most crucial one (3) the object - which contains almost everything except the spaces and avatars. The objects inside the AWs have TWO basic elements: (1) the model; and (2) the property. The object-model means road, grass, fences, palm trees, buildings, furniture, commodities and all products' outlooks while the object-property is about the attribute of that visual object. For instance, some objects have hyperlinks or embedded email accounts, or some objects can play music or sounds when avatars approach them. These functions in AWs provide the possibilities of building environmental stimulation for conducting design-thinking exercises for design students. Additionally, participants are not only able to experience this enormous virtual space autonomously, but they can also create visible and movable virtual objects and structures inside the virtual environment. AWs offer a menu of all available virtual bodies for participants to choose, and avatars are able to perform simple emotional displays, idle motion sequences and behavioral expressions that participants can use - default human-like expressions to facilitate their communication with others. In view of the text-based conversation, AWs provide a text window which allows participants to read scrollable texts with the names of responsible participants. Within the rendering window, overhead texts are displayed with the avatars, which allow participants to *see* the sentences during the conversation.

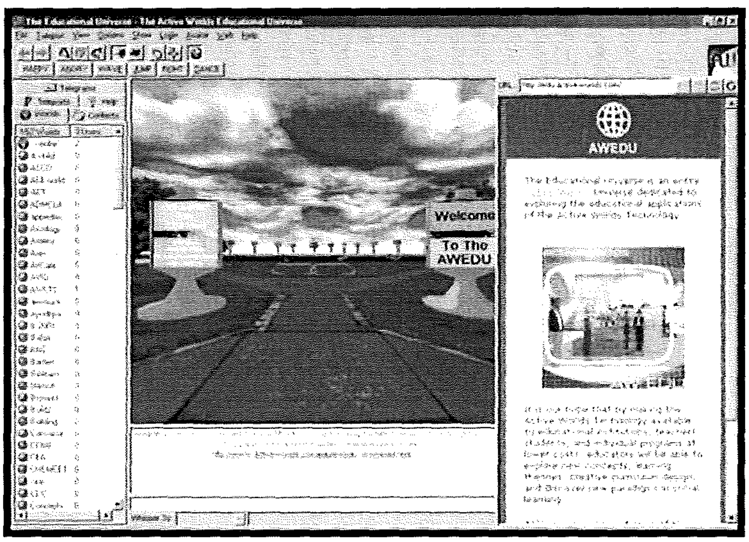

Figure 14: The interface of ActiveWorld ©

My research in Phase FOUR and Phase FIVE follows the surmise, based on my reviews of all provided worlds inside the system, that AWs do not have any existing world which is deliberately designed for undertaking creative thinking exercises. Moreover, according to the findings of my preliminary research (Part 1 and Part 2), design students suggested that an ideal creative-friendly environment should contain FIVE major components: (1) comfortable and tranquil; (2) playful; (3) relaxed; (4) able to maintain privacy; and (5) equipped with formal and informal references. Many design students believe a café is one ideal place for group discussion and creative thinking. Therefore, I established a proposed creative-friendly environment in AWs in my Phase THREE research. I called it Robert's Café. Figure 15 shows the main entrance and interface of Robert's Café.

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Before the research of Phase FOUR and Phase Five commenced, it was difficult for me to assume which types of Café would be suitable as a creative-friendly environment for design students. As students are not familiar with the learning spaces in virtual worlds, was difficult to design a prefect learning environment in AWs. Moreover, the aim of my research was not to establish a prefect shared virtual reality for students, but to try to understand the learning experiences of design students in virtual reality. Therefore, I designed and built the proposed creative-friendly environment under THREE conditions:

(1) The space has to be comfortable enough for long discussion;

(2) The space should provide free choices (different rooms) for participants to select; and

(3) These choices are different in nature, so participants can experience diverse environmental stimulation.

Based on the above conditions, the shared virtual environment is divided into THREE main areas (See figure 16), they are (1) **Area 1: Café Grand** - a common area, which is the biggest area inside Robert's Café, for gathering and creative discussion; (2) **Area 2: Café Top** - a small private area for discussion, located at the top of the main room. Participants have to climb the stairs in order to reach this area; and (3) **Area 3: Café Open** - an open area out of the main building. This area is surrounded by plants, trees and flowers. My research in Phase FOUR and Phase FIVE was also looking at participants' choices in these three different areas in order to find out the clues for designing and establishing an educational shared virtual reality in future.

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[redacted]

Descriptions
Area 1: Café Grand • This is a common area for gathering and creative discussion; and • It is the biggest indoor area inside Robert's Café.
Area 2: Café Top • This is a small private area for discussion which located at the top of the main room; and • Participants have to climb the stairs in order to reach this area.
Area 3: Café Open • This is an open area where out of the main building; and • This area is surrounded by plants, trees and flowers

Figure 16: Three different areas of Robert's Café and their descriptions

Apart from the design of different areas in Robert's Café, the design students also emphasized the formal and informal information that the virtual space could possibly provide. Likewise, in Chapter 1.2.3, I have highlighted the importance of providing formal and informal knowledge in a learning space. Environment serves as stimulus and information provider for design study. Thus, the information system of Robert's Café in AWs not only provides virtual environmental stimulation for students to experience, but also facilitates their creative thinking and learning processes by offering them sufficient formal and informal knowledge. Since the Internet is full of informal information and knowledge that students can access easily anytime by using the web browser in AWs, it was not the major concern for me to provide informal references in my information system for Robert's Café. For the formal information, such as (1) the criteria of the project, which asked participants to explore 101 ways to squeeze a lemon in order eventually to design a creative lemon juicer; (2) the FOUR essential learning stages which include the preparation, incubation, evaluation and implementation; and (3) the ground rules of brainstorming exercise and steps for undertaking creative thinking exercises, are listed clearly in the shared virtual reality. As figure 17 shows, there are some signs located at the main entrance of Robert's Café which provide students with the descriptions of the designed creative task and facilitate their learning process by providing relevant hyperlinks. Similarly, there are some signs located inside Robert's Café which provide the ground rules of the brainstorming exercise. Participants are free to access them during the creative thinking process. Some hanging signs are created everywhere inside Robert's Café, which provide hyperlinks for some supporting learning materials. In addition, a web blog was created under the name "Learning Design Thinking in Virtual Reality" (LDTVR). It provides students with all sorts of information which students need during the creative thinking process. Details of the LDTVR and why I chose web blog as a mean to deliver formal information are explained clearly in Chapter 5.3 Creating a web blog to provide guided learning materials.

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[redacted]

Descriptions
Signs for introducing the creative task and providing relevant hyperlinks There are some signs located at the main entrance of the Robert's Café. They provide students the descriptions of the designed creative task and facilitating their learning process by providing relevant hyperlinks.
Signs for indicating the ground rules of undertaking brainstorming exercise There are some signs located inside Robert's Café. They provide the ground rules of undertaking brainstorming exercise. Participants are free to access them during the creative thinking process.
Hyperlinks for facilitating the creative thinking process There are some hanging signs everywhere inside Robert's Café which provides hyperlinks for some supporting learning materials.

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[redacted]

Veb blog for providing uided learning materials

A web blog has been created nder the name "Learning Design Thinking in Virtual Reality" (IDTVR). It provides tudents all sorts of nformation of which students eed during the creative hinking process.

Figure 17: The information systems in Robert's Café

Despite the establishment of a creative-friendly learning environment in AWs, some strategies to remove students' obstacles to creativity and facilitate their communication in group discussion were essential in this research. As I mentioned, Hong Kong's design students are passive and quiet during the creative thinking process, especially during group discussion. This is because they are afraid of being criticized by others (Lau, 2003; 2006a; 2006b) (See Section 1.1.3). The use of avatars in a virtual platform was seen as a way to address this problem since the students' true names and identities are hidden during the process (Lau, 2006a; 2006b). In AWs, there are 95 different avatars that participants can choose for their representatives. Figure 18 showed the selected avatars of the EIGHT design students in Phase FOUR and Phase FIVE. The reasons why students are choosing these avatars as their representatives are explored in Phase FIVE (Post-lesson Data Collection) and the findings will be discussed in Chapter SIX: Multimodal interaction research and post-lesson online interviews.

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Figure 18: The selected avatars of participants (Students)

AWs not only allows participants to communicate in textual format, but also provides them with some default emotions by using the gesture system. This gesture system is a system of displaying emotions. Therefore, avatars can communicate with each other by gesturing as well as by chatting inside AWs. For the operation of this emotion display system, students can use the gesture buttons which are located just above the main view screen (See figure 14). They simply click the appropriate gesture that they would like everyone around them to see. Figure 19 shows the total 11 default emotion displays of all avatars.

No.	Default Emotion Displays	Actions
1	Turn Around	Turn the body around
2	Wave	Waving hands
3	Jump	Jump
4	Spin	Spin the body
5	Joy	Jump and turn around
6	Yes	Hand sign
7	Blow Kiss	Kiss
8	Egyptian	Egyptian dance
9	Macarena	Dance
10	Karate	Martial arts
11	Kick	Kick

Figure 19: Summary of the emotion displays in AWs

The AW's system team designed all the emotion displays. Some of them are simple body actions, for example turning the avatars' bodies around, waving their hands and jumping. According to the research in Phase FOUR, students were more familiar with these simple body actions and they were performed quite often for everyday purposes (saying hello or goodbye) during the process. However, some weird actions, like Egyptian and Macarena dances, students deployed without a clear. For example during 00:52 – 00:54 in Phase FOUR, based on the observation of me as an observer, participants <S06> and <S08> performed the Macarena dances with no direct relation to their discussion.

<S03> (374) put the lemon into any "ball", basketball, volley {Jump}
<S04> (375) we make a cup is look like a shoes {Jump}
<S03> (376) Anyone wants to end? {Jump}
<S06> (377) dead air.................................... [time intervals] **{Macarena dance}**
<S07> (378) and then use the shock to filter the remainder
<S03> (379) Silent.....[pitch]
<S08> (380) let's move to step six first **{Macarena dance}** {Jump}

Nonetheless, I looked at how these simple body actions and weird actions are employed by design students to express their emotions in this research. These are a part of their learning experiences in virtual reality. Unfortunately, according to my research findings in Phase FOUR, the multimodal interaction analysis of using emotional displays for communication, I found that participants tended to use emotion displays in textual format rather than the default emotional displays in gesture (See Chapter 6.2.1). Similarly, according to the post-lesson interviews in Phase FIVE, participants liked to use dialogue to present their ideas and opinions instead of using default emotional displays. Participants' ways of using the avatar's gestures were not often related to the subject of conversation (See Chapter 7.2.1). The findings imply that the shared virtual reality, to a certain extent, failed to provide an immersive simulated environment since the emotional display system is not working effectively for virtual communication through avatars. As suggested by participants, an emotional display system should be designed according to some human behaviors, namely laughing and crying for effective communication (See chapter 6.2.3)

5.3 Creating a web blog to provide guided learning materials

Downes (2004) noted, in the keynote speech of the conference *Reusable Media, Social Software and Openness in Education*, that information producers are trying to build a closed system for everything whilst users are expecting an open system. This situation causes a divergence between the learning content producers and the content users. Thus, Downes (2004) foresaw that the use of a Web blog is one of the key approaches to the future of learning. Interestingly, children and young teenagers are more knowledgeable, comfortable and literate than adults in society's functioning in virtual worlds (Tapscott, 1998). Writing blog is one significant online activity that students are more familiar with than are their teachers. Web blog is a regularly updated diary of web surfers, and it contains individual's thoughts, experiences, and any kind of shared personal information (Blood, 2000). As a user, it is very easy to set up a blog and update it without any special technique.

Web blog, working as a learning partner in my research, has TWO obvious functions: (1) Providing guided learning materials to participants; (2) Enabling participants to record their learning processes. In other words, the web blog works as a lablog for the creative thinking exercises in virtual reality. In Phase FOUR and Phase FIVE of this study, a web blog containing relevant information and learning materials was designed to facilitate the participants' creative thinking processes in the shared virtual environment (See figure 20). This web blog has EIGHT functions: (1) introducing the aims and objectives of the research project; (2) providing a guideline for arranging appropriate learning activities for creative thinking; (3) listing the steps and ground rules of Brainstorming exercise; (4) briefing on the creative task for the research; (5)

introducing the assessment criteria of the research project; (6) providing space for collecting participants' reflective journals after the research; (8) providing space for participants to record their creative thinking process textually; and (7) providing useful links for downloading relevant materials.

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Figure 20: Interface of the LDTVR Blog

The designed web blog was given a title "Learning Design Thinking in Virtual Reality" (LDTVR). It gives participants a clear picture that they are working in a virtual space. Regarding the detailed content of LDTVR, first of all, LDTVR lists the assigned design-thinking exercise which asks participants to explore 101 ways to squeeze a lemon. Participants need to discuss the possibilities of designing a creative juicer for squeezing lemons and post the proposed solution on LDTVR. Second, LDTVR listed the FOUR essential stages of an appropriate learning activity for design thinking: (1) the preparation stage, which participants have to build up their knowledge by gathering versatile information in this stage; (2) the incubation stage is the accent of the entire learning process which involves the use of various creative thinking skills that allow participants to explore possible solutions to address problems; (3) the evaluation stage allows participants to look at their explorations and creative thoughts deliberately in order to determine the most appropriate solution from hundreds of possibilities; and participants are giving the opportunity to examine their selected solution in (4) the implementation stage. Third, the ground rules for doing the design-thinking exercise and the steps for the brainstorming exercise are listed clearly in the LDTVR blog. There are FOUR main rules that have been emphasized strongly to guide the participants during the design thinking process: (1) Judicial judgment is ruled out. Criticism of ideas will be withheld until the next day; (2) Wildness is welcomed. The crazier the ideas, the better; it is easier to tone down than to think up; (3) Quantity is wanted. The more ideas we pile up, the more likelihood of winners; and (4) Combination and improvement are sought. LDTVR also listed the SEVEN steps for the group brainstorming exercise for participants to consider during the design thinking process: (1) Step One - A positive approach to problem identification and exploration; (2) Step Two - 25 minutes for every participant to do the brainstorming exercise; (3) Step Three - Everyone presents his/her ideas without any explanation and judgment; (4) Step Four - Select five possible ideas from all concepts; (5) Step Five - Seeking and discussing a fine criterion for the problem; (6) Step Six - Create a score system (0-5 points); give points to selected ideas; and (7) Step Seven - Implement the idea with highest score (Baumgartner, 2002). Fourth, LDTVR lists the assessment criteria of this design-thinking exercise, which is divided into FOUR main aspects: (1) Experiments (Learning by doing); (2) Versatility of thinking (Ability to solve problems by using different styles of thinking); (3) Independent learning (Self-motivation in furthering knowledge, skills and interests); and (4) Critical reflection (Ability to evaluate own process of learning to make improvements). Last but not least, each participant is required to post a reflective journal with 150-250 words to describe what they have learnt from the design-thinking exercise and how they can employ this concept or method to other creative design tasks.

5.4 Summary of Chapter FIVE: Learning experiences in virtual environments

This chapter has discussed a range of literature on virtual learning experiences. It has included the exploration of hyperrealistic simulation in virtual environments for education purposes, the development of immersive virtual environment for students, and a discussion about how to construct a virtual learning community to enhance learning experiences. The second half of this chapter explained the details of establishing a virtual environment for enhancing design students' learning experiences and the educational web blog for the entire research of this thesis.

In conclusion, the application of various virtual technologies, including shared virtual reality and immersive virtual environment, to enhance students' learning experiences in creative thinking exercises does not necessitate the provision of advanced hardware, but rather the creation of a simulated virtual environment for them to *experience*. However, the design of the simulated virtual environment is far more complex than merely providing a hyperrealistic immersive environment. It is necessary to include representations of the social systems and their shared attributes. In other words, the simulated virtual environment is not simply a replication of real-world reality but with a social system. In this case, the concept of FORs is useful, that is the deliberate arrangement of spatial learning, visualization and navigation, to provide students with a unique learning experience. In view of using computer-generated simulations to facilitate students' problem-solving skills for ill-structured problems, virtual reality technologies are able to help students to explore a broad range of objects, environments and phenomena in virtual space.

In addition, some researchers believe that creative-thinking and problem-solving skills can be facilitated by collaborative learning within a virtual community. However, we should pay more attention to the social interaction and how students are connecting to other people within this virtual community. This is because the virtual community has many-to-many interactions around a wide range of disciplines and forms, hence it is far more complex than the ways of interaction and communication in physical world. It is the task of educators to introduce new and innovative educational approaches targeting the virtual community in order to enhance students' learning experiences within this community. And the diverse studies of educational approaches are also crucial for developing collaborative learning environments in virtual space as well as the establishment of shared educational virtual environments. After all, the computer-simulated environment and virtual community are possible ways to enhance students' learning experiences within virtual space. Indeed, various researchers have pointed out that these two aspects can be utilized to enhance students' learning experiences through virtual reality (e.g. Beck, 1979; Pollard, 1990; Pantelidis, 1993; Mantovani, 2001; Dirckinck-Holmfeld, 2002; Blascovich and Bailenson, 2006). This literature review gave rise to the formulation of TWO directional hypotheses underpinning the design of a shared virtual reality. They are; **H 1 – Establishing a computer-simulated learning environment is a factor for developing students' design thinking skills;** and **H2 – Constructing a virtual community for hyperlearning is important in establishing collaborative learning among design students engaged in design thinking.** The whole research study of this thesis, including the establishment of a shared virtual reality, the multimodal interaction research and the post-lesson interviews was based on these TWO directional hypotheses.

In this research, I introduced the educational virtual platform *ActiveWorld©* (AWs) for Phases Four and Five of this study. The advantage of this platform is that it provides the possibility of building an environmental stimulation for conducting design-thinking exercises for design students as well as offering students visible and movable virtual objects and structures inside the virtual environment. The findings of my preliminary research (Part 1 and Part 2), described in Chapter 2.3, suggested that designing and building a creative-friendly environment should involve THREE conditions: (1) the space has to be comfortable enough for long discussion; (2) the space should provide free choices (different rooms) for participants to select; and (3) these choices are different in nature, so participants can experience diverse environmental stimulation. Thus, a tailor-made shared virtual environment and its guided learning materials have been introduced in this chapter. This tailor-made shared virtual environment has THREE virtual spaces (1) **Area 1: Café Grand** - a common area, which is the biggest area inside Robert's Café, for gathering and creative discussion; (2) **Area 2: Café Top** - a small private area for discussion, located at the top of the main room. Participants have to climb the stairs in order to reach this area; and (3) **Area 3: Café Open** - an open area out of the main building. In addition, the designed web blog with the title "Learning Design Thinking in Virtual Reality (LDTVR)" was introduced to provide students with guided learning materials during their learning processes in virtual space.

Chapter SIX: Multimodal Interaction Research and Post-Lesson Online Interviews

This chapter presents: (1) the background reports of the multimodal interaction research in Phase FOUR and the post-lesson online interviews in Phase FIVE; and (2) the overall statistics and analysis of the said two phases. The findings and implications of these two phases will be discussed and presented in the final Chapter SEVEN.

The multimodal interaction research of Phase FOUR was scheduled on 12 October 2007. The post-lesson data collection of Phase FIVE took place on 24 October 2007. Three data analysis methods were employed to analyze the findings of Phase FOUR and Phase FIVE: (1) Conversation Analysis (Psathas, 1995); (2) Textual Analysis (Adolphs, 2006; Hughes, 2007); and (3) Multimodal Interaction Analysis (Norris, 2002; 2004). The methods of Conversation Analysis and Textual Analysis were used to analyze the conversations among participants in Phase FOUR and the dialogues between interviewer and interviewee in Phase FIVE. The method of Multimodal Interaction Analysis was applied to study the multimodal interactions of participants by means of avatars in Phase FOUR.

6.1 Analyzing multimodal interaction data

This research studied design students' learning experiences in creativity training in virtual reality. A huge amount of multimodal interaction data were collected in Phase FOUR in order to study these experiences. In relation to this, the following sections will discuss the nature of multimodal interaction as well as how to analyze the multimodal interaction data collected in Phase FOUR.

Some researchers (e.g. Goodwin, 2001; Kress, et al, 2001; Norris, 2002; 2004) have explained that communication involves a multiplicity of communicative models with diverse modes interacting together and separately. In other words, every individual uses several modes separately and/or simultaneously in expressing their experiences, thoughts and feelings. Actually, the function of any communicative action is to establish interpersonal relations (Habermas, 1984). In view of multimodal interaction analysis, the overall meaning of the interaction is made up by various higher-level (a series of multiple actions) and lower-level (simple and single action) actions. To be more specific, a system of representation, such as spoken languages and hand signs, creates lower-level action; and these multiple lower-level actions are chained to form a higher-level action, then create meaning eventually (Norris, 2004). Kress and Leeuwen (2001) explained that there is a semiotic system, which includes rules and regularities, attached to any system of representation or mode of communication. In other words, the unit of mediated action and the modes of representation need to be analyzed in the multimodal interaction research. Thus, the multimodal interaction analysis is going to analyze this unit of mediated action as well as the modes of representation.

However, some gesture representations are a mixture of synthetic and syntactical methods such as the signing systems of deaf people. Generally speaking, Norris (2004) reminded us that it is difficult to analyze the meaning of gesture, because a complex gesture representation is not necessarily a logical combination of various simple gestures. Different from spoken language, which is structured sequentially, gesture is structured synthetically (McNeill, 1992; Norris, 2004). However, this theory might not apply to analyzing the participants' performed gestures in virtual reality. In my research, the gestures and emotional displays of avatars were programmed by the computer system, and participants performed structured gestures sequentially by clicking the action buttons one by one. In other words, every simple performed gesture had its own meaning. Moreover, the default actions were limited and structured for all participants within the system; this means that participants were performing those default actions with full understanding of what messages they wanted to deliver. Therefore, I analyzed participants' expressions by the default actions they used for constructing meaning for communication in order to find out their learning experiences through these default actions. Indeed, it is valid to study participants' ways of communicating through the use of the default actions of avatars in the virtual reality. It helps me to understand how students' are communicating by using avatars, and this is indeed a part of their learning experience in virtual reality.

Multimodal interaction analysis is a well-developed qualitative methodology for analyzing nonverbal behavior in forms of multimodal transcripts (Norris, 2002; 2004). These transcripts facilitate complex presentation of multimodal analysis. According to Goodwin (2001), any transcription system has to attend simultaneously to two separate fields by looking in one direction at one time; and this multimodal transcription aims to translate the visual and audio aspects into a printable format (Norris, 2002; 2004). Therefore, I employed multimodal interaction analysis in my multimodal interaction research in Phase FOUR, to record and analyze the real-time interactions of all participants in virtual reality in order to provide theoretical assumptions. The aim of my research was to look at the design students' learning experiences by analyzing their multimodal interactions in the shared virtual reality.

6.1.1 Ways of analyzing communicative modes and mediated actions

For the multimodal interaction research in Phase FOUR (See the attached file: Raw-Data File 1_Phase FOUR), EIGHT participants (design students) were involved. The techniques of the (1) Conversation Analysis (Psathas, 1995); (2) Textual Analysis (Adolphs, 2006; Hughes, 2007); and (3) Multimodal Interaction Analysis (Norris, 2002; 2004) were employed to analyze the participants' conversations and multimodal actions. There are FIVE main areas for the researcher to focus on when doing transcriptions and analysis:

(1) Analyzing the *discourse marker* which the participant performs: The discourse marker includes those incomplete sentences, often interrupted by pauses and breaks, and the employment of "ah", "hm", "well", "oh" and "ic" that participants have uttered during the conversations (Schiffrin, 1987). In my research, the participants' dialogues are mainly in textual format and they employ various discourse markers during conversation. Below is the example

of analyzing the conversations in Phase FOUR. I used the [ ] to work as discourse markers and { } for the markers of body position and gesture.

<S03>	(28) Participant[s] are required to explore 101 ways to squeeze a lemon by posting the solutions.
<S01>	(29) okay
<S07>	(30) back {Flying}
<S08>	(31) Ideas?
<S03>	(32) the task is written on the red board
<S06>	(33) I can see that =.= [icon "boring face"– means she feels bored]
<S03>	(34) here, near the door
<S08>	(35) lemon juice ar [Chinese, means questioning]
<S06>	(36) So... where will we discuss?
<S01>	(37) Letz [let's] have a brainstorming first
<S08>	(38) ok, follow me la [Chinese intonation] plz [please] {Raise hand}

The above discourse markers (See Raw Data File 1_Phase FOUR.doc, p.3) have been applied to analyze students' conversations, body and gestures in order to understand their ways of communicating in virtual reality;

(2) Analyzing the *proxemic behavior* of participants: This is concerned with how the participants arrange and utilize their spaces during the conversation. These spaces give some indicators of social relationship among participants (Hall. 1966). Further elaborations from Hall, there are FOUR distances in proxemic behavior: *intimate distance*, *personal distance*, *social distance* and *public distance*. Norris (2002; 2004) stated that individuals are used to adopting a system of representation of proxemics that they have learned through socialization particularly in real-time conversation. Although the participants of this research were physically separated and apart from one another at their various screens, the basic concept of analyzing the proxemic behavior can help to study how participants arranged and utilized their *virtual* spaces

during the learning process. It is similar to some later research on studying the interpersonal distances between avatars in virtual reality (e.g. Yee, Bailenson, Urbanek, Chang and Merget, 2007). Below is the example of analyzing the proxemic behavior of participants in Phase FOUR (See Raw Data File 1_Phase FOUR.doc, p.16). I used the [[ ]] to work as proxemics markers.

00:58– 00:60	[[<S01>, <S03>, <S04>, <S06>, <S07> and <S08> stayed in Open Cafe/Area Three and formed a circle for discussion]]
	[[<S02>joined the discussion group at 00:59]]

In the light of this research, the reason for studying proxemic behavior in my research was to gain some understanding about the social relationships among participants in virtual reality;

(3) Analyzing the participants' *body positions and gestures*: This is a study of the ways in which participants position themselves during the conversation. Norris (2004) highlighted TWO crucial aspects that I had to look at, the *form of body position* and the *postural direction* that the participant takes up towards others. The participants' performed gestures were limited and structured by the computer system in my study, therefore, the body position was an important indicator for understand the meaning making of the avatar (Participant). I applied the proxemics markers (e.g. [[ ]]) to analyze students' body position and the postural direction in Phase FOUR;

(4) Analyzing the *prints* that participants have presented: This is concerned with the embodied mode when participants use tools, such as paper, pen and book,

to express their perceptions, thoughts or feelings (Norris, 2004). In my research, participants (as a form of avatar) were not able to hold any object to create meanings during the conversation due to the limitation of the computer system. However, the virtual platform allowed the participants to use web pages and other intangible references to create meanings and messages during the conversation. Therefore, no indicator or marker has been used for analyzing print; and

(5) Analyzing the *modal density* during the conversation: This is to analyze how many modals the participants used in an interaction, and the emphasis is given to studying the intensity, weight and importance of specific modes in interaction (Norris, 2004). Below is the example of analyzing the modal density during the conversion in Phase FOUR (See Raw Data File 1_Phase FOUR.doc, p.17). I used the maker # for indicating the analysis of model density.

00:60-01:02	# Total 16 dialogues and 0 emotion display
	# No. of participant involvement in discussion: 4
	# Textual-based emotion display: 1
	# Descriptions of the activates: Scoring ideas and discussion

Since the modals that participants could possibly perform are limited in a virtual platform, it was important to study the modal density during their conversations in order to review the methods of communication among them in virtual reality.

In addition, there are some studying areas in multimodal interaction analysis that were not employed in my research: (1) Gaze: Although gaze plays an essential role in interaction by indicating the organization, direction and intensity of looking (Norris, 2004; Yee, Bailenson, Urbanek, Chang and Merget, 2007; Tampone, 2008), it was not applicable in my research since the participants (as a form of avatar) were not able to use gaze while interacting with others intentionally; and (2) Position of the Head: Similarly, heard movement is important to understanding the hidden meanings that participants want to express, however, it was also not applicable in my study since the participants were not able to move their avatars' heads. Besides, I understand, as Norris (2004) pointed out, the analysis of modal density only represents a qualitative notion instead of a quantitative one since modes cannot be counted. Moreover, it is very difficult to analyze higher-level actions because they are not a given unit.

6.1.2 Background report of the multimodal interaction research in Phase FOUR

Phase FOUR of this research was completed on 12 October 2007 at 12:00 [GMT +800] and the duration of it was 1 hour and 14 minutes (74 minutes). The number of participants was NINE, which included EIGHT design students and ONE researcher who acted as an observer. I played this role of observer during the entire research progress. All participants were identified with a code and an avatar. The gender distribution of the participants was FOUR male students, with the codes from <S01> to <S04>, and FOUR female students, with the codes from <S05> to <S08>. I (as an observer) had the code <S00>. These codes were given by the researcher, and participants had no right to select or change them. For choosing avatars, participants had the right to select their favorite presentation. Some interesting behaviors were found in the participants' selections of avatars. According to figure 21 the FOUR male participants chose the joker, godfather, Egyptian and alien. The FOUR female participants chose the fat male tourist, female thief, western lady and bald male (See figure 21). Details of why participants chose these avatars as their representative and the gender differences are explored in Phase FIVE.

The EIGHT participants were asked to undertake a proposed creative task within a designed shared virtual reality (Robert's Café) using the representations of their selected avatars. Participants are separated physically and apart from one another at their own screens. They were unable to identify other participants because the personal details of each participant remained unknown during the entire process. This proposed creative task on which they worked was based on my finding in Chapter 3.3.2. There was NO intervention from me (as an observer) during the entire process; I (as an observer) was looking mainly at the participants' interactions.

Phase FOUR Multimodal Interaction Analysis in the Shared Virtual Reality			
Date of the Research	12 October 2007	Time	12:00 [GMT +8:00]
Duration of the Research	1 hour and 14 minutes (74 minutes)	Number of Participant	9 (8 design students + 1 researcher as an observer)
Interaction	Proposed Creativity Exercise for SD2000	File name of the video	Phase FOUR_1 hr 21 mins.avi
Description	8 design students were asked to undertake a brainstorming exercise within a designed shared virtual reality (Robert's Café) by the representations of their selected avatars. Students were unable to identify other participants because the details of each participant remained unknown during the process.		

Details of the Participants				
Name of the Participant	Gender	Login Account of the Active World	Name of the Avatar	Symbols for Analysis
Kung-wong LAU, Robert	Male	robertlau	Observer	<S00>
Lam Ka Ming (Ivan)	Male	Designer1	Navi	<S01>
Wong Sze Sing	Male	Designer2	Godfather	<S02>
Kwok Yuet Hang (Jeff)	Male	Designer3	Pharaoh	<S03>

Chan Kit (Tenno)	Male	Designer4	Gary	<S04>
Chak Wing Yan (Da)	Female	Designer5	Luke	<S05>
Lau Yik Ka (Ar Ka)	Female	Designer6	MeSmEr	<S06>
Wong Mei Yee (Carol)	Female	Designer7	Bingo	<S07>
Chan Lok Man (Adrian)	Female	Designer8	Mankare	<S08>

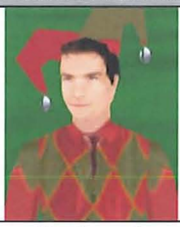
Avatars Selected by Participants			
			
Designer1	Designer2	Designer3	Designer4
<S01>	<S02>	<S03>	<S04>
			
Designer5	Designer6	Designer7	Designer8
<S05>	<S06>	<S07>	<S08>

Figure 21: Background report of the multimodal interaction analysis

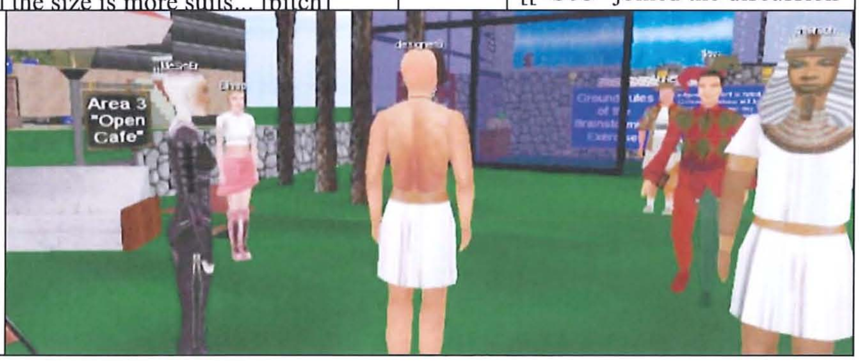
For the sake of recording the multimodal interactions of the participants during the entire process, the lesson was separated into 37 units, with each unit being of 2 minutes' duration. After the study of the participants' conversation patterns, the researcher decided to adopt 2 minutes as a unit due to the slow responses of participants' interaction. For instance, the average dialogue rate per 2 minutes was normally only 15.4 for 6 participants. The conversation pattern among participants during the process was slow, because they were using typing as the main communication tool instead of any verbal means. Figure 22 shows the sample of a transcript which indicates 2 units (4 minutes). Each unit includes a frame of the scenario, a table of transcription of conversation, a table of time code and a table of multimodal transcription. The researcher indicated the discourse markers, body position, gesture and emotion displays in the table of transcription of conversation. Similarly, the researcher indicated the proxemics and environmental stimulation in the table of multimodal transcription. Details of the indicators for diverse transcriptions can be found in figure 22.

<table>
<tr><td colspan="4">Transcript of the Multimodal Interaction Analysis in the Shared Virtual Reality
SAMPLES (Pls refer to file: Raw-Data File 1_Phase FOUR for the entire transcript)</td></tr>
<tr><td>SCENCE 1

Frame – Shared Virtual Reality [AWs]</td><td colspan="3"></td></tr>
<tr><td colspan="2">Transcription of Conversation
Indicators:
[Discourse Markers]
{Body Position and Gesture/Emotion Display}</td><td>Time Code 2 mins per/f</td><td>Multimodal Transcription
Indicators:
[[Proxemics]]
((Environmenental stimulation))</td></tr>
<tr><td><S06></td><td>(355) how about mouse trap</td><td rowspan="6">00:48
–
00:50</td><td rowspan="6">[[All participants stayed in Open Cafe/Area Three]]
[[All participants stand still and formed a circle]]

[[<S08> left the group and went inside the main building, just hanging around]]

[[<S08> joined the discussion</td></tr>
<tr><td><S08></td><td>(356) throw it into the black hole in the space</td></tr>
<tr><td><S04></td><td>(357) I think we should consider how to collect the juice. {Hand waving}</td></tr>
<tr><td><S06></td><td>(358) or... [time intervals] clip it at the folding chair</td></tr>
<tr><td><S06></td><td>(359) Or.... [time intervals] use the F.C [folding chair] to hit the lemon</td></tr>
<tr><td><S05></td><td>(360) I think CD driver is better....... [time intervals] the size is more suits... [pitch]</td></tr>
<tr><td>SCENCE 2

Frame – Shared Virtual Reality [AWs]</td><td colspan="3">
</td></tr>
</table>

Transcription of Conversation Indicators: [Discourse Markers] {Body Position and Gesture/Emotion Display}		Time Code 2 mins per/T	Multimodal Transcription Indicators: [[Proxemics]] ((Environnemental stimulation))
<S03>	(535) quick quick quick [emphasis]	01:10 – 01:12	[[All participants stayed in Open Cafe/Area Three]] [[All participants stand still and formed a circle]] - Total 10 dialogues and 3 emotion displays - No. of participant involvement in discussion: 5 - Textual-based emotion display: 2 - Descriptions of the activates: Scoring ideas and discussion
<S01>	(536) WINDOW [emphasis]		
<S08>	(537) 3.7		
<S02>	(538) So, vote all method?		
<S06>	(539) who didn't give the score~ be quick {Raise hand}		
<S02>	(540) Finished? {Raise hand}		
<S08>	(541) wait {Raise hand}		
<S08>	(542) Which one is the best???		
<S08>	(543) Highest score?		

Figure 22: Sample transcript of the multimodal interaction analysis

6.1.3 Background report of the post-lesson online interviews in Phase FIVE

After the multimodal interaction research in Phase FOUR, the post-lesson online interviews with all participants in the form of answering open-ended questions and writing self-reflective journals were conducted on 14 October 2007 in order to collect participants' feedback on their learning experiences in the shared virtual reality in Phase FIVE. A report was made for the researcher to understand the students' opinions about their learning experiences, virtual identity and environmental stimulation (Details of the entire report, see the file: Raw-Data File 2_Phase FIVE). The report involves TWO types of transcriptions (Self-reflective journal and post online interview) for each participant. In total SEVEN participants, except ONE who withdrew for personal reasons, were involved in these TWO procedures in Phase FIVE. The techniques of the (1) Conversation Analysis (Psathas, 1995) and (2) Textual Analysis (Adolphs, 2006; Hughes, 2007) were employed in analyzing the transcripts. For making transcription conventions, the analyst used **[square brackets]** to indicate translations; and **(parentheses)** for descriptions.

As the figure 23 shows, there are SEVEN participants engaged in both post-lesson interviews and writing self-reflective journals. The duration of each post-lesson online interview was between 6 minutes 24 seconds and 14 minutes 24 seconds. All participants finished all questions.

Accounts of AWs	Names of Avatars	Symbols	Sex	Self-reflective Journals	Post-lesson Interview	Date and duration of the Post-lesson Online Interviews
Interviewer	Nil	<S00>	M	**a**	**a**	Nil
Designer1	Navi	<S01>	M	**r**	**r**	Withdraw (Personal Reasons)
Designer2	Godfather	<S02>	M	**a**	**a**	14 October 2007 14 minutes 24 seconds
Designer3	Pharaoh	<S03>	M	**a**	**a**	14 October 2007 07 minutes 56 seconds
Designer4	Gary	<S04>	M	**a**	**a**	14 October 2007 06 minutes 35 seconds
Designer5	Luke	<S05>	F	**a**	**a**	14 October 2007 06 minutes 24 seconds
Designer6	MeSmEr	<S06>	F	**a**	**a**	14 October 2007 09 minutes 10 seconds
Designer7	Bingo	<S07>	F	**a**	**a**	14 October 2007 08 minutes 20 seconds
Designer8	Mankare	<S08>	F	**a**	**a**	14 October 2007 07 minutes 01 seconds

Figure 23: Background report of Phase FIVE

For the content of the post-lesson online interview, SEVENTEEN questions were asked to SEVEN participants. There were NO difference among participants in terms of questions nature and structure. Figure 24 shows the questions being asked in the post-lesson online interview. For the sake of effectively analysis of the participants' various opinions and feedback on the multimodal interaction research, the said SEVENTEEN questions were classified into THREE genres: (1) virtual identity of the participants (See Q1, 2, 3, 11 and 12); (2) environmental stimulation inside virtual reality (See Q4, 5, 6, 7, 8, 9 and 10); and (3) participants' learning experiences (See Q13, 14, 15, 16 and 17). For instance, the researcher asked the participants about the reasons for selecting the particular avatars as their representatives in order to understand how the virtual identities help participants to release their creative potential. Similarly, participants' feedback on the application of emotion displays and the virtual environment are essential for the researcher to understand the environmental stimulation in the shared virtual reality. Last but not least, since understanding participants' learning experiences inside virtual reality was the main objective of my research, the last FIVE questions have been allocated to investigate participants' opinions and feedback on the actual learning product and the problems they confronted during the designed module in AWs.

Code	Type of Question	Questions
Q1	Virtual Identity	What is the name of your avatar?
Q2	Virtual Identity	Why did you choose this avatar?
Q3	Virtual Identity	Do you like to use an avatar instead of your real personal identity inside any virtual platform?
Q4	Environmental stimulation	Where do you want to conduct this interview inside virtual reality? Which Café?
Q5	Environmental stimulation	Why did you choose this café?
Q6	Environmental stimulation	Do you like to work in virtual reality? Or prefer traditional face-to-face conversation?
Q7	Environmental stimulation	What would you think if the exercise were conducted in MSN, discussion forum or other internet applications?
Q8	Environmental stimulation	Did you check emails, browse webpages or listen to music during the process?
Q9	Environmental stimulation	I saw someone was flying in the sky inside the virtual reality, What you think about this action?
Q10	Environmental stimulation	Do you like the emotion displays inside the system? If you could add more functions of the emotional display, what would you like?
Q11	Virtual Identity	Did you feel more relaxed and free by using avatars during the brainstorming exercise?
Q12	Virtual Identity	Do you think, to a certain extent, you changed your personality or learning behavior inside the virtual reality?
Q13	Learning experience	In what way do you think virtual reality can facilitate your creative thinking process?
Q14	Learning experience	You had learnt the brainstorming technique before in the classroom. Please comment about using this technique again inside the virtual reality?
Q15	Learning experience	Did you face any learning problem during the process? What were they?
Q16	Learning experience	If one of the design modules could be totally conducted in virtual reality, what do you think, which subject is appropriate?
Q17	Learning experience	What is your overall learning experience inside the virtual reality? Do you like it?

Figure 24: Genre of questions of the post-lesson online interview

6.2 Overall statistics and analysis of the Phase FOUR and Phase FIVE

This chapter reports: (1) the overall statistics and analysis of the multimodal interaction research in Phase FOUR; (2) the participants' interactions in different learning activities in Phase FOUR; and (3) the analysis of the self-reflective journals and post-lesson online interviews in Phase FIVE. Although some significant discoveries were found during the analysis of the aforesaid areas, the findings and implications will be discussed in Chapter SEVEN.

6.2.1 Overall statistics and analysis of the multimodal interaction research in Phase FOUR

After an initial analysis of the learning activities in which participants were participating during the research, I classified all their activities into FIVE different genres: (1) social gathering; (2) briefing and brainstorming; (3) critique of the explored ideas; (4) evaluation of the working process; and (5) scoring ideas and discussion. Further explanations are as follows.

(1) **Genre 1** - Social gathering: Participants are doing social gathering activities, for instance, saying hello and meeting group mates. This genre of discussion is usually at the beginning and the end of the lesson;

(2) **Genre 2** - Briefing and brainstorming: Participants are trying to understand the brief of the design task and doing brainstorming exercises namely idea

exploration and development. This genre of discussion is mainly for creative thinking and exploration;

(3) **Genre 3** - Critique of the explored ideas: Participants are evaluating and criticizing the explored ideas among other participants. For instance, they are discussing the possibilities of carrying out the explored ideas. This genre of discussion is mainly for critical thinking and evaluation;

(4) **Genre 4** - Evaluation of the working process: Participants are evaluating and criticizing the working and thinking process. For instance, they are discussing the working schedule and the criteria of the project. This genre of discussion is mainly for reflecting the participants' ability in independent learning; and

(5) **Genre 5** - Scoring ideas and discussion: Participants are criticizing and scoring the explored ideas into different levels. In other words, they are scoring their ideas for seeking a creative solution. This genre of discussion is mainly for critical thinking and judgement.

Figure 25 shows the overall statistics of participants' multimodal interactions in Phase FOUR. This figure helped me to understand: (1) how many participants engaged in discussion per unit; (2) how many emotional displays were performed totally throughout the entire process; (3) how many participants' dialogues per unit; (4) how many emotion displays (in gesture) were performed per unit; and (5) how many emotional displays (in textual format) were performed per unit. Figure 25 is a table for analyzing the *modal density* in Phase FOUR.

During this 1 hour and 14 minutes (74 minutes), there were overall 6.1 of the total of 8 participants engaged in discussion per unit. This figure shows that, no matter what genre of learning activities, a higher participating rate was achieved throughout the entire process. Besides, there were keen discussions among participants during the process which can be reviewed by the higher rate of dialogues per unit. This was 15.3 per unit, which was equal to a total number of 565 dialogues for 74 minutes. In other words, there were 15.3 conversations recorded per 2 minutes. This is a higher rate of information exchange since the participants had to type texts and wait for responses step-by-step instead of the quick verbal conversation in the real world. Regarding the modal density of emotion displays during the process, totally 152 emotion displays in textual format and 89 emotion displays in gesture (default function of avatar in AWs) were performed. The rates were 4.1 and 2.4 respectively. This comparison shows that the participants tended to use emotion displays in textual format rather than the emotion displays in gesture. If we combine these two figures, which is 6.5 per unit, to compare the rate of dialogues which is 15.3, we can easily find out that the participants liked to use dialogue to present their ideas and opinions instead of using emotion displays. The reasons why participants used less emotion displays than dialogues will be discussed in Chapter SEVEN.

Overall Statistics on Participants' Interactions (2 minutes per unit)					
Time Code 2 mins per unit	No. of participant in discussion	Statistics for dialogues	No. of emotion displays in gestures	No. of emotion displays in textual format	Description of the activities (5 Genres)
00:00 – 00:02	4	9	2	2	Genre 1 – Social gathering
00:02 – 00:04	4	9	2	1	Genre 1 - Social gathering
00:04 – 00:06	6	11	2	4	Genre 1 - Social gathering
00:06 – 00:08	6	12	2	2	Genre 1 - Social gathering
00:08 – 00:10	7	27	2	9	Genre 2 -Briefing and brainstorming
00:10 – 00:12	7	18	5	1	Genre 2 -Briefing and brainstorming
00:12 – 00:14	7	19	1	6	Genre 2 -Briefing and brainstorming
00:14 – 00:16	6	10	2	5	Genre 2 -Briefing and brainstorming
00:16 – 00:18	6	13	1	4	Genre 2 -Briefing and brainstorming
00:18 – 00:20	7	15	0	8	Genre 2 -Briefing and brainstorming
00:20 – 00:22	7	16	0	5	Genre 2 -Briefing and brainstorming
00:22 – 00:24	8	25	1	8	Genre 2 -Briefing and brainstorming
00:24 – 00:26	6	9	1	2	Genre 3 – Critique of the explored ideas
00:26 – 00:28	6	10	0	3	Genre 4 - Evaluation of the working process
00:28 – 00:30	7	22	0	4	Genre 4 - Evaluation of the working process
00:30 – 00:32	7	16	4	4	Genre 4 - Evaluation of the working process and doing something side tracking (four of them are flying)
00:32 –	7	14	2	2	Genre 2 -Briefing

00:34					and brainstorming
00:34 – 00:36	6	12	1	6	Genre 2 -Briefing and brainstorming
00:36 – 00:38	6	17	4	5	Genre 3 – Critique of the explored ideas
00:38 – 00:40	6	19	4	9	Genre 4 - Evaluation of the working process
00:40 – 00:42	7	11	3	6	Genre 3 – Critique of the explored ideas
00:42 – 00:44	5	15	2	5	Genre 3 – Critique of the explored ideas
00:44 – 00:46	5	13	0	4	Genre 3 – Critique of the explored ideas
00:46 – 00:48	7	14	5	6	Genre 3 – Critique of the explored ideas
00:48 – 00:50	5	9	2	3	Genre 3 – Critique of the explored ideas
00:50 – 00:52	4	10	5	4	Genre 3 – Critique of the explored ideas
00:52 – 00:54	6	11	7	4	Genre 4 - Evaluation of the working process
00:54 – 00:56	7	17	2	5	Genre 4 - Evaluation of the working process
00:56 – 00:58	4	8	1	3	Genre 5 - Scoring ideas and discussion
00:58 – 00:60	6	15	2	8	Genre 5 - Scoring ideas and discussion
00:60 – 01:02	4	16	0	1	Genre 5 - Scoring ideas and discussion
01:02 – 01:04	7	22	2	1	Genre 5 - Scoring ideas and discussion
01:04 – 01:06	7	33	5	5	Genre 5 - Scoring ideas and discussion
01:06 – 01:08	8	16	5	1	Genre 5 - Scoring ideas and discussion
01:08 – 01:10	7	22	6	1	Genre 5 - Scoring ideas and discussion
01:10 – 01:12	5	10	3	2	Genre 5 - Scoring ideas and discussion
01:12 – 01:14	6	20	3	3	Genre 1 - Social gathering

Total hour	Average of the participation rate	Average of dialogue rate	Average of the emotion displays	Average of the emotion displays rate in textual	Genres of activities

			rate in gestures	format	
1 hour 14 minutes	Total 226/37 units = **6.1** participation per unit	Total 565/37 units = **15.3** dialogues per unit	Total 89/37 units = **2.4** emotion displays per unit	Total 152/37 units = **4.1** emotion displays per unit	Genre 1 - Social gathering Genre 2 - Briefing and brainstorming Genre 3 – Critique of the explored ideas Genre 4 - Evaluation of the working process Genre 5 - Scoring ideas and discussion

Figure 25: Overall statistics on participants' multimodal interactions in Phase FOUR

Regarding the participants' interactions among different learning activities, which are the aforesaid FIVE genres, figure 26 shows the percentage of the duration of each specific learning activity. During this 1 hour and 14 minutes (74 minutes), participants spent 12 minutes, which is equal to 16.2% of the total time, on Genre 1 - Social gathering; 20 minutes on Genre 2 – Briefing and brainstorming; 14 minutes on Genre 3 - Critique of the explored ideas; 12 minutes on Genre 4 - Evaluation of the working process; and 16 minutes on Genre 5 - Scoring ideas and discussion. This report shows that participants spent most of their time on briefing, brainstorming and scoring their ideas. Participants used 83.8% of their time doing the creative task. Only 16.2% of the total duration was allocated for social gathering. In general, this circumstance can be interpreted as a sound working process throughout the entire learning process. In addition, all genres of learning activities are distributed fairly equally. The higher genre is 27% and the lower genre is 16.2%. The difference between the higher one and the lower one is 10.8%. This means the difference is about 8 minutes. In this case, the entire learning process was effective and well structured. Participants conducted the entire lesson by themselves with the support of the guided learning materials only (See Chapter 5.3). I (as a teacher) played a role of an observer and did not intervene in any stage of the lesson. In other words, the teacher made no instructions. This suggests that the participants displayed a high quality of organizational skill during the process.

Learning activities	Duration	Percentage of total duration
Genre 1 - Social gathering	12 minutes	16.2%
Genre 2 - Briefing and brainstorming	20 minutes	27%
Genre 3 - Critique of the explored ideas	14 minutes	18.9%
Genre 4 - Evaluation of the working process	12 minutes	16.2%
Genre 5 - Scoring ideas and discussion	16 minutes	21.6%

Figure 26: Percentage of participation in diverse learning activities

6.2.2 Participants' interactions in different learning activities in Phase FOUR

In addition to the analysis of the distribution of diverse learning activities in Phase FOUR, it is important to find out the forms of participants' multimodal interactions during the process in order to understand how they were interacting with each other to complete the creative task and how virtual reality affected the participants' learning process. In the following sections, there is a total of SIX figures to report the participants' interactions in different learning activities. First of all, figure 27 shows the numbers and types of interactions that participants performed during the process. In the previous sections, we discussed that the participants tended to use textual-based dialogues as the core means of communication. This phenomenon can be reviewed by the curves in figure 27. The curve of textual-based dialogues (colored in purple) reaches a higher level throughout the entire process, whereas the curves of emotion displays in gesture (colored in orange) and emotion displays in textual format (colored in blue) are situated in the lower levels. It is interesting to find out that the purple and blue curves are similar in fluctuation. This similarity of curves implies that, the more the textual-based dialogue participants have been used, the more emotion displays in textual format have been employed. On the other hand, the curve of emotion displays in gestures (colored in orange) is totally different from the said two curves. This implies that participants were using those default emotion displays in a different manner or they were not really familiar with these ways of presentation. Nonetheless, figure 27 only shows the general picture of how participants were interacting during the research. As we have discussed, there were FIVE genres of learning activities in the entire research. The following sections will describe the analysis of the relationships of participants' ways of interaction from these five perspectives.

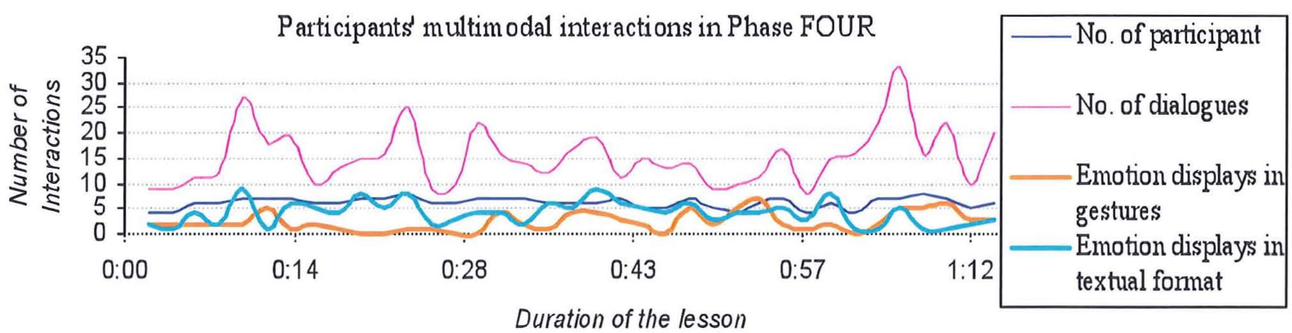


Figure 27: Participants' multimodal interactions in different learning activities

First, figure 28 shows the numbers and types of interactions that participants performed for the Genre 1 – Social Gathering. These 12 minutes include the beginning and the end of the research when they were welcoming and saying goodbye to each other. The curves of the numbers of participants (colored in black) and the numbers of dialogues (colored in purple) are in a parallel increase. The curve of the emotion displays in textual format (colored in blue) fluctuates. These curves imply that the more participants joined the virtual environment, the more dialogues they used for communication. Participants were communicating mainly by textual-based dialogues with the assistance of emotion displays in textual format. Obviously, the curve of the emotion displays in a gesture was situated in a lower level for this genre. This implies that the participants were using less emotion displays in gesture during social gathering.

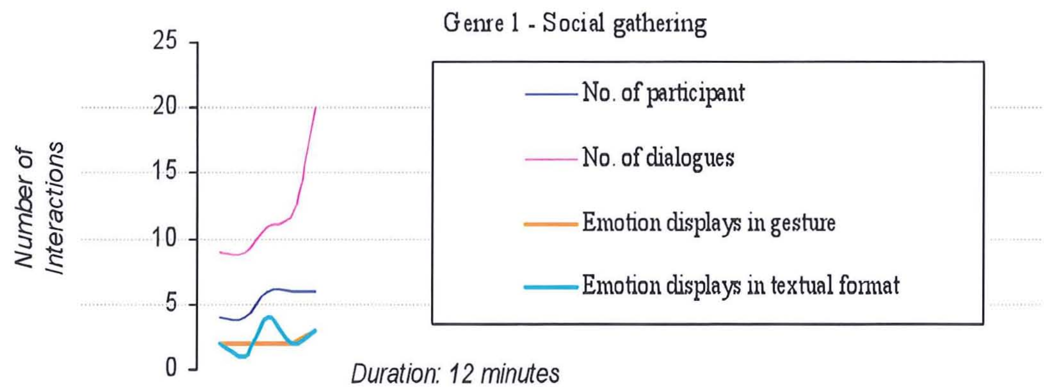


Figure 28: Statistics of Genre 1 – Social gathering

Second, figure 29 shows the relationships of interactions in Genre 2 – Briefing and brainstorming. All curves fluctuated seriously during these 20 minutes except the numbers of participants (colored in black). The black curve is stable throughout this section, in other words, there was an equal number of participants in each unit. The fluctuation of the other curves in the figure can be explained as that participants engaged in serious discussions in this learning activity. It is clear that the curves indicating the numbers of dialogues (colored in purple) and the numbers of emotion displays in textural format (colored in blue) fluctuate considerably but do form a pattern. This implies that participants used textual format, no matter whether in dialogues or emotion displays, as the main tool for exchanging ideas, whereas the curve of the numbers of emotion displays in gesture (colored in orange) is in a counter situation with the said two curves. This implies that when participants were discussing some ideas seriously, fewer emotional displays in gesture were employed to express their opinions and feelings.

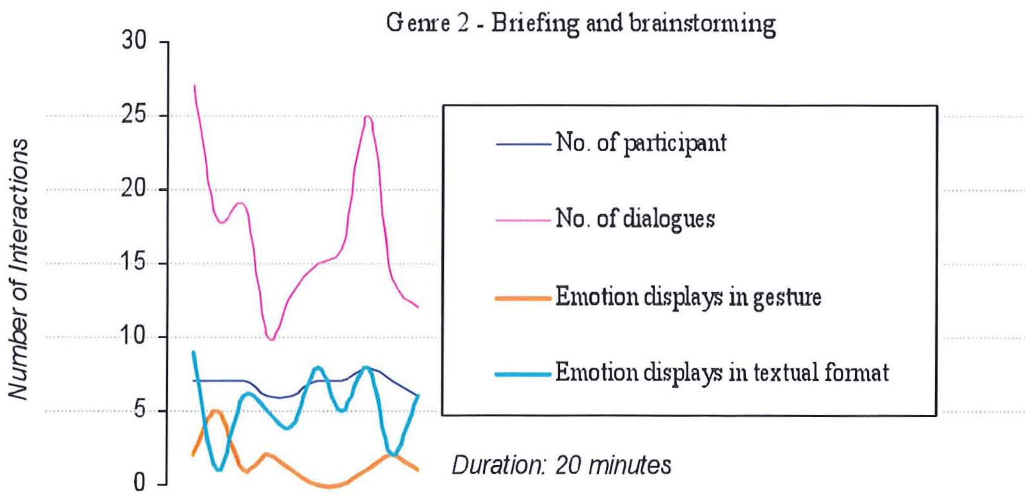


Figure 29: Statistics of Genre 2 – Briefing and brainstorming

Third, the curves in figure 30, which shows the relationships of participants' interactions in Genre 3 – Critique of the explored ideas, are different from the previous two figures. All curves are in the same fluctuation. This means that participants were using all forms of interactions during these 14 minutes. Although the curve representing the numbers of emotion displays in gesture is at a lower level, participants were using this form of interaction actively in comparison with Genre 1 and Genre 2. Moreover, participants were integrating the emotion displays in gesture with the other forms of communication in this section.

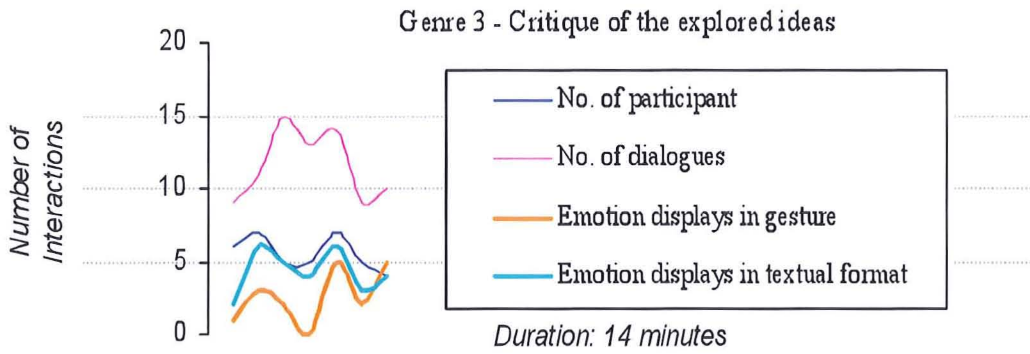


Figure 30: Statistics of Genre 3 – Critique of the explored ideas

Fourthly, figure 31 shows the participants' interactions for Genre 4 – Evaluation of the working process during 12 minutes. It is interesting to see that the participants used more emotion displays in gesture (colored in orange) in this section. In comparison with the curve of numbers of dialogues (colored in purple), particularly at the end of these 12 minutes, participants used more emotion displays in gesture, and used less textual based dialogues for communication. This implies that they were getting used to using avatars to express their opinions and feelings in this section. Moreover, this learning activity is not related to idea exploration, which does not need serious discussion; participants had time to explore the ways of presenting their opinions in gesture.

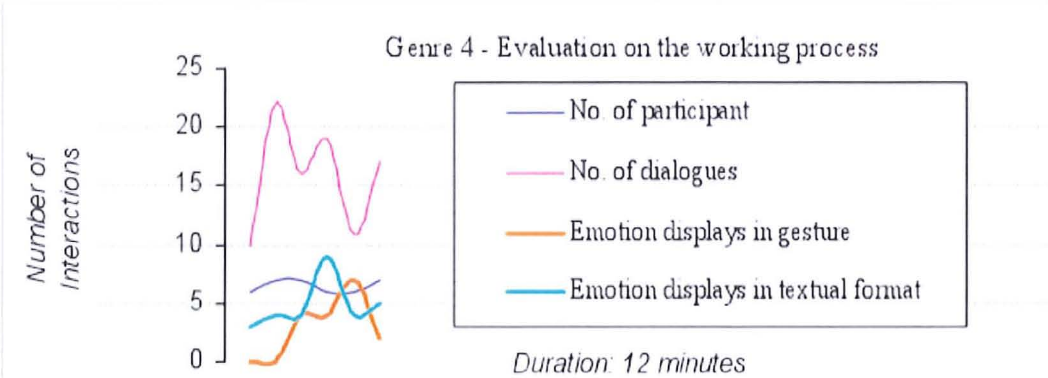


Figure 31: Statistics of Genre 4 – Evaluation of the working process

Finally, figure 32 shows the last learning activity of the entire research, in which participants engaged in scoring ideas and discussion. Apparently, the participants used more textual-based dialogue to exchange their ideas and opinions. Another significant finding is that the participants used more emotion displays in gesture (orange curve) and less emotion displays in textual format (blue curve), particular in the later part of these 16 minutes. This implies that the participants found ways to use avatar to express their opinions and feelings instead of using the textual-based emotion display.

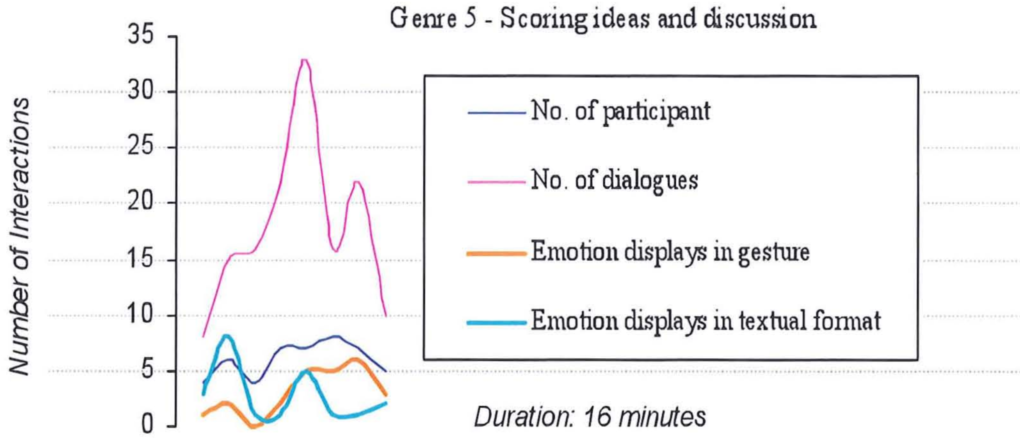


Figure 32: Statistics of Genre 5– Scoring ideas and discussion

Despite the quantitative analysis of the participants' multimodal interactions throughout the entire process, there were some qualitative observations done by me, as a researcher, to look at their proxemic behavior (Hall, 1966). First, this is similar to what I have explained in the previous sections, that participants tended to use textual-based dialogue as the main communication channel during the process. However, some simple gestures were performed for some simple communication. For instance they used the *hand wave*, which is one of the default functions of avatars, to welcome other participants and draw attention while they were expressing their ideas and opinions. Moreover, the participants were excited about doing the creative exercise in virtual reality; therefore they performed many default gestures without any reasons. Second, I found that they were curious and explorative in virtual reality; they tried to explore any new function inside the system. I was impressed by one of their findings, which was flying in virtual reality. As figure 33 shows, some of the participants were flying inside the virtual reality. It is important to note that the *flying* function is not provided by the system as any default function. It is actually a system error inside this virtual platform. The participants made use of this error and played with this function during the process. In another example, the participants spent time to figure out what is a virtual lemon in virtual reality.

Figure 33: Participants flying inside virtual reality

Third, I observed an interesting learning behavior of the participants while they were discussing in virtual reality; this was that they tried to form a physical circle in any kind of discussion with a *social distance* (Hall, 1966; Norris, 2002; 2004). Figure 34 shows two of the scenes in which the participants were trying to form a circle for a discussion, particularly in Genres 2, 3 and 4. As we discussed about the interface of this virtual platform in the previous Chapter 5.2, the chat room for textual-based dialogue is separated from the display window of virtual reality. It is not necessary for participants to form a physical circle in virtual reality for discussion; it is indeed useless for textual-based communication. On the other hand, although the avatar is a representative of the participant which will not cause any physical threat to his/her real body, there were no two avatars situated in an imitate or personal distance throughout the entire process. The participants were in group discussion with distance between them. Furthermore, the participants were aware of their postural directions during the discussion. They tried to face the other avatar who was speaking.

Therefore, according to these cases, I assume that the participants tried to imitate the actual situation in discussion in the real world as well as protecting themselves with a certain distance. The participants treated the virtual reality as a real world.

Figure 34: Participants making circle for discussion

A similar case of imitation can also be found in Genre 4, when the participants were evaluating their working progress. As figure 35 shows, the participants were actually looking at the notice boards seeking for information instead of using web browser for the same purpose. They were turning their postural directions towards the notice boards. They applied their usual behavior with in this virtual reality. I (As an observer) did not expect these acts since students could check out the rules from the provided webblog LDTVR on webpage instead of actually finding the notice board in virtual reality. Students were imitating the human behavior in the physical world. This is a very interesting human behavior in virtual reality which needs further study.

Figure 35: Participants reading the guided materials at the main entrance

Fourth, in view of autonomy and independent learning, the participants performed an effective and organized lesson without the teacher's supervision. According to my observation, there was no obvious leader found in any of the discussion. The participants were managing themselves with mutual respect. Furthermore, the participants were not aware of time management in the virtual reality. They felt that the virtual reality had provided sufficient time for them to discuss and needed not to have instant response to the conversations, for example:

<S05> *"I think the virtual reality can give [us] convenient in time and space..."*

(See Raw Data File 2_Phase FIVE.doc, p.18 – Dialogue 14 - 01:45)

<S07> *"Although discussion forum didn't provide an instant interaction, it permanently keep the conversation record and we can review at anytime."*

(See Raw Data File 2_Phase FIVE.doc, p.27 – Dialogue 13 - 02:50)

This implies that the shared virtual reality offers an autonomous learning experience to students. In other words, they are able to follow their own pace of learning during their learning process.

6.2.3 Analysis of the self-reflective journals and post-lesson online interviews in Phase FIVE

Phase FIVE contains data from self-reflective journals and post-lesson online interviews. Different from the quantitative data and observation in Phase FOUR, data in Phase FIVE are qualitative in generally aiming to reflect the participants' subjective feedback and opinions on their learning experiences in the shared virtual reality. To facilitate the analysis of the self-reflective journals of the final participants, I have summarized their feedback and opinions in the following sections.

In the self-reflective journals, participant <S02> recorded the feeling that the whole creative process was successful in spite of some minor problems during the process. <S02> agreed that some of the ideas they (participants) made during the process (though these ideas were NOT selected eventually for solution) were creative and actually broke their paradigm. <S02> gave positive comments on the research exercise although he did not explain anything about the assistance of virtual reality. Participant <S03> gave some negative comments on his performance within AWs due to his personal matters, for instance, he had to borrow a friend's computer for the exercise; he was not good at typing, especially in English; and he did not have enough preparation in reading the instructional materials before the exercise. However, participant <S03> reported that he could possibly take advantage of using AWs for the brainstorming exercise if the said problems were being solved. Participant <S04> pointed out an essential problem, which was the short sentences that participants used to type during the discussion. The participants were afraid of typing and the barrier of English (for most, their second or third language) which hindered the effectiveness of their communication, particularly in exchanging creative ideas and making decisions collaboratively.

Participant <S05> pointed out that it was difficult to organize ideas and manage discussion within the virtual environment. Time management is a big issue in virtual discussion; it is very easy to run out of time. Participant <S05> queried the perception of time in virtual reality. Moreover, participant <S05> highlighted the shift of the problem nature during the process; for instance, the core matter "lemon" became a concept of the virtual object in virtual reality instead of a tangible fruit in the real world after the participants' discussions. Participant <S05> believed that other participants changed their perceptions of objects and beliefs because they situated themselves in the virtual platform. Participant <S06> contributed some comments on the ways of communication in virtual reality. She stated:

<S06> *"Wanna [Want to] tell you one thing is that, when there are so much ppl [many people] talking at the same time, even if you name the guy in your sentence, the sentence will fade away becoz [because] another dialogs are coming~~ this time, you'll totally don't know wt [what] you are doing >< [crying sign]"*

See Raw Data File 2_Phase FIVE.doc, p.21)

Participant <S06> mentioned that because of the system limitation of the dialogue box, it was easy to post ideas but difficult to draw attention from the others. Participant <S07> stated that the group brainstorming exercise helped her a lot in generating ideas, because she could raise her ideas based on other participants' contributions. Participant <S07> expressed the belief that virtual reality could actually help her to relax and avoid quick demands of ideas. Nonetheless, participant <S07> agreed that the textual-based communication in the virtual reality hindered the effectiveness of idea exchange. Participant <S07> was getting confused in communication since the avatars were not perfectly performing human responses during the process. Participant <S08> believed that the group brainstorming exercise did help her to explore more ideas than individual practices. She enjoyed the process of brainstorming and understood the ground rules of it in virtual reality.

All in all, the participants enjoyed their learning experiences in the shared virtual reality according to their self-reflective journals, and the platform helped them to relax and feel free to suggest, explore and evaluate ideas. The platform also released their creative potential by encouraging them to diverge from their habitual thinking. For instance, they suggested using common software WinZip to squeeze the lemon since the lemon is a virtual object in virtual reality. From the design teacher's perspective, students' proposals to use WINZIP for "squeeze the lemon" is thinking out of the box. In my entire teaching experience, this answer has never been proposed by any students in the same subject in a face-to-face environment. I reason that the students were stimulated by the virtual environment in judging the solution and even the definition of "lemon" in cyberspace. Students <S03> and <S04> made the following comment in their reflective journals.

<S03> *"...some of the solutions were very practical and some of them are very creative, for instance, open the window system, put a lemon inside, then minimizing the window, this method will "Squeeze the lemon. Personally, I think that the said method is breaking the rule and out of our paradigm. However, the problem is the definition of lemon."*

See Raw Data File 2_Phase FIVE.doc, p.4)

<S04> *"We can not sure about whether the lemon juicer we designed should also cooperate to collect the juice and the juice collected should be drinkable or not."*

(See Raw Data File 2_Phase FIVE.doc, p.13)

<S05> *"In fact, the ideas we have given firstly are [were] workable. However when we [was] keep on thinking, some crazy ideas were given. The "lemon" seems to be no longer a real lemon! We became a bit confused near the end of discussion."*

(See Raw Data File 2_Phase FIVE.doc, p.17)

In view of enhancing students' creativity through creative training, I am not saying that the above creative solution is workable for actual design practices. As discused in Chapter 3.3.1, a comprehensive creative thinking training needs four stages, which are the (1) preparation; (2) incubation; (3) evaluation; and (4) implementation. This research in Phase FOUR was only looking at the incubation stage (See Chapter 3.1.1 – Figure 12). The practical implementation of the creative idea is not being addressed in this research. Nonetheless, students do change their ways of thinking due to the stimulation of virtual environments, in particular the fundamental design principles such as problem identification and usability of designs. This shift helped students to move their ways of thinking from tangible ways of squeezing a lemon to an intangible solution. For instance, when student <S08> raised the idea of using *WINZIP* to squeeze the lemon (Dialogue 106) at 00:14 – 00:16 in Phase FOUR, student <S01> proposed using *imagination* to squeeze it (Dialogue 126) at 00:16 – 00:18.

<S08> 00:14 – 00:16
(106) *"...put it in a file and then you zip it up" {Flying with <S03>}*

.
.
.

<S01> 00:16 – 00:18
(126) *"use your imagination to squeeze it and then you've done."*

(See Raw Data File 1_Phase FOUR.doc, p.5-6)

This reflects that students changed their ways of thinking through the stimulation of the virtual platform quickly (only between 20 dialogues within 2 minutes) from one single spark idea.

Although the development of ideas sounds effective according to the quick responses, the participants complained about the communication system in the shared virtual reality; they found problems in communication with the default chat room system as well as managing meaningful gestures by using avatars. Different from using the chat room system in MSN, the participants had difficulties with AWs, particularly in handling different forms of communication at once.

In view of the post-lesson online interviews in Phase FIVE, as we discussed in Chapter 6.1.3, the total number of SEVENTEEN questions was asked from THREE directions: (1) virtual identity of the participants; (2) environmental stimulation inside virtual reality; and (3) participants' learning experiences in the post-lesson online interviews. (For the details of the questions, see figure 31). First of all, I wanted to understand how virtual identity was affecting the participants' learning experiences. Five questions (Questions Q1, 2, 3, 11 and 12) were designed to collect their feedback and opinions on their virtual identities in virtual reality. The results show that all participants chose avatars based on TWO main reasons: (1) projecting their favorite images which are different from their real identities; and (2) finding weird identities to hide their personalities. For instance, participant <S02> chose the God-father because this avatar was holding a gun; participant <S03> chose an alien because it was inhuman; and participant <S07> chose a western young lady because she looked beautiful. Besides, all participants agreed that the use of avatars facilitated their creative thinking in the areas of hiding their real identities, avoiding being criticized by others, creating an atmosphere of relaxation and fun. This sense of anonymity helped participants to be free and active in group discussion. For instance, participant <S02> believed that she changed her personality a lot in the virtual reality; participant <S07> mentioned that she was more active and creative in virtual reality due to the anonymity and excitement. Some of the students' comments are below:

<S02> *"Of course I like to. With an avatar, no one will know who I am, and I can do what I want to without considering any ceremony or being ...... laughed at, hurt, hated ...etc. by others. (S02 likes using avatar since he was worrying about being criticized)..... Most importantly, it's fun to use a man so the others don't know who am I, I don't know why I like this feeling, I can only sat [say] that I like this kind of ...activity/thing."*

(See Raw Data File 2_Phase FIVE.doc, p.5 - Dialogue 6 -01:04)

"Yes, because I need NOT to care about many things that I need to in the real world. For instance, I dare to say anything I like, do anything I like. And I think that when I get a chance to try other things without any consequence/ aftermath, why didn't I do that, why didn't I say that? If I really do that, I believe that my personality or learning behavior will change inside the virtual reality (maybe that one is my real personality that I don't even know since I don't express that in the real world, HAHA [laugh])."

(See Raw Data File 2_Phase FIVE.doc, p.7 - Dialogue 30 -09:58)

<S07> *"...I should say I felt more relaxed and free to raise creative idea in the VR, the avatar makes the process more interesting. In the VR [virtual reality], no one stares at me, and I don't feel nervous."*

(See Raw Data File 2_Phase FIVE.doc, p.27 - Dialogue 21 -04:56)

"I am a little more active in the VR [virtual reality], maybe because I am excited."

(See Raw Data File 2_Phase FIVE.doc, p.27 - Dialogue 23 -05:20)
"The atmosphere relaxes me."

(See Raw Data File 2_Phase FIVE.doc, p.27 - Dialogue 25 -05:46)

It is important to mention that this study has shown that design students felt relaxed and free during the creativity training exercise in the virtual platform. This finding further supported my prior research on studying this area (See Chapter 1.4.3). Student <S07> made the following comment in her reflective journal.

<S07> *"For [In] the Active World, it provides a relaxed atmosphere for us to discuss the issue, this is good. People with slow reactions [passive] such as me will be happy that I can give the response not immediately, and have sufficient time to think about it while the others are giving response. Besides this can avoid nervousness."*

(See Raw Data File 2_Phase FIVE.doc, p.25)

Furthermore, in the post-lesson online interviews I asked the question "Did you feel more relaxed and free to raise your creative idea by using the avatar?". Except for student <S03>, who reported that he was nervous in front of the computer, the rest of the design students agreed that the virtual environment helped them to be relaxed and free during the process. Some interesting comments are listed below.

<S02> *"Em [thinking].....a little bit, because I need not care whether my idea is valuable or contributing as I will not really be blamed or laughed at by others about the idea I said (provided that others don't know who I am)".*

(See Raw Data File 2_Phase FIVE.doc, p.7 – Dialogue 26 -08:52)

<S07> *"Yes. More correctly [absolutely correct], I should say I felt more relaxed and free to raise my creative ideas in the VR, the avatar just made the process interesting. In the VR [virtual reality], no one stares at me, and I don't feel nervous".*

(See Raw Data File 2_Phase FIVE.doc, p.27 – Dialogue 25 - 05:46)

<S08> *"Yes, because the atmosphere is fun and relaxed, it's like*

encouraging you to keep raising ideas. The avatar I chose looks weird, so I naturally keep making fun with others".

(See Raw Data File 2_Phase FIVE.doc, p.31 – Dialogue 21 - 03:48)

Second, 7 questions (Questions Q4, 5, 6, 7, 8, 9 and 10) were asked to understand the impact of environmental stimulation in the virtual reality. The result shows that the majority of participants preferred doing the creative exercise in virtual reality, especially in the open area in AWs. As we discussed, considering the lack of working and living space of Hong Kong's design students described in Chapter 2.3, the open area in AWs gives a good impression to them not only in providing a huge spatial impact, but also offering an unlimited space for them to play with, like flying. For instances, participants <S04> and <S05> mentioned that AWs is close to a natural environment and give them freedom to think; it is a very rare space for Hong Kong's design students who mainly live in urban cities. They stated:

<S04> *"I would like to conduct this interview in area three because it is an outdoor area... I choose [chose] this as I feel close to nature in this cafe."*

(See Raw Data File 2_Phase FIVE.doc, p.14 – Dialogue 11 - 01:40)

<S05> *"The open area seems to give more freedom for me to think".*

(See Raw Data File 2_Phase FIVE.doc, p.18 – Dialogue 14 - 01:45)

Likewise, participants <S02> and <S03> were very excited by flying inside AWs unrealistically. Below are their comments;

<S02> *"So great!!!!! This "secret gesture" (it is not a default action of the avatar) is so great!!! It fulfills my dream of flying (HAHAHA) [laugh]. And it just like playing TV/computer games."*

(See Raw Data File 2_Phase FIVE.doc, p.6 – Dialogue 23 -07:32)

<S03> *"haha [laugh] I'm very interested in flying. Substitution is my comment. For my avatar, I like the identity [of] pharaoh having the power of god, so that I was trying to substitute myself into this virtual identity. It resulted I flew, same as ET, Egyptian. If I use some ordinary avatars, Peter or Mary, I would probably not fly."*

(See Raw Data File 2_Phase FIVE.doc, p.11– Dialogue 15 -03:02)

In addition, although almost all participants supported the functions of emotion displays in AWs which created a game-like learning experience for them and allowed them to use body language to present themselves, they criticized the default emotion displays as not being enough to present themselves effectively due to the limited choices. They suggested that the emotion displays must be designed according to some human behaviors, namely laughing and crying. Below are some of the students' comments on the default emotional displays in Phase FIVE's interviews:

<S02> *"I like it. It makes the avatar more humanistic. Sometimes I can react with others just by/with the emotion... I will add laughing [emotion display] and what we always said in real world "O 嘴" [means shocking] (which is mean that we don't know how to react with one's sentence, question, answer...etc). Because we don't know how to react to others since sometime people will say something very stupid and...I don't know, just don't know why they will say that and don't know how to react."*

(See Raw Data File 2_Phase FIVE.doc, p.6 – Dialogue 25 -08:10)

<S03> *"Definitely it's too few compared with some online games I've played, said for example, world of Warcraft [computer game]. The visuals of active world give my the feeling of computer games, like the Sims [computer game], Wow etc so that I expect it is doing the same as, or even better than those games... I would like to have "lying on land", "fake dead", "teasing". Importantly, I think some emotional displays are necessary like laughing, crying."*

(See Raw Data File 2_Phase FIVE.doc, p.11– Dialogue 17 -03:57)

<S05> *"Quite good. But looks still awkward...pls add maybe addition of sitting, sleeping, laughing."*

(See Raw Data File 2_Phase FIVE.doc, p.19– Dialogue 22 -03:02)

<S07> *"...there are many complex emotion displays but fewer or no basic ones*

such as laughing, crying, punching/fisting (angry), yawning (boring), sleepy, feeling sorry, annoyed, surprise…etc."

(See Raw Data File 2_Phase FIVE.doc, p.27– Dialogue 19 -04:26)

<S08> *"I love it, but it is far too little for me. Smoking, boredom, nodding, shaking head, scratching, kissing, hugging."*

(See Raw Data File 2_Phase FIVE.doc, p.31– Dialogue 19 -03:13)

Moreover, the participants pointed out some system problems of the textual-based chat room. They felt difficulties in communicating with more than 3 participants at the same time by using typing. Unlike the MSN chat room, which was one of their favorite and most familiar chat systems, the input texts in AWs will not change color; it is difficult to identify who is speaking in there. For example, student <S05> commented: *"…I think MSN seems to the virtual, but the strength in MSN is that you can type, draw and even talk. Also in MSN you can change the color of words and font to expand your feeling."* (See Raw Data File 2_Phase FIVE.doc, p.18). Nonetheless, almost all participants agreed that the hyperrealistic environment in AWs gave them an exciting learning experience, and the support from the Internet during the process was useful in facilitating their problem identification and creative thinking processes.

Third, 5 questions (Questions Q13, 14, 15, 16 and 17) were asked to understand the participants' learning experiences in virtual reality. The results are contradictory in general with some positive and negative comments. The positive comments were: (1) AWs create a fun and game-like learning experience; (2) participants felt relaxed and free during the entire process because of the sense of anonymity; and (3) the hyper-realistic environment and the support from the Internet were useful. The participants agreed that the above positive areas facilitated their learning and creative thinking processes. Besides, participants requested more design modules, namely thinking skills, practical skills and history, conducted in virtual reality. For the negative comments, they criticized that: (1) they spent lots of time in typing instead of thinking of ideas; (2) it is difficult to organize ideas and fail to see the whole picture of explored ideas in AWs; (3) it is difficult to manage diverse windows at the same time, namely dialogue box, virtual scene and the Internet browser. . For example:

<S02> *"If virtual reality enabled us to discuss/chat in verbal ways (with the sound edited), just like chatting on a phone, then the problem of typing is solved, so I will not feel annoyed about seeing and typing, I will feel free to say something."*

(See Raw Data File 2_Phase FIVE.doc, p.7 – Dialogue 34 -11:18)

<S08> *"One big problem is that sometimes I must use a few sentences to explain my ideas and type them out."*

(See Raw Data File 2_Phase FIVE.doc, p.7 – Dialogue 29 -05:26)

The participants believed that the above negative areas of AWs hindered their learning process. Nonetheless, the participants supported this learning environment if the aforesaid problems could be solved. The participants also suggested some future improvement for AWs: (1) creating a verbal communication system to replace the textual-based communication; (2) designing a drawing pad which allows participants to see the whole picture of the explored ideas; and (3) changing the instructional materials to virtual objects instead of a list on a web page. Participants could actually play with these objects in virtual reality.

Last but not least, regarding gender issues in the use of virtual technology in AWs, there were no significant differences between male and female students in operating the system and avatars, except for one male student <03> who reported his anxiety about using the computer during the process.

> <S03> *"Absolutely none [no]. I'm not the kind [of] person who can relax in front of a computer and I still think that pen and paper is the best way to be creative. No matter what things I'm doing using a computer, my mind is automatically nervous."*
>
> (See Raw-Data File 2_Phase FIVE, p.11 – Dialogue 5 -04:49)

Other students, male and female alike, had only reported the problem of using text-based communication during the process. The gender gap in the use of technology in the shared virtual reality did not occur in my research. The reasons for this could be that (1) the shared virtual reality is fundamentally different from other web-based learning platforms, so the students did not need sophisticated computer skills to operate this simulated virtual environment; (2) AWs provides students with a user-friendly "what-they-see-is-what-they-get" interface. Therefore, both male and female students could handle the system and avatar easily. However, this research identified an interesting gender difference in selecting and using avatars to present the participants' virtual identities. The results indicated that the artificial gender distinctions in the shared virtual reality can potentially influence students' learning experiences. The female students were more aware of choosing appropriate avatars to present their virtual appearances and identities than were the male students. The research involved equal gender distribution, four male students and four female students. However, there were six male avatars and only two female avatars (see figure 18). In other words, all of the male students chose male avatars but only two female students chose female avatars. This result implies that the male students tended to use their own gender to present themselves in the virtual world, whereas the female students were more varied. The male students appear to have shown a strong identity of their own gender, whereas half of the female students wanted to change their genders in the virtual world. Below is an interesting comment from a female student about her choice of an avatar.

<S05> *"But I chose a different sex as I hope to become a different person compared with the real world".*

(See Raw Data File 2_Phase FIVE.doc, p.18 – Dialogue 5 -00:35)

In addition to the gender identity, an interesting finding is that two female students <S06> <S07> were more concerned about their avatar's outlooks. Following are their comments during the post-lesson online interviews.

<S06> *"Because I like science fiction, the "Borg female" gives me a feeling for StarWars [name of movie]".*

(See Raw Data File 2_Phase FIVE.doc, p.22 – Dialogue 4 -00:30)

"Of course!! Because it is pretending a real life. And I think it's very convenient for those who are usually very busy, like me. You can go to meetings without makeup!!"

(See Raw Data File 2_Phase FIVE.doc, p.22 – Dialogue 7 -01:14)

<S07> *"Because she had a better looking, and had many gestures".*

(See Raw Data File 2_Phase FIVE.doc, p.26 – Dialogue 4 -00:51)

"No. I would be happier if I could make mine, if not, at least, I could change the appearance of the avatar, such as its hair color, clothing, accessories and so on".

(See Raw Data File 2_Phase FIVE.doc, p.26 – Dialogue 6 -01:30)

This result contradicts the findings of recent research (e.g. Brizendine, 2006; Abraham, 2007) of no gender differences in cyberspace. The students' awareness of their gender distinctions and identities can influence their learning experiences in cyberspace in many ways, for example how they identify themselves in an online community and the gender roles they adopt in collaborative exercises. This result suggests the need for a further exploration of artificial gender distinctions in virtual communities.

6.3 Assessing participants' creative performances by the criterion-referenced assessment rubric

In view of assessing participants' creative performances in virtual reality, as we discussed in the Chapter 3.4, it is difficult to measure their creativity by various measuring tools, except the Criterion-referenced Assessment Rubric (CRAR) which has been employed continuously in assessing design students' creative learning outcomes and performances in the School of Design (SD). Therefore, the CARA was employed in this research so as to provide evidence for me to understand the participants' strength and weakness in handling design thinking skills in the research. However, the CRAR report of participants in this research is not comprehensive and accurate for the following TWO reasons: (1) the creativity training in Phase FOUR was only a part of the comprehensive design thinking module. According to my designed pilot lesson plan for creative thinking in Chapter 3.3.2, there were FOUR stages for a comprehensive design thinking module namely preparation, incubation, evaluation and implementation. The learning activity in Phase FOUR was the stage of incubation, which focused on idea exploration and development. The other three stages were not included in this research; and (2) the assessment of design students' creative performance in SD was based on the process folio reviews by means of a lablog. In other words, the design students had to submit lablogs, containing their journeys of experimentations and self-reflections, to the subject lecturer for revision and marking. In this research, the participants only finished the online reflective reports which were posted in the designed web blog "Learning Design Thinking in Virtual Reality (LDTVR)". There was no comprehensive lablog collected after the design pilot lesson. Nonetheless, the CARA helped me to perceive participants' learning experiences in doing design thinking in virtual reality as well as their creative performances during the process.

Since this research was not a real module assessment, therefore, participants were given neither marks nor grades in the CARA report but there are some indicators of their learning performances. The indicators included FOUR main areas: (1) Experiments (Learning by doing); (2) Versatility of Thinking (Ability to solve problems by using different styles of thinking); (3) Independent Learning (Self-motivation in furthering knowledge, skills and interests); and (4) Critical Reflection (ability to evaluate own process of learning to make improvements). The FIVE levels of participants' achievements, outstanding, good, satisfactory, barely adequate and fail, will be reported with comments.

Figure 36 shows the overall CARA report of all participants (except <S01> who withdrew for personal reasons) in this design pilot lesson (For the references of participants' performances, see the file: Raw-Data File 2_Phase FIVE.doc). For the indicator 1 – Experiments (Learning by doing), all participants obtained outstanding and good performances. This means they demonstrated openness to experimenting with new approaches and challenging conventions as well as exhibiting courage to leave comfort zones and test existing boundaries, conventions and rules for unknown possibilities. For the indicator 2 - Versatility of thinking (Ability to solve problems by using different styles of thinking), all participants obtained outstanding or good performances. This means they demonstrated a high level of flexibility to generate diverse ideas by thinking analytically and laterally. Likewise in the indicator 3 - Independent learning (Self-motivation in furthering knowledge, skills and interests), all participants obtained outstanding or good performances. This means they demonstrated their abilities in furthering knowledge through analysis and interpretation of issues discussed, using information from a range of sources as well as comparing and contrasting information from various sources with their own interpretations relating to issues discussed. However, in view of the indicator 4 - Critical reflection (Ability to evaluate own process of learning to make improvements), only participant <S08> achieved the outstanding performance in this category. The other six participants attained satisfactory or barely adequate. This means they only gave a discussion of learning experience, but the account was generally descriptive without critical or alternative comments; or some attempts to discuss own learning experience, which remained descriptive and superficial.

Participant	Assessment Criterion			
	1. Experiments (Learning by doing)	2. Versatility of thinking (Ability to solve problems by using different styles of thinking)	3. Independent learning (Self-motivation in furthering knowledge, skills and interests)	4. Critical reflection (Ability to evaluate own process of learning to make improvements)
<S01>	Withdraw (Personal Reasons)			
<S02>	Demonstrated openness to experiment with new approaches and challenge conventions	A high level of flexibility to generate diverse ideas by thinking analytically and laterally	Compared and contrasted information from various sources with own interpretation relating to issues discussed	Gave a discussion of learning experience, but the account was generally descriptive without critical or alternative comments
<S03>	Demonstrated openness to experiment with new approaches and challenge conventions	Generated ideas of a diverse nature by thinking analytically and laterally	Furthering knowledge through analysis and interpretation of issues discussed, using information from a range of sources	Some attempts to discuss own learning experience, which remained descriptive and superficial
<S04>	Demonstrated openness to experiment with new approaches and challenge conventions	A high level of flexibility to generate diverse ideas by thinking analytically and laterally	Furthering knowledge through analysis and interpretation of issues discussed, using information from a range of sources	Gave a discussion of learning experience, but the account was generally descriptive without critical or alternative comments
<S05>	Exhibited courage to leave comfort zones and test existing boundaries, conventions and rules for	A high level of flexibility to generate diverse ideas by thinking analytically and laterally	Compared and contrasted information from various sources with own interpretation relating to issues discussed	Gave a discussion of learning experience, but the account was generally descriptive without critical or alternative comments

	unknown possibilities			
<S06>	Demonstrated openness to experiment with new approaches and challenge conventions	Generated ideas of a diverse nature by thinking analytically and laterally	Furthering knowledge through analysis and interpretation of issues discussed, using information from a range of sources	Some attempts to discuss own learning experience, which remained descriptive and superficial
<S07>	Demonstrated openness to experiment with new approaches and challenge conventions	A high level of flexibility to generate diverse ideas by thinking analytically and laterally	Compared and contrasted information from various sources with own interpretation relating to issues discussed	Gave a discussion of learning experience, but the account was generally descriptive without critical or alternative comments
<S08>	Exhibited courage to leave comfort zones and test existing boundaries, conventions and rules for unknown possibilities	A high level of flexibility to generate diverse ideas by thinking analytically and laterally	Furthering knowledge through analysis and interpretation of issues discussed, using information from a range of sources	Discussed own learning experience with evidence of a critical approach

Figure 36: Participants' creative performances in virtual reality

Overall speaking, the CARA report shows that the participants were good at doing experiments, handling versatility of thinking and working independently inside the virtual reality, but comparatively poor in critical reflection on their learning process. In this case, despite the accuracy of this CARA report, the participants generated a lot of possible ideas, raised many ideas without any hesitation, and took risks during the process. As a design educator (and also the observer), I was impressed by the numbers of ideas that students made within a short period of time in virtual reality. In genre (2) briefing and brainstorming, there was a total of 56 rough ideas proposed within 16 minutes in Phase FOUR (From 00:10 to 00:28). In the physical classroom, students typically take about half an hour to produce around 50 rough ideas, while in this research they showed that they are able to generate more rough ideas in virtual reality than in traditional classroom practices. Besides, participants worked independently since they conducted the whole lesson. Regarding the satisfactory case in the area of critical reflection, it was difficult for the participants to reflect critically on their own learning processes by only attending this pilot lesson plan, due to the aforesaid reasons.

Chapter SEVEN: Conclusion and Implications

To study design students' learning experience in a shared virtual reality particularly for creativity training is a very complicated area for research. As I mentioned in the first chapter, design educators cannot only focus on students' experiences in the empirical research, but also the pedagogical planning of the learnign environment, the students' expectations of learning environments and the methods being used to assess creativity. After the discussions of a range of literature on creativity training, design education and virtual reality in Chapters THREE, FOUR and FIVE, TWO main factors were identified for applying shared virtual reality to enhance design students' learning experiences: (1) hyperrealistic simulation in virtual reality; and (2) virtual communities for collaborative learning. Surprisingly, these TWO directional hypotheses were not fully supported by the findings of the empirical research reported in Chapter SIX. The findings showed that these two directional hypotheses were not the crucial factors for enhancing students' learning experience in virtual reality in this specific research. However, THREE new directional areas have been found from this research and are reported in this final chapter, they are **D1 - Creating environmental stimulation to facilitate design students' creative thinking; D2 - Developing a game-like virtual learning environment to enhance design students' learning experience; and D3 - Using avatars as role-playing simulation to develop design students' creative-friendly learning behavior.** These THREE new directional areas give some insight into the main question of this research, regarding design students' learning experiences in creativity training in a shared virtual environment. The insights are that:

(1) Design students' learning experiences were stimulated by virtual environment;

(2) They obtained a game-like virtual learning experience; and

(3) They had a creative-friendly learning experience through the role-playing simulation by using avatars.

All in all, these THREE new directional areas are the main contributions of this research to knowledge for triggering further studies in the areas of virtual creativity training and virtual learning experiences for design education.

The first half of this chapter summarizes the entire research and describes the findings of each phase. In the second part, the afore-mentioned THREE new directional areas for applying shared virtual reality to enhance design students' learning experiences have been explored and discussed. Specifically, this discussion focuses on: (1) computer-simulated vs. computer-stimulated learning environments; (2) ccollaborative learning vs. game-like learning experiences in virtual reality; and (3) using avatars as a role-playing exercise for exploratory learning. Finally, conclusions are drawn from the research and suggestions made for TWO main areas for further study, namely the Mixed Reality and Second Life.

7.1 Summary of the entire research

This research, as an entity, has attempted to deepen understanding of design students' learning experiences in undertaking design-thinking exercises in a shared virtual reality. The intention of the study was to identify the key aspects of an appropriate pedagogy for E-learning and the use of a shared virtual environment to enhance design students' learning experiences in design thinking. Numerous related areas have been explored to support the research, as well as to contribute knowledge to these areas for further studies. In Chapter ONE, I have explained the structure of the existing subject SD2000 that was the focus of this study, and its relationship to tertiary design education in Hong Kong. Here, I have argued that E-learning and computer-aided pedagogy could be possible solutions to address the explored problems. This chapter also discusses the essential role of environmental factors in releasing design students' creative potentials. This discussion urged the development of a creative-friendly space for students, particularly to foster social-cultural stimulation and build a heuristic learning atmosphere. It is suggested that the shared virtual reality is one possible way to establish this creativity-friendly learning environment for creative thinking. In addition, it is proposed that it is equally important for design students to have creativity-friendly learning attitudes in order to release their creative potential. The assumption is made that the advantages of virtual reality, such as the flexibility, anonymity and impact of a hyperrealistic environment, can facilitate students' creative thinking processes in such a way as to enrich their learning experiences and eventually release their creative potentials. Therefore, it is suggested that a carefully designed pilot lesson plan and a shared virtual reality could be used to examine my hypotheses in these areas.

Based on the discussions of the background of my study, I designed an entire research plan which is presented in Chapter TWO. This research plan was divided into FIVE phases. Phase ONE included the pilot quantitative research (Part 1) and photo ethnographic research (Part 2). These pilot investigations were used to find out the students' expectations of a creativity-friendly learning environment for design thinking. Three computer-simulated creative environments were created in a shared virtual reality in the later phases. The establishment of these environments was based on the findings of the Phase ONE. Phase TWO involved the development of an appropriate lesson plan for research. Phase THREE was the establishment of a shared virtual environment for implementing the design lesson plan. Phase FOUR was an interaction study of students' learning experiences in virtual reality. Phase FIVE was the completion of self-reflective journals and post-lesson interviews in order to collect students' feedback and reflections regarding their learning experiences. THREE methods of data analysis were employed, namely: (1) Conversation Analysis (Psathas, 1995); (2) Textual Analysis (Adolphs, 2006; Hughes, 2007); and (3) Interaction Analysis (Norris, 2002; 2004). The methods of Conversation Analysis and Textual Analysis were used to analyze the conversations among participants in Phase FOUR and the dialogues between interviewer and interviewee in Phase FIVE respectively. The method of Interaction Analysis was applied to study the participants' multimodal interactions by examining avatars' interactions and communications in Phase FOUR.

Overall, the discussions in Chapters ONE and TWO have led to a comprehensive understanding of design students' learning situations, both intrinsic and extrinsic. The findings have also provided some compelling reasons for employing shared virtual reality to help design students to tackle their intrinsic problems (learning attitudes and learning behavior) and extrinsic problems (the limited space).

In Chapter THREE, I have discussed the literature reviews which focus on design thinking and creativity. I have discussed the nature, definition and characteristics of creativity. It is important to discuss the above knowledge areas because these are the main factors of students' learning processes in design education. Students are not playing a *game* inside the virtual reality but undertaking an entire learning process of creativity training. After the discussions, I discovered that the creativity and creative performance of design students can be enhanced by undertaking a systematic and deliberate creative thinking process. Similarly, students' learning experiences could be enhanced by such an arrangement. The second part of this chapter reviewed the connection between design education and creativity training. It is essential to provide a theoretical background about the differences between professional design thinking skills in design education and other formal creativity training for all disciplines. I found that creative thinking plays a crucial role in design education. Teaching *design thinking* is indeed educating design students to manage creative thinking and design planning. Design thinking is a hybrid process which involves *free* creative exploration and *scientific* planning procedures. The final part of this chapter discussed the measurement of creative learning outcomes and performances. I suggested that it would be appropriate to assess design students' creative outcomes and performances during the design thinking process. Thus, a Criterion-referenced Assessment Rubric was selected to assess their performances in their design thinking subject as well as to measure their creative achievements in the virtual reality environment.

Chapter FOUR discussed and explored the relationships, opportunities and implementations between virtual technologies and design education by reviewing the various virtual technologies as well as research and practices in applying such technologies in education. I found that it is possible to use a hypermedia platform to facilitate design students' problem-solving processes and to help them to identify wicked problems by mapping problem attributes. Based on the various discussions of virtual reality and multi-user domains, I believe the use of virtual reality in education can possibly provide students with a unique learning experience. Thus, the virtual technologies seem to be valuable in enhancing design students' learning experiences, particularly in the use of interactivity and simulations to enhance collaborative learning.

Chapter FIVE discussed a range of literature on virtual learning experiences, including the exploration of hyperrealistic simulation in virtual environments for educational purposes, the development of immersive virtual environment for students, and a discussion of how to construct a virtual learning community to enhance learning experiences. TWO directional hypotheses (**H 1 – Establishing a computer-simulated learning environment is a factor for developing students' design thinking skills;** and **H2 – Constructing a virtual community for hyperlearning is important in establishing collaborative learning among design students engaged in design thinking**) were formulated, based on various literature reviews and discussions. The second half of this chapter explained the details of establishing a virtual environment for enhancing design students' learning experiences in an educational virtual platform *ActiveWorld*© (AWs), and the educational web blog for this entire research study.

Chapter SIX reported and analyzed the findings of interaction research and the post-lesson online interviews. In Phases FOUR and FIVE, EIGHT participants were asked to attend the designed pilot lesson of the selected design thinking subject (SD2000) in a shared virtual reality. They were also asked to participate in a series of semi-structured post-lesson online interviews after the pilot lesson. The TWO hypotheses of my research were addressed in this chapter. As mentioned above, it was surprising that these two directional hypotheses were not fully supported by my study. However, the findings contributed some core issues relating to the use of virtual reality for design-thinking exercises, and some implications have been explored.

To maximize the validity of the research findings, attention was paid to the various digital records of participants' learning experiences in the shared virtual reality and verification of the transcript by online interviews. Nevertheless, inevitably, research of this nature has some limitations. Since the research focused on a small number of core participants in tertiary design education in Hong Kong, the results cannot be considered as a generalization of the area of study. The researcher acknowledges that the participants have different cultural and ideological backgrounds as well as psychological reactions to the shared virtual reality and online platforms, thus making it difficult to form any generalizations regarding their opinions and biases about operating virtual platforms.

The results of this kind of research may be influenced by the lecturer-student relationship between researcher and participants. This relationship might have affected the participants' responses to questions and performances in the research in

Phase FOUR and Phase FIVE. I was aware of these distortions and studied the observations and participants' responses carefully. All transcripts and notes have been kept by me to further support the analysis and/or to serve as triangulation of certain pieces of information if necessary. Another potential inconsistency is that SD 2000 is delivered on a collaborative basis which involves another three faculty members. This might have had some effect on the content of the module and on perceptions of the relevant theories and concepts which may have influenced how the participants expressed their opinions and ideas. To minimize any influence of discrepancies in teaching and learning strategies of different faculty members in SD 2000, a unique teaching plan was designed in Phase TWO and adopted in the research of Phase FOUR.

7.2 Design students' learning experiences in shared virtual reality

The main focus of this research was to study design students' learning experience in a shared virtual reality. Some researchers (e.g. Brown, Collins and Daguid, 1989; Lave and Wenger, 1991) believe a computer-simulated environment in virtual reality creates a meaningful and effective learning experience for students, because they are given opportunities to learn in a situated context with real world conditions. These practices allow participants to learn knowledge and skills in effective, safe and cheaper ways. Others (e.g. Jiang and Potter, 1994; Kelly, 1997) believe virtual reality and computer-simulated environment can scaffold students' learning by individualizing the learning activities. The prior research (e.g. Beck, 1979; Pollard, 1990; Pantelidis, 1993; Mantovani, 2001; Dirckinck-Holmfeld, 2002; Blascovich and Bailenson, 2006) has focused mainly on TWO domains, (1) hyperrealistic simulation in virtual reality and (2) virtual communities for collaborative and constructive learning. In addition, the majority of research on the use of simulation has been in the areas of mathematics and science. Very little research has studied abstract thinking (e.g. Berlin and White, 1986) and creativity (e.g. Michael, 2001). Here I would like to analyze my findings critically to depict the main factors that contribute to enhancing students' learning experience for design thinking in shared virtual reality.

7.2.1 Computer-simulated vs. computer-stimulated learning environment

It appears that one of the powerful features of virtual reality is the creation of a highly photorealistic environment which can possibly provide real-world simulation for enhancing students' learning experiences. Morton Heilig presented a multi-sensorial simulator called 'Sensorama' in 1962. This prototype simulated a real-world experience of motorcycling through New York City. This simulator produced fan-generated wind, smell and noise of the city. It was the first virtual reality system in modern human history. Initially, the development of the Distributed Interactive Simulation (DIS) in the virtual world was mainly for military purposes. The Government of the United States has been using the highly immersive simulators to teach soldiers to operate military helicopters, flights and tanks since the 1970s. Because of the highly photorealistic presentation of DIS, it can help soldiers to become immersed in the three-dimensional spaces easily. This system has been used in projects like the training of ship handling skills (Lochlan, 1997), soldier training (Goldberg and Knerr, 1997), and flight training (Hue, Delannoy and Berland, 1997). As the virtual reality technologies become more popular and cheaper, the use of virtual simulation for educational purposes has shifted from the kinds of programmes used in traditional vehicle or military training programmes to providing more structural tasks in virtual environments (Standsfield, Shawver and Sobel, 1998), for example, the VR-based training of shipboard firefighting developed by Tate and his colleagues (Tate, Silbert and King, 1997) and Johnson's (Johnson, et al, 1998) VR system for training equipment operation. Many researchers (e.g. Beck, 1979; Pollard, 1990; Reed and Liu, 1994; DeNardo and Pyzdrowski, 1994) have underlined the advantages of using computer-assisted instruction as a part of students' learning experiences. In particular, Winn (1995) reported that the use of virtual reality has created better student learning experiences. Other notable research projects are the Narrative-based, Immersive, Collaborative Environments (NICE) project, which was launched as the first immersive, multiuser learning environment for teaching the relationships between plant growth, sunlight and water (Roussos, et al, 1999); and the Project Atlanta Virtual Zoo which was designed to teach university students about habitat design. This system emphasized fostering students' understanding of the abstract concepts of designing habitat environments and decision-making skills (Mantovani, 2001). The computer-simulated learning environment became the most prevailing focus for applying immersive virtual technologies in education. For example, an immersive educational environment for teaching and learning Japanese languages, called "Zengo Sayu", was developed by researchers at the Human Interface Technology Laboratory of the University of Washington (Rose and Billinghurst, 1995). Other examples are TerraQuest's Virtual Galapagos (http://www.terraquest.com/galapagos), used to teach the ecology, history and geology of the Galapagos Islands, and the Virtual Reality Skeleton Project for teaching and learning the anatomy of the human skull (http://www.lib.uiowa.edu/commons/skullvr/background.html). In university education, researchers at George Mason University and the University of Houston developed TWO virtual reality systems named "NewtonWorld" and "MaxwellWorld" to teach abstract physics concepts (Dede and Salzman and Loftin, 1996). However, the question arises as to whether these research projects are really using computer simulation to enhance learners' learning experiences and effectiveness. Is it the core concern of computer simulation use in education to just use a hypperealistic environment to simulate a real-world situation? Lotens and Riemersma (1997) defined that the difference between conventional technology in education and virtual environment technology in education as the level of interaction. Simulation takes many forms, from computer renderings of 3-D objects and environments to computer-simulated virtual realities with high levels of interactivity (Strangman and Hall, 2003). Simulation is a method of presenting reality with all of its physical and social system interactions, indeed it is a model of a system (e.g. Pearce, 1997; Horn, 1997). This idea is also supported by Sastry and Boyd (Sastry and Boyd, 1998), who stated that the level of *interactivity* that users experience within a simulated environment is more important than the richness and faithfulness of available images to create a feeling of presence. Kaser (1996) conducted a study of students' attitudes towards the use of computer-assisted simulation as a part of the learning experience. Their results showed no significant differences based on instructional strategy. Therefore, it is not enough to merely provide a hyperrealistic environment in order to create a computer simulation. Interactivity and communication among participants are the key factors of a simulated learning environment. Therefore, in this research I have paid particular attention to the interactivity and the participants' ways of communication.

In the interaction research in Phase FOUR, I classified all students' learning processes into FIVE different genres: (1) social gathering; (2) briefing and brainstorming; (3) critique of the explored ideas; (4) evaluation of the working process; and (5) scoring ideas and discussion. During this 1 hour and 14 minutes (74 minutes), there were 6.1 of the 8 participants engaged in discussion per unit. This was 15.3 per unit, which was equal to a total number of 565 dialogues for 74 minutes. Considering that the virtual communication was conducted in textual format, this suggests a higher rate of information exchange during the learning process, since the participants had to type texts and wait for responses one-by-one, which is very different from the quick verbal conversations of the real world. The data indicate that the participants spent most of their time on briefing, brainstorming and scoring their ideas. Participants used 83.8% of their time on the creative task. Only 16.2% of the total duration was spent in social interactions. In general, this circumstance can be interpreted as a sound working process throughout the entire learning process. In this case, the entire working process was effective and well structured without the teacher's supervision. The participants demonstrated a high quality of organizational skills during the process. However, they tended to use textual-based dialogues as the core means of communication. They particularly liked to use dialogue to present their ideas and opinions instead of using default emotion displays in the system namely hand wave and dance. Comparisons of the usage of textual-based communication and default emotion displays indicated that the students mainly used textual-based communication when discussing some ideas seriously. Only a few emotional gestures were employed to express their opinions and feelings (See Chapter 6.2 – the multimodal interaction analysis of genres and the student's voices in post-lesson online interviews).This implies that the shared virtual reality failed to provide an immersive virtual and computer-simulated environment since the participants were still using a "chatroom-like" communication method. It must be noted, however, that they did use more default emotional displays in the later stage of the research, because they were more familiar with the ways of expressing their feelings and comments by using the avatar's gestures. However, their ways of using the avatar's gestures (emotional displays) were not often related to the subject of conversation. This implies that they were exploring the ways of using avatars, or just felt interested to use them, instead of actually using these emotional displays for expression and communication, according to the principle that an immersive virtual environment needs to make participants perceive themselves as exciting within it (Blascovich and Bailenson, 2006). In this case, the selected avatars and default emotion displays failed to work as participants' virtual presentations in a computer-simulated environment since these functions were far not enough to replace real world communication. According to the participants' self-reflective journals completed in

Phase FIVE (See Chapter 6.2), they complained about the communication system in the shared virtual reality; they found problems in communication with the default chat room system as well as with managing meaningful gestures by using avatars. Unlike when using the chat room system in MSN, the participants had difficulties with AWs, particularly in handling different forms of communication at once. In the post-lesson online interviews, they pointed out some system problems with the textual-based chat room. They experienced difficulties in communicating with more than 3 people at the same time by using typing. Unlike the MSN chat room, which was one of their favorite and most familiar chat systems, the input texts in AWs will not change colour, hence it is difficult to identify who is speaking.

Additionally, I observed an interesting learning experience that occurred while the participants were discussing ideas in the virtual reality. They tried to form a physical circle for any kind of discussion with a *social distance* (Hall, 1966; Norris, 2002; 2004). It means that those avatars were trying to simulate the real world situation that keeping certain physical distance among them. Actually, it is not necessary for participants to form a physical circle in virtual reality for discussion. It is indeed useless for textual-based communication. In addition, no two avatars situated within an intimate or personal distance throughout the entire process. Based on this situation, I assume that the participants tried to imitate the actual situation of discussing in the real world as well as protecting themselves by creating a certain distance from the others. The participants treated the computer-simulated environment as a real world. However, this finding is insufficient to support the study of interpersonal distance between avatars in virtual reality. Further investigations are needed (Yee, Bailenson, Urbanek, Chang and Merget, 2007). A similar case of imitation can also be found in

Genre 4, when the participants were evaluating their working progress. They actually went to and looked at the provided notice boards, seeking information, instead of using the web browser for the same purpose. This implies that, to a large degree, the participants perceived themselves to be partially inside the simulated environment. When this attitude is compared with the textual-based communication, it is reasonable to assume that the shared virtual reality creates a sense of immersion that can enhance students' learning experiences through the application of hypperealistic simulation, high levels of interactivity and multimodal communication channels in this learning environment. Immersion is indeed an intense feeling of self-location within the computer-simulated reality (Cronin, 1997).

Laurel (1993) cautioned that it is not enough to create only *inactive fantasy machinery*; since the virtual reality environment has the potential to offer a platform for exercising individuals' imagination, judgment and even spirit. Rheingold (1992) agreed that virtual reality is able to stimulate individuals to rethink and redefine the underlying concepts of identity, community and reality. Rheingold also claimed that an appropriate employment of virtual reality can trigger individuals' understandings of the past as well as predicting the future. Krueger (1991) highlighted the importance of the behavioral, psychological and social aspects of virtual reality at a time when everyone was focusing only on the technological development. Krueger (1977) described the concept that the *response is the medium,* referring to the unfamiliar sense of reality in cyberspace. In other words, virtual reality provides hyperrealistic stimulation, instead of simulation, to individuals by removing their habitual thinking and creating a new perceptual mental model in their minds (Rheingold, 1992). Currently, there is a sizeable research body of research studying the effectiveness of virtual learning environments as well as computer simulations in diverse educational practices (Strangman and Hall, 2003). The use of virtual reality extends to impossible physical reality, for instance, traveling around Mars and visiting a castle in the Middle Ages like a time machine (Mantovani, 2001), Similarly, the use of virtual reality broadens the scope from teaching simple tasks to complex skills, for example, abstract reasoning (Salzman, et al, 1999). However, the use of advanced technology does not improve education automatically (Osberg, 1992; Mantovani, 2001), educators need to explore appropriate and innovative ways to make technology useful. Osberg (1992) suggested that educators should pay more attention to the needs of learners instead of the technology. His idea was to use technology to empower the learner through some interesting learning environments, teaching materials, and processes. Likewise, Rodriguez (2001) suggested to educators to study the learning process in virtual reality He expressed the belief that the more senses that are involved in a learning process, the better will be the learning experiences. While Jung (2002), basing on his research on students' experience in learning language in virtual reality, cautioned that virtual reality cannot replace the experiences of the real world because it is unable to reproduce the culture and feelings that the students experience in social world, he claimed that what it can do it to create experiences that help students understand places, people, language and processes in a better way.

In this research, the participants were excited about doing the creative exercise in virtual reality, therefore they performed many default gestures without any reasons. They only felt interesting to perform those defaulted emotion displays. Second, it was evident that the participants were curious and explorative in the virtual reality environment; they tried to explore any new function inside the system. I was impressed by one of their explorations, which was flying in the virtual reality. The *flying* function is not provided by the system as a default function. It is actually a system error inside this virtual platform. The participants made use of this error and played with this function during the process. This unusual situation created an environmental stimulation to students, and they felt free and relax by flying over the virtual space (See Chapter 6.2). In another example, the participants spent time figuring out what a virtual lemon is in virtual reality. They found this to be a pitfall of the designed creative task, which asked them to deal with a lemon juicer in the virtual world. Additionally, students enjoyed the open area in the shared virtual reality. In Phase Four, the total time was 74 minutes. The students spent 58 minutes in the Open Café (virtual open area) for discussion; this means that they only spent 16 minutes in those inside areas. This implies that students prefer the open areas in virtual space. However, the open areas in AWs provide an illusion of open space. There are no differences technically between inside and outside areas in computer programming. It is only a computer simulated open area. The students were enjoying this virtual open area during the process due to the aforementioned environmental problems in Hong Kong (See Chapter 2.3). The limited working and living space of Hong Kong design students made them eager for an open area for learning, even though this was an illusion. Nonetheless, this virtual open area stimulated the design students in doing their creative exercises.

Nonetheless, based on this evidence, I concluded in Chapter ONE that the participants' learning experience in the virtual reality was explorative and fun. These two learning attitudes are very important to develop design students' creativity-friendly learning attitude. Moreover, the participants' self-reflective journals revealed that they enjoyed their learning experiences in the shared virtual reality, and the platform helped them to relax and feel free to suggest, explore and evaluate ideas. The platform also released their creative potential by encouraging them to diverge from their habitual thinking. For instance, they suggested using common software WinZip to squeeze the lemon since the lemon was a virtual object in virtual reality (See Chapter 6.2). Similar responses were collected in the post-lesson online interviews, in which all participants agreed that the use of avatars facilitated their creative thinking through hiding their real identities, allowing them to avoid being criticized by others, and creating an atmosphere of relaxation and fun. This sense of anonymity helped the participants to be free and active in the group's discussion. Moreover, in the report of the post-lesson online interviews, almost all participants agreed that the hyperrealistic environment in the selected virtual reality gave them an exciting learning experience, and that the support from the Internet during the process was useful in facilitating their problem identification and creative thinking processes. Likewise, considering the lack of working and living space of Hong Kong's design students discussed in Chapter 2.3, the open area in AWs created a good impression for them, not only in providing a huge spatial impact, but also by offering an unlimited space for them to play with, like flying.

In conclusion, according to my findings, I contend that the advantage of using a shared virtual reality in teaching and learning design thinking skills is not about creating computer simulations for students to tackle real-world situations, but creating unusual environmental stimulation to motivate them to explore new ideas. Furthermore, the hyperrealistic and game-like environments could help design students to develop creativity-friendly learning behavior in design thinking, because these environments make the learning process fun, instead of providing simulated real-world situations for creative thinking. Indeed, students do not need real-world simulation to develop design thinking since there is no situation that can be simulated in the design profession. Therefore, design educators should concentrate on creating virtual stimulations in the learning environment instead of creating real-world simulation. Based on the above analysis and discussion, the first new directional area is introduced, it is **D1 - Creating environmental stimulation to facilitate design students' creative thinking.** In fact, Chapter 1.2 discussed the essential role of the environmental stimulation in creativity training. Particularly how the environment serves as a stimulus and information provider for design study, and the function of a heuristic shared space for design thinking.

7.2.2 Collaborative learning vs. game-like learning experiences in virtual reality

It has been mentioned earlier that one of the most important factors in enhancing students' learning experience is to construct a virtual learning community in a shared virtual environment. Actually, Lewis (1993), who coined the term "*Hyperlearning*", distinguished the uniqueness of the learning experience in hypermedia which differs from other educational approaches. Lewis expounded that the characteristics of hyperlearning are concerned not only with the tremendous speed and scope of virtual environments, but also the connections of knowledge, experience, media, human and non-human brains. These interwoven connections are unpredictable and have never occurred before in human history. However, the *virtual space* is not merely a digitalization of teaching materials and visualization of the virtual classroom, but involves establishing a proactive and collaborative learning space for knowledge building. The virtual learning space is indeed a learning community with various learning activities. To design a virtual community is to provide a sense of embodiment, a sense of being in some place instead of only making something happen on the screen (Doyle and Hayes-Roth, 1997). Certainly, simply having many groups of people interacting within a virtual environment does not necessarily mean that it is an online community (Herring, 2004). An online learning community is a kind of networked learning which involves social construction of knowledge and collaborative learning process (Afonso, 2006). Howard Rheingold (1993) coined the term "*Virtual Community*", which describes a community of like-minded people that group together with similar interests, backgrounds or attitudes in order to share their views, exchange information as well as building relationships (Gauntlett, 2000). However, subsequent researchers (e.g. Garrison and Anderson, 2003; Kreijns and Kirschner, 2004; Stahl, 2006; Kanuka, Rourke and LaFlamme, 2007; McKerlich and Anderson, 2007) have been working on assessing students' learning experiences in virtual communities. However, no significant findings or assessment tools had been found to date.

Designing an effective learning community needs strong communication channels among students. This means including more than just text-based chat or simple emotional displays. These default communication functions in existing immersive virtual platforms are insufficient to replace face-to-face communication, especially when it comes to discussing abstract concepts and idea exploration. Furthermore, because of the inadequacy of communication support, group size also becomes a great problem in the actual implementation.

Another communication problem that arose, during the process, was that some avatars were idle. This might have been because the students were working on research, or simply that they were leaving the conversation for personal reasons. This is the problem with communication. Nonetheless, when looking at autonomy and independency in the learning process, it was observed that the participants performed an effective and organized lesson without the teacher's supervision. No obvious leader emerged in any of the discussion. The participants showed mutual respect in the way they expressed themselves. This implies that the shared virtual reality was able to help them, to a certain degree, to form a virtual learning community with mutual respect. In the design domain, designers are facing challenges to be more creative and to create more sustainable solutions nowadays (Giaccardi and Fisher, 2008), therefore current researchers (e.g. Fischer, 2006; Fischer and Giaccardi, 2007; Giaccardi and Fisher, 2008) have urged for a new form of collaboration. The embodiment of the mutual interactions is essential in the socio-technical environment (Fischer and Giaccardi, 2006; Giaccardi, 2006a; 2006b; 2007). In this case, the shared virtual reality could possibly facilitate new kinds of collaboration in the design domain.

Furthermore, creativity is indeed correlated highly with autonomy and openness to experience (Kelly, 2005; 2006). A creative environment can facilitate students' creative thinking if it allows them a fuller, less stereotyped but also collaborative and non-hierarchical system (Eisler, 2007). Likewise, an autonomous learning approach (e.g. Shore and Irving, 2005) can enhance students' problem-solving competencies. Moreover, social networks within a learning environment contain crucial knowledge and information that can facilitate individual creativity (Kijkuit and van den Ende, 2007; Leenders, van Engelen and Kratzer, 2007). This social capital has a strong influence on collaborative and organizational learning (Allwood and Hedelin, 2005; Evans, Cook and Griffiths, 2008). However, it is never easy to measure the effectiveness of a learning space since it contains diverse variables, namely learning techniques and the method of delivery (Jankowska and Atlay, 2008). Nonetheless, a shared virtual reality is able to facilitate design students' creative thinking by providing an autonomous space and a social network for them to experience. This learning experience can motivate students to explore, experience and discover (Jankowska and Atlay, 2008). However, according to my findings, design educators have to address the communication problems in the shared virtual environment in order to construct a collaborative working environment in a shared virtual reality. The virtual environment is supporting mass collaborations and social production positively for creativity development (Tapscott and Williams, 2006), but the evaluation of this system is needed (Fischer, 2005).

Despite this suggestion of a virtual learning community, however, one of the interesting findings in my research is that the participants regarded themselves as playing a game with group members during the process instead of seeing themselves as a learning community. The underlying principles of a *game* include some elements like rules, goals, outcomes, feedback, interaction, challenge, and competition and, of course, fun (Pensky, 2001; 2006). Applying these principles to design learning activity means that an educational game-like activity needs to have learning objectives, rules, goals and outcomes (teacher and learners expect educational outcomes; learners collect feedback from teacher and peer groups), strong interaction between teacher-student and student-student, students competing with others in academic achievement, and challenge to the participants. Thus, *learning* is a game if it has a fun element. In addition, fun is a fundamental element for enhancing students' motivation in learning. Game-based learning is not just sugaring the pill of boring or difficult learning, it is about enhancing learners' motivations by means of the selected learning activities. In this research, the participants experienced a game-like learning experience through the role-playing (use of avatars) and computer-stimulated environment. In the post-lesson online interviews conducted in Phase FIVE, the participants stated that this game-like learning experience not only helping them to remove obstacles to creativity, but also created stimulated them through role-playing other characters. They were motivated and shifted their paradigms by changing their identities.

Current researchers (e.g. Steinkuehler, 2004; Thorsen, 2006; Van, 2007; Johnson and Levine, 2008) have shown that a game-like virtual environment could benefit students and provide scaffolding for learning activities. For instance, Johnson and Levine (2008) used Maslow's Hierarchy of Needs (Maslow, 1943) to highlight the importance of reward when applying virtual reality in education. They explained that students can receive many simple rewards during the cycle of learning in this game-like virtual learning space. Thorsen (2006) pointed out that educational simulations must involve *"interesting, realistic characters, and they must compress time by displaying as much information as possible in each snippet of dialogue and in each graphic"* (Thorsen, 2006, p. 261). According to Thorsen, it is not necessary for a computer-simulated game to be relevant to the real world as it is for educational simulations. In other words, creating a game-like learning environment in a shared virtual reality is not necessarily based on simulated real world situations. However, the deliberate arrangement of virtual simulation in shared virtual reality is one of the key factors to enhance students' learning experiences. As Aarseth (2001) underlined the advantage of using game-like simulations in virtual space, he stated, "*Games, are not static labyrinths like hypertexts or literary fictions. The simulation aspect is crucial: it is a radically different alternative to narratives as a cognitive and communicative structure...they can't be read as texts or listened to as music. They must be played*" (p.2). In conclusion, a game-like virtual learning environment is able to enhance design students' learning experiences by allowing them to *play* in the environment. It is indeed a playful learning experience, and these playful learning experiences can motivate students' learning (Squire, 2005). Based on the above analysis and discussion, the second new directional area is introduced, it is **D2 - Developing a game-like virtual learning environment to enhance design students' learning experience.**

7.2.3 Using avatars as a role-playing simulation for discovery learning

On the Internet and other virtual learning platforms there are huge numbers of informative websites and learning resources which allow students to browse, download and read without time and space limitations. It is easy for students to explore and learn from those resources. These virtual platforms seem to provide a useful learning environment for discovery learning. However, researchers (e.g. Hammond, McKendree, Reader, Trapp and Scott, 1995; Özdemir and Alpaslan, 2002; de Frietas, 2006; Johnson and Levine, 2008) have criticized virtual courses for mostly being little more than electronic multimedia textbooks. Students can become confused with a mess of links in these online learning materials. Discovery learning in virtual space is indeed more complex than simply providing a huge space or unlimited information resources for students to explore and experience in any form. Nevertheless, the Internet and various virtual environments do have potential for developing discovery learning. One of the main advantages of using virtual reality and hypermedia approaches in education is that students can be given the chance to explore and integrate information and learning materials via a rich, nonlinear and multimedia database which contains full texts, audio and video information (Ambron, 1986). Similarly, as mentioned earlier, Lewis (1992) pointed out that the use of virtual reality in education can facilitate discovery learning. He stated *"Discovery learning is highly efficacious: Information is learned 'more deeply" and remembered longer if discovery is involved"* (Lewis, 1992; p.18). Mantovani (2001) pointed out that if students are given sufficient freedom to move and engage in self-directed learning activities, they can assimilate knowledge effectively.

Student motivation is always the key focus in designing student-centred learning activities as well as a main factor for creating active participation during a learning process. In other words, developing students' motivation is always an important start to facilitating discovery learning. Some researchers (e.g. Bulter, 2000; Mantovani, 2001) pointed out that it is possible in a virtual environment to foster students as active participants within the learning context. In addition, Liu et al (2002) highlighted that interactivity within a virtual environment could possibly motivate students' learning and enrich their learning experiences by some well-structured instructional resources. Similarly, Mantovani (2001) stated that interacting with a virtual model is more motivating and interesting than interacting with the real thing because these actions create a game-like learning experience. However, Volery and Lord (2000) pointed out that students often feel isolated in a distributed learning environment due to the limitations of student-instructor and peer interactions. In my research in Phase FOUR, therefore, the *shared* virtual reality became one of the solutions allowing various interactions among the instructor, students and network systems in the form of avatars. According to the findings presented in Chapter SIX, the students demonstrated active participation in all genres (See figure 26). It is important to know that the entire virtual lesson in Phase FOUR was conducted by participants without any teacher's supervision. The results showed that students displayed high-quality organizational skills and were highly active during the learning process. The students agreed that the game-like learning environment enhanced their motivation during the learning process.

Gredler (1992) listed an outline of a role-playing simulation in a learning context, based on the work of Jones (1984; 1987), which focuses on how the simulation replicates reality. He defined five major characteristics of simulation: (1) simulations are a form of problem-based learning. Players are required to complete a particular task, crisis or problem. Depending on the nature of the simulation, the default problem can be either implicit or explicit; (2) stimulations require players to determine "cut-and-dried" answers quickly; (3) players have a strong sense of their own roles and functions; (4) the outcomes in a simulation come from the players' decisions and actions instead of chance or luck; (5) players experience reality of function by fulfilling their default roles conscientiously and executing all the responsibilities associated with their roles. If they have only a brief understanding of the above characteristics of role-playing simulation, readers can easily mix up the notions of games and simulations. According to Gredler's (1992) taxonomy, a game is not a replication of real life but a complete new environment with its own set of rules. Therefore, the learning activity for role-playing simulation has a relatively complex learning function, since it allows the participants to acquire knowledge in more complex and ambiguous situations. Similarly, Thorsen (2006) stated that the role-playing simulation is different from other types of simulations, since it requires participants to inspect the results closely, set parameters and observe any consequences. For example, when playing a role-play virtual game such as SimCity, the participant has to make decisions and monitor the change closer.

As early as 1995, Negroponte highlighted that the role-playing simulation in virtual reality could possibly help students to acquire and apply knowledge through this playful environment. An early study regarding role-playing simulations in virtual classrooms, which was conducted by Frye and Frager (1996), reported that students took this game-like learning process as a friendly competition or pleasure. Currently, Rebberger (2006) pointed out that role-playing simulation in virtual reality and other digital platforms is a useful and effective tool for teaching and learning some complex topics, particularly in the areas of social sciences and humanities. The Horizon Report (2007) indicated that educational approaches have been growing within virtual spaces, particularly through the use of avatars. Johnson and Levine (2008) described one of the key advantages of applying role-playing simulation to shared virtual reality, that participants are able to role-play by choosing avatars, selecting the manner of dress and appearance and having tools or objects that have symbolic meanings. Actually, students do have awareness of their avatars' appearances before interacting with others (Stoerger, 2008). Furthermore, Moseley (2001) stated that the sense of realness created by stimulations in contemporary digital technologies can facilitate teaching and learning by providing students with highly realistic decision situations to suspend reality. Indeed, some computer games, for instance SimCity, Sid Meier's Civilization, Roller Coaster Tycoon, The Sims and The Oregon Trail, allow players to play different roles in negotiating and addressing various social issues within the platform (Rebberger, 2006). According to some research on the use of avatars as personal representatives (e.g. Griffiths, Davies and Chappel, 2003; Yee, 2006a; 2006b), online users typically spend around 22 hours per week interacting and communicating through avatars, and this figure is increasing. This implies that the use of avatars for role-playing has high potential for enabling students to experience many types of innovative educational approaches.

However, no matter how advanced and sophisticated the role-playing simulations that can be provided by virtual technologies, the students' attitudes and behaviors in the role-playing simulation are crucial in determining the quality of their learning experiences. Participants must play their roles seriously as well as in a professional manner in order to create the "reality of function" (Gredler, 1992). Likewise, Alessi and Trollip (2001) stated that one of the strongest motivating factors of successful stimulation is based on the students' seriousness in role-playing their given roles within the environmental fantasy. Second, the interaction among participants in diverse circumstances needs to be highly focused (Van Ments, 1999). Real participants are extending themselves into the virtual space by using avatars (Johnson and Levine, 2008). Indeed, the avatars in shared virtual reality are a crucial vehicle for various interactions and communications among participants. As Koster (2007) stated, avatars are the representations of actual people in a digital platform, since their appearances, actions, and emotional displays can be considered to be as valid as actual human behaviors in other situations. The results of Phases FOUR and FIVE of my research showed that the participating design students chose avatars based on TWO main reasons: (1) projecting their favorite images which are different from their real identities; and (2) finding weird identities to hide their personalities. For example, participants <S02> and <S03> chose the God-father and Alien respectively because of their weird identities. Participating students took their role-playing seriously, which has been demonstrated by the high response rate and active participation in all genres throughout the entire learning process. Moreover, the participants explained that the sense of anonymity helped them to be free and active in group discussion. For instance, participant <S07> mentioned that she was more active and creative in virtual reality due to the anonymity and excitement, and participant <S08> believed that she had changed her personality a lot in the virtual reality. Thus, the use of avatars in shared virtual reality facilitated their creative thinking with respect to hiding their real identities, avoiding being criticized by others, and creating an atmosphere of relaxation and fun. This reflects evidence from the CARA report (See figure 38) that after the virtual lesson, participating students demonstrated openness to experimenting with new approaches and challenging conventions as well as exhibiting courage to leave their comfort zones and test their existing boundaries, conventions and rules for unknown possibilities. This result supported Steinkuehler's (2004) claim that virtual reality is able to provide a safe environment by minimizing embarrassment and risk of failure in group discussion.

Another crucial factor in creating effective stimulation for students is the design of the interface (Norman, 1988; Laurel, 1993; de Frietas, 2006; Johnson and Levine, 2008). The interface should match students' expectations of how to behave in the role. If educators fail to address this role expectation, then it creates greater stress and overdramatic renditions during the learning process under stimulation (Hill and Lance, 2001). Besides, students are easily distracted during the learning process (Dalgarno, 2002; Lim, Nonis and Hedberg, 2006). Moreover, the user interface, in any possible form, plays an essential role of connecting between humans and machines (Grau, 2004). The interface design needs deliberate arrangement and establishment in order to provide participant with specific virtual experience. In Phase FOUR of my research, three tailor-made virtual environments (See figure 16), namely the Area 1: Café Grand, Area 2: Café Top and Area 3: Café Open, were designed exclusively for the purpose of the creativity training. The design and establishment of these virtual environments were based on the ideas and comments from design students in the preliminary research (See Chapter 2.3). More specifically, these virtual environments are closer to the design students' expectations of an ideal creative-friendly environment which contains the aforementioned FIVE major components: (1) comfortable and tranquil; (2) playful; (3) relaxed; (4) able to maintain privacy; and (5) equipped with formal and informal references. Eventually, the Café Open gave a good impression to design students not only in providing a huge spatial impact, but also by offering an unlimited space for them to play with, like flying.

In addition, Patranek (1994; 2000) suggested that asking students to write about their learning experiences could help to conceptualizing learning process from simulations. According to the participants' self-reflective journals completed in Phase FIVE, they complained about the communication system in the shared virtual reality; they found problems in communication with the default chat room system as well as with managing meaningful gestures by using avatars. For example, participant <S06> mentioned that, because of the system limitation of the dialogue box, it was easy to post ideas but difficult to draw attention from the others; and participant <S07> became confused in communication since the avatars were not performing human responses perfectly during the process. The self-reflective journals helped students to conceptualize their learning experiences and to point out some problems critically during their learning process. These experiences helped the students to accommodate new ways of seeing the world through the role-playing simulation (Rebberger, 2006). Nonetheless, role-playing simulation in virtual reality can possibly give students an alterative form of education, particularly those who have most likely been brought up in a didactic education system (Robertson, 2000; Rebberger, 2006). Rebberger (2006) advised that students have to be equipped with specific knowledge about the topic in order to create an effective educational role-play simulation. In other words, students are able to enjoy the learning process by having sufficient preparation of background knowledge. Students are motivated by the role-playing simulation through the use of various weird avatars and identities, which helped them to relax and feel like working in a game-like environment. The role-playing simulation in shared virtual reality eventually facilitates discovery learning, which is one of the essential learning behaviors for enhancing students' creativity (See Chapter 3.1), in virtual space for design education. Design students could possibly develop their creative-friendly learning behaviors through using avatars as virtual role-playing simulation. Based on the above analysis and discussion, the second new directional area is introduced, it is

D3 - Using avatars as role-playing simulation to develop design students' creative-friendly learning behavior.

7.2.4 What are design students' learning experiences in shared virtual reality?

To conclude, the above discussions and findings provide some answers to the main research question of this thesis, about the design students' learning experiences in shared virtual reality. Based on the research findings from the multimodal interaction research in Phase FOUR, the post-lesson online interviews and the self-reflective journals in Phase FIVE, I argue that design students need a computer-stimulated learning environment in virtual reality instead of created virtual simulations to conduct creativity training exercises; they need game-like learning experiences in virtual reality instead of a collaborative learning community; and they were stimulated for discovery learning by role-playing with avatars. Thus, it can be concluded that:

(1) **The design students' learning experiences were stimulated by virtual environment;**
(2) **They obtained a game-like virtual learning experience; and**
(3) **They had a creative-friendly learning experience through the role-playing simulation by using avatars.**

The above findings about design students' learning experiences in shared virtual reality have provided new directions for further studies in the areas of virtual creativity training and virtual learning experiences for design education.

7.3 Conclusion and implications

This thesis has reported a study of the virtual learning experiences of design students in a shared virtual environment that investigated the possibility and processes of using this shared virtual environment to enhance design students' creative thinking skills. The students' learning experience while engaging in virtual reality was the major focus of the study. Chapters ONE to FIVE have discussed the existing literature in the areas of design thinking and creativity, virtual technologies and design education, and learning experiences in virtual environment. A preliminary investigation (Parts 1 and 2), which included a pilot quantitative questionnaire and a photo ethnographic study, addressed the fundamental issues of design students' learning experiences in a traditional creative thinking exercise in physical space as well as exploring possibilities for using virtual technologies to enhance their learning experiences. Some major features of building a shared virtual reality for design education were also explored in this preliminary research. As well, the pedagogical planning of the learning environment for design education, the students' expectations of creative learning environments in virtual space and the method being used to assess creativity for design students were discussed in these chapters. A pilot lesson plan, a tailor-made shared virtual environment in AWs and the students' assessment method were created according to the discussion and findings of these chapters. More significantly, TWO directional hypotheses for this thesis were introduced at this stage:

H 1 – Establishing a computer-simulated learning environment is a factor for developing students' design thinking skills.

H2 – Constructing a virtual community for hyperlearning is important in

establishing collaborative learning among design students engaged **in design thinking.**

Surprisingly, these two directional hypotheses were not fully supported in my study. According to my findings in Phases FOUR and FIVE, I contend that the advantage of using a shared virtual reality in teaching and learning design thinking skills is not about creating computer simulation for students to tackle real-world situations, but rather creating unusual environmental stimulation to motivate them to explore new ideas. This is particularly important in design education since design students are required to tackle ill-structured problems that require creativity and design thinking skills, rather than being engaged in some other professional training which can be simulated by virtual technologies. In other words, no particular situation in the design profession can be simulated, but using virtual reality and its impacts as a *stimulation* to enhance students' learning experiences during the creative problem-solving process hold promise for developing students' design thinking skills. Moreover, many researchers in education believe that using collaborative learning in virtual environments is a useful pedagogical strategy for E-Learning. According to my research findings, creating a game-like learning environment is more important than establishing a collaborative learning environment in the context of a design thinking module and other creativity training in design education. This is because the game-like virtual learning environment is able to enhance the design students' learning experiences by allowing them to *play* within it. It is this playful learning experience that facilitates their creative thinking. The nature of creative idea is indeed unexpected, original and sometime risky (Runco, 2004). Students were motivated by using this game-like environment to think differently. The use of game-like environments is, in fact, far more conducive to creative thinking exercises for design education than the use of simulation in virtual reality. Indeed, some researchers (e.g. Kalay, 2004; de Freitas, 2006; Stoerger, 2008) have stated that the differences between virtual simulations and virtual games have begun to blur. Students need a game-like environment more than a simulated environment in order to have a playful learning experience. Furthermore, there is evidence that this type of experience created by multimedia stimulation can potentially shift students' learning behaviors and values (Brown and Thomas, 2006; Wagner, 2008).

Another essential finding of this research is that using avatars in role-playing simulation can enhance students' learning experiences during their creative thinking process, which can eventually facilitate discovery learning. Students could seek, know and do through role-playing within an immersive and hyperrealistic environment (Stoerger, 2008). Discovery learning is essential in design education since designers are working with diverse explorations and inspirations. The use of avatars, which change students' identities in virtual space, also helped the students to be more relaxed about receiving criticism from others. This is particularly useful for Hong Kong design students since they are typically more self-conscious and afraid to present their rough ideas in group discussion and brainstorming exercises (See Sections 1.1.3 and 1.3.6). In addition, this research also found some fundamental communication problems among design students in the shared virtual reality. For instance the English language environment created some barriers. The students felt it was difficult to discuss some of the more abstract concepts and theoretical frameworks in English. Moreover, some avatars were idle during the learning process. This might have been because the students were working on research online, or simply that they were leaving the conversation for personal reasons. Thus, design educators have to address these communication problems in order to construct an effective learning environment in shared virtual reality.

To summarize the above THREE new directional areas, they are **(1) Creating environmental stimulation to facilitate design students' creative thinking; (2) Developing a game-like virtual learning environment to enhance design students' learning experience; and (3) Using avatars as role-playing simulation to develop design students' creative-friendly learning behavior.** These THREE new directional areas are the main contributions of this research to knowledge for triggering further studies in the areas of virtual creativity training and virtual learning experiences for design education.

After all, virtual reality cannot, or should not, replace real-world experiences, particularly in design education. As Jung (2002) stated, the best way to use virtual reality in learning is to create experiences that help students to understand the learning context better. An effective design of virtual experiences must be functional and purposeful, thus helping the participants to engage, compel, memorize and enjoy the learning process (McLellan, 2000). This is because the participants' total experience is the key for success (Seybold, 1998). Regarding this issue, experience design is emerging as one of the most important research domains for educators. In fact, experience design is not a new idea, its history can be traced back to the earliest human impulses to develop ceremonies, rituals and architecture (McLellan, 2000). It is, nevertheless, essential to learn more about this to be able to design students' virtual learning experiences optimally for any cyber campus (McLellan, 2000). According to Kolb's (1984) mode of experiential learning, the immediate or concrete learning experiences are essential for providing students with a basis for observation and reflection, particularly refining these observations and reflections into abstract concepts and cross contexts. In addition, our society is moving rapidly from a service economy to an experience one (Pine and Gilmore, 1999). Walt Disney was one of the pioneers that has emphasized the design of experiences. He believed that economic value is achieved by the customers' enjoyment and memory of the experiences (McLellan, 2000). Other example is the Danish futurist Rolf Jensen (1999), who created a model called "The Dream Society" to articulate the experience economy. He emphasized the quality of the experience that is able to provide participants with a memorable dimension. He also highlighted SIX major human needs that should be targeted: (1) adventure; (2) togetherness; (3) caring and being cared for; (4) self-definition; (5) feeling safe and secure; and (6) being able to demonstrate our convictions. In view of art and design, Laurel (1993) used theatre performance as an example to illustrate the importance of experience design in changing audiences' roles from passive observers to active participants: Jane Prophet's TechnoSphere (1994-95) focused on the interactivity of artificial life forms (Shanken, 2007). These projects provided audiences with a unique virtual experience. Moreover, a huge research study of augmented and mixed reality systems, called "Equator-Technical Innovation in Physical and Digital Life", was carried out in eight academic institutions in the United Kingdom over a six-year period (Scaife and Traversin, 2001). This project also provided participants with a virtual experience. Accordantly, an experience is supposed to engage participants from multiple perspectives, including type of participation and type of connection (Pine and Gilmore, 1999). To explain this further, the type of participation is concerned with whether the participation is active or passive; and the type of connection with the external or internal environmental relationship. Nonetheless, making the learning process a personal experience for the students is one of the essential factors underpinning the application of virtual reality in education. These areas of research undoubtedly need further exploration, particularly with the rapid development of virtual technologies, E-Learning pedagogies and virtual learning environments. Last but not least, design educators also need to rethink the time and cost spent on building virtual reality. This is sometimes more costly than re-designing traditional pedagogy in the physical classroom. For example, to build up a virtual space in AWs for educational purposes, educators need approximately US$3,650.00 (US$ 650 for package price + US 3,000 for establishment of virtual space) to set up the virtual space for only 20 student licenses. In addition there is a need for US$ 12,395 annually (US$ 395 for annual renewal + at least US 12,00 for hiring a technician to maintain the service). Under the same projection, educators have to pay a huge amount to provide the said service in all other virtual educational platforms such as SecondLife and SimCity. It becomes more expensive if educators decided to develop their own virtual platforms. Therefore, using virtual reality to enhance design students' learning experiences is not a promising way to gain expected results. Deliberate design and arrangements are needed before introducing any learning approach in shared virtual reality.

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Appendices

Appendix A: Questionnaire – Pilot research on constructing creative space for creative thinking exercises

Questionnaire – Pilot Research on Constructing Creative Space for Creative Thinking Exercises

Estimated duration: 20-30 minutes,
Researcher: Robert Lau

The objective of this research is to study how the physical and virtual spaces can carry out effective creative thinking exercises in tertiary design education. 20 behavioral and classified questions have been set to investigate the (1) students' obstacles to creative thinking; and (2) components of constructing a space for creative thinking exercises.

Your participation is encouraged that because only a small sample of design students has been randomly selected, and a high percent of returns is necessary for a successful study. Thank you for your time.

❖ **Section A: Classified Questions**

Q1	Gender	Male ❐	Female ❐	
Q2	Mode of Study	Full-time❐	Part-time ❐	Others r Please specify:
Q3	Level of Study	Sub-degree ❐	Undergraduate ❐	Post-graduate ❐
Q4	Design Disciplines	Visual Communication ❐	Advertising ❐	
		Environmental & Interior ❐	Interactive Multimedia ❐	
		Product & Industrial ❐	Fashion ❐	
		Others r Please specify:		
Q5	Years of experience in creative thinking exercises in tertiary design education?	Less than 1 year ❐	1 - 2 years ❐	
		2 - 4 years ❐	More than 4 years ❐	

❖ **Section B: Understanding of Creativity**

Q6	Which of the following items are related to creativity? (select <u>THREE</u> of them) ❐Natural behavior ❐ Systematic and deliberate thinking process ❐Newness and novelty ❐Valuable solution ❐Techniques and skills ❐Playfulness ❐Workable effort ❐Craziness ❐Exploration ❐None of the above, please specify:..
Q7	Do you consider yourself creative? Very creative ❐5 ❐4 ❐3 ❐2 ❐1 Less creative
Q8	If you were given a new toy or game to play, would you ❐Play around, improvise with the materials given by the environment ❐Devise variations after learning the correct way ❐Always go by the instructions

Q9a	What are the major obstacles to creative thinking? (select <u>THREE</u> of them) ❒Personality, for examples:……………………………………………………………………… ❒Motivation ❒Lack of training exercises ❒Physical environment ❒Culture and ideology ❒Peer groups ❒Others, please specify:…………………………………………………………………
Q9b	Can you describe your major obstacle according to your past experience? ……………………………………………………………………………………… ……………………………………………………………………………………… ……………………………………………………………………………………… ………………………………………………………………………………………
Q10a	Are you hesitate to launch your crazy/rough ideas to other participants during creative group thinking exercises? ❒Never *(go to Q11)* ❒Sometimes *(go to Q10b)* ❒Every time *(go to Q10b)*
Q10b	What is your hesitation? ……………………………………………………………………………………… ……………………………………………………………………………………… ……………………………………………………………………………………… ………………………………………………………………………………………
Q11	Do you believe creative thinking skill can be taught? And Why? ❒Yes ❒No Why and how it can/cannot be taught?…………………………………………… ……………………………………………………………………………………… ……………………………………………………………………………………… ………………………………………………………………………………………
Q12	Do you agree that a comprehensive creative training course can make you more creative? ❒Strongly agree ❒Agree ❒Depends ❒Disagree ❒Strongly disagree

❖ **Section C: Investigating Creative Space for Creative Thinking Exercises**

Q13a	When you are working with brainstorming or other creative thinking exercises, do you

	❑Prefer to work alone *(go to Q17)* ❑Prefer to work in group physically *(go to Q13b)* ❑Prefer to work in group in hyperspace, for instance, Internet, chatroom and discussion forum. *(go to Q13c)*
Q13b	How many participants each time? Why?... .... *(go to answer Q16)*
Q13c	How many participants each time? Why?... ....
Q14a	Which hypermedia channel do you prefer? ❑Synchronized platform, namely chatroom, ICQ, virtual reality and video conference ❑Asynchronized platform, namely discussion forum, newsgroup, blog and email ❑Others, please specify..
Q14b	Do you prefer to use "Avatar" instead of using your own name? ❑Yes, why? .... ❑No, why? ....
Q15	Why do you prefer to work in hypermedia space? Can you share one of your past experiences here? ....
Q16	Where do you prefer to carry out a creative thinking exercise? ❑Classroom ❑Conference or meeting room ❑Exterior areas around the University ❑Home or some private areas ❑Restaurants or other entertaining areas ❑Never mind ❑None of the above ❑Others, please specify:...
Q17	To what extent that the physical space can help you in carrying out an effective creative thinking exercise? ❑Very important ❑Important ❑Fair ❑Less important
Q18	What is the appropriate duration for each creative exercise? ❑Less than 30 minutes ❑Between 30 to 60 minutes ❑Between 1 to 2 hours ❑As much as we can

Q19	Can the physical space help you to remove your obstacles in creative thinking process? And how? ....
Q20	What is your dream space for carrying out creative thinking exercises? Please describe it in details ....

Thank you very much for your time.
Please send the completed questionnaire to
sdrobert@polyu.edu.hk

❏

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sdrobert@polyu.edu.hk
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- End of appendix A -

Consent Form (Modified based on Johnson and Christensen, 2000)

Title:	**Learning design thinking online: studying students' learning experience in virtual reality**
Principal Investigator:	Robert Lau
Department:	School of Arts and Humanities, Institute of Education, University of London
Email:	sdrobert@polyu.edu.hk

You are invited to participate in a research study investigating the learning experience in shared virtual reality for teaching and learning design thinking online. If you volunteer to participate in this research study, we will ask you to join a series of online design-thinking exercises within a virtual platform. The research will involve asking you to talk about different things, such as your learning experiences; your creative solutions, your comments on identified design problems and reporting your reflections by means of web blogs. Your response and comments will be recorded so we can study that later. The study will take between one or one-and-half hours per times, and the whole research will not more than THREE times.

You may not get any benefit from participating in this study, but the exercises and interviews we give you may help us understand the students' learning experience in shared virtual reality. If you volunteer to participate in this study, you should always remember that you may withdraw and stop participating in the study at any time you wish. You will not be penalized in any way if you withdraw and stop participating in the study. There are no risks from participating in this study other than perhaps you may get tired of doing exercises online or over the screen display.

All information that you provide to us will be kept strictly confidential. At no time will we give any information to anyone outside the research staff. The recordings of your online learning experience and responses will be erased when the research is finished. The results of this study may be presented at my PhD thesis or published in professional journals, but you name and any other identifying information will not be revealed.

If you have any questions about this study or if you have any questions regarding your rights as a research participant, you may call the School of Arts and Humanities, Institute of Education, University of London at +44 (0)20 7612 6745. You may also contact Dr. Meecham at +44 (0)20 7612 6201.

Agreement to participate in research

I have read, or have had read to me, and understand the above study and have had an opportunity to ask questions which have been answered to my satisfaction. I agree voluntarily to participate in the study as described.

Participant's name:

__________Date:______	___________Date:______	___________Date:______
Signature of Consenting Party	Signature of Investigator	Signature of Witness

-End of appendix B –

Appendix C: Consent Form – Research on design students' physical working environment

Consent Form (Modified based on Johnson and Christensen, 2000)

Title: **Phase ONE (Part 2): The photo ethnographic research on design students' physical working environment in Hong Kong**

Principal Investigator: Robert Lau (Mphil/PhD Student)

Department: School of Arts and Humanities, Institute of Education, University of London

Email: sdrobert@polyu.edu.hk

You are invited to participate in a research study investigating the design students' physical working environment in Hong Kong. If you volunteer to participate in this research study, we will ask you to take a series pictures of your working environment at home.

You may not get any benefit from participating in this study, but the pictures you took may help us understand the actual working environments of Hong Kong's design students at home. If you volunteer to participate in this study, you should always remember that you may withdraw and stop participating in the study at any time you wish. You will not be penalized in any way if you withdraw and stop participating in the study. There are no risks from participating in this study.

All information that you provide to us will be kept strictly confidential. At no time will we give any information to anyone outside the research staff. Your pictures will be erased when the research is finished. The results of this study may be presented at my PhD thesis or published in professional journals, but you name will not be revealed in any case.

If you have any questions about this study or if you have any questions regarding your rights as a research participant, you may call the School of Arts and Humanities, Institute of Education, University of London at +44 (0)20 7612 6745. You may also contact Dr. Meecham at +44 (0)20 7612 6201.

Agreement to participate in research

I have read, or have had read to me, and understand the above study and have had an opportunity to ask questions which have been answered to my satisfaction. I agree voluntarily to participate in the study as described.

Participant's name:

__________Date:______	__________Date:______	__________Date:______
Signature of Consenting Party	Signature of Investigator	Signature of Witness

-End of appendix C -

Frequencies

Notes

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	Cases Used	Statistics are based on all cases with valid data.
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Frequency Table

Q1 Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	5	27.8	27.8	27.8
	Female	13	72.2	72.2	100.0
	Total	18	100.0	100.0	

Q2 Mode of Study

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Full-time	17	94.4	94.4	94.4
	Part-time	1	5.6	5.6	100.0
	Total	18	100.0	100.0	

Q3 Level of Study

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Sub-degree	18	100.0	100.0	100.0

Q4 Design Disciplines

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Visual Communication	18	100.0	100.0	100.0

Q5 Years of experience in creative thinking exercises in tertiary design education?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 year	2	11.1	11.1	11.1
	1-2 years	16	88.9	88.9	100.0
	Total	18	100.0	100.0	

Q6a Natural behavior

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Natural behavior	2	11.1	100.0	100.0
Missing	System	16	88.9		
Total		18	100.0		

Q6b Systematic and deliberate thinking process

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Systematic and deliberate thinking process	5	27.8	100.0	100.0
Missing	System	13	72.2		
Total		18	100.0		

Q6c Newness and novelty

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Newness and novelty	7	38.9	100.0	100.0
Missing	System	11	61.1		
Total		18	100.0		

Q6d Valuable solution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Valuable solution	6	33.3	100.0	100.0
Missing	System	12	66.7		
Total		18	100.0		

Q6e Techniques and skills

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Techniques and skills	5	27.8	100.0	100.0
Missing	System	13	72.2		
Total		18	100.0		

Q6f Playfulness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Playfulness	5	27.8	100.0	100.0
Missing	System	13	72.2		
Total		18	100.0		

Q6g Workable effort

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Workable effort	2	11.1	100.0	100.0
Missing	System	16	88.9		
Total		18	100.0		

Q6h Craziness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Crazine	10	55.6	100.0	100.0
Missing	System	8	44.4		
Total		18	100.0		

Q6i Exploration

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Exploration	12	66.7	100.0	100.0
Missing	System	6	33.3		
Total		18	100.0		

Q6j None of the above

		Frequency	Percent
Missing	System	18	100.0

Q7 Do you consider yourself creative?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	2	11.1	11.1	11.1
	3	11	61.1	61.1	72.2
	4	5	27.8	27.8	100.0
	Total	18	100.0	100.0	

Q8 If you were given a new toy or game to play, would you

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Play around, improvise with the materials given by the envir	10	55.6	55.6	55.6

Devise variations after learning the correct way	7	38.9	38.9	94.4
Always go by the instructions	1	5.6	5.6	100.0
Total	18	100.0	100.0	

Q9a Personality

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Personality, for examples:	2	11.1	100.0	100.0
Missing	System	16	88.9		
Total		18	100.0		

Q9b Motivation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Motivation	10	55.6	100.0	100.0
Missing	System	8	44.4		
Total		18	100.0		

Q9c Lack of training exercises

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Lack of training exercises	9	50.0	100.0	100.0
Missing	System	9	50.0		
Total		18	100.0		

Q9d Physical environment

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Physical environment	6	33.3	100.0	100.0
Missing	System	12	66.7		
Total		18	100.0		

Q9e Culture and ideology

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Culture and ideology	10	55.6	100.0	100.0
Missing	System	8	44.4		
Total		18	100.0		

Q9f Peer group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Peer groups	6	33.3	100.0	100.0
Missing	System	12	66.7		
Total		18	100.0		

Q9g Other, please specify

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Others, please specify:	4	22.2	100.0	100.0
Missing	System	14	77.8		
Total		18	100.0		

Q10a Are you hesitate to launch your crazy/rough ideas to the participants during creative group thinking exercises?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never (go to Q11)	9	50.0	52.9	52.9
	Sometimes (go to Q10b)	6	33.3	35.3	88.2
	Every time (go to Q10b)	2	11.1	11.8	100.0
	Total	17	94.4	100.0	
Missing	System	1	5.6		
Total		18	100.0		

Q11 Do you believe creative thinking skill can be taught? And Why?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	13	72.2	86.7	86.7
	No	2	11.1	13.3	100.0
	Total	15	83.3	100.0	
Missing	System	3	16.7		
Total		18	100.0		

Q12 Do you agree that a comprehensive creative training course can be make you more creative?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly agree	3	16.7	17.6	17.6
	Agree	7	38.9	41.2	58.8
	Depends	7	38.9	41.2	100.0
	Total	17	94.4	100.0	
Missing	System	1	5.6		
Total		18	100.0		

Q13a When you are working with brainstorming or other creative thinking exercises, do you

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Prefer to work alone (go to Q17)	9	50.0	50.0	50.0
	Prefer to work in group physically (go to Q13b)	8	44.4	44.4	94.4
	Prefer to work in group in hyperspace, for instance, Interne	1	5.6	5.6	100.0
	Total	18	100.0	100.0	

Q14a Which hypermedia channel do you prefer?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Synchronized platform, namely chartroom, ICQ, virtual reality	2	11.1	40.0	40.0
	A synchronized platform, namely discussion forum, newsgroup,	1	5.6	20.0	60.0
	Missing	2	11.1	40.0	100.0
	Total	5	27.8	100.0	
Missing	System	13	72.2		
Total		18	100.0		

Q14b Do you prefer to use "Avatar" instead of using your own name?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes, why?	1	5.6	25.0	25.0
	No, why?	1	5.6	25.0	50.0
	Missing	2	11.1	50.0	100.0
	Total	4	22.2	100.0	
Missing	System	14	77.8		
Total		18	100.0		

Q16 Where do you prefer to carry out a creative thinking exercise?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Classroom	1	5.6	10.0	10.0
	Conference or meeting room	2	11.1	20.0	30.0
	Exterior areas around the University	1	5.6	10.0	40.0
	Home or some private areas	3	16.7	30.0	70.0
	Never mind	3	16.7	30.0	100.0
	Total	10	55.6	100.0	
Missing	System	8	44.4		
Total		18	100.0		

Q17 To what extent that the physical space can help you in carrying out an effective creative thinking exercise?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very important	3	16.7	16.7	16.7
	Important	13	72.2	72.2	88.9
	Fair	2	11.1	11.1	100.0
	Total	18	100.0	100.0	

Q18 What is the appropriate duration for each creative exercise?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 30 minutes	3	16.7	16.7	16.7
	Between 30 to 60 minutes	11	61.1	61.1	77.8
	As much as we can	4	22.2	22.2	100.0
	Total	18	100.0	100.0	

-End of appendix D –

PICTURE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

-End of appendix E -

Appendix F: List of the participants for the interaction research and post-lesson data collection to study students' learning experience in a shared virtual reality

Accounts of AW*	Names of Avatars	Names of Participants	Sex	Emails address and MSN accounts	Contact
Designer1		Lam Ka Ming (Ivan)	M	ivanlamkaming@gmail.com ivanlamkaming@hotmail.com	92778001
Designer2		Wong Sze Sing	M	Sing.s222@homtail.com	61560698
Designer3		Kwok Yuet Hang (Jeff)	M	Jeffrey.zeal@gmail.com Zeal_ism@hotmail.com	61889040
Designer4		Chan Kit (Tenno)	M	Tenno_chan@homtail.com	66854054
Designer5		Chak Wing Yan (Da)	F	Dada_chak1008@yahoo.com.hk	67718783
Designer6		Lau Yik Ka (Ar Ka)	F	Wise01lyk@yahoo.com.hk	95220091
Designer7		Wong Mei Yee (Carol)	F	Gal_carol@hotmail.com	61536907
Designer8		Chan Lok Man (Adrian)	F	booohemian@hotmail.com	64276268

*(*AW: ActiveWorld – An Educational Shared Virtual Reality)*

-End of appendix F -

Appendix G: Proposed Lesson Plan for SD2000 – Instruction Material to Participants in Phase Four and Phase Five

	Stage	Proposed Lesson Plan for SD 2000	Learning Activities	Proposed ICT/VR Supports
	1	Preparation	• Problem identification (Using creativity training method: Identifying and mapping attribute)	• ICT supported mapping tools (e.g. Inspiration)
			• Research and analysis	• e.g. Internet, Web images and eLibrary
Research area for the Phase FOUR andPhase FIVE	2	Incubation	• Idea development by employing various creativity training methods for creative thinking (e.g. [1] Making quantity of possibilities; [2] Changing and shifting perspectives; [3] Making association and analogical thinking; and [4] Probing emotion and subconscious)	• *ActiveWorld* © will be introduced to study the students' learning experience in the shared virtual reality. • Environmental stimulation • Creating virtual learning community
	3	Evaluation	• Idea evaluation and assessment	• Using digital communication tools, such as emails and web blogs to collect opinions and feedback from diverse channels namely teachers, schoolmates, professional designers and potential clients.
	4	Implementation	• Testing idea or solutions	• Not Applicable

-End of appendix G -

Appendix H: Assessment Criteria for SD2000 – Instruction Material to Participants in Phase Four and Phase Five

<table>
<tr><th rowspan="2">Assessment Criteria</th><th colspan="2">Outstanding / Excellent</th><th colspan="2">Very Good / Good</th><th colspan="2">Wholly Satisfactory / Satisfactory</th><th colspan="2">Barely Adequate / Weak</th><th>Fail</th></tr>
<tr><th>A+</th><th>A</th><th>B+</th><th>B</th><th>C+</th><th>C</th><th>D+</th><th>D</th><th>F</th></tr>
<tr><td>1. Experiments (Learning by doing) 25%</td><td colspan="2">Exhibited courage to leave comfort zones and test existing boundaries, conventions and rules for unknown possibilities.</td><td colspan="2">Demonstrated openness to experiment with new approaches and challenge conventions.</td><td colspan="2">Experimented with a number of different approaches, techniques & materials to solve problems but did not go beyond conventions.</td><td colspan="2">Some attempts to experiment, but the approaches, techniques & materials used are limited and lacked diversity.</td><td>No or little evidence of attempted experiment.</td></tr>
<tr><td>2. Versatility of thinking (Ability to solve problems by using different styles of thinking) 25%</td><td colspan="2">A high level of flexibility to generate diverse ideas by thinking analytically and laterally.</td><td colspan="2">Generated ideas of a diverse nature by thinking analytically and laterally.</td><td colspan="2">Generated some ideas to solve problems but most are based on a similar style of thinking.</td><td colspan="2">Only a few ideas generated with barely any diversity in style of thinking.</td><td>No or little evidence of diversity in style of thinking.</td></tr>
<tr><td>3. Independent learning (Self-motivation in furthering knowledge, skills and interests) 25%</td><td colspan="2">Furthering knowledge through analysis and interpretation of issues discussed, using information from a range of sources.</td><td colspan="2">Compared and contrasted information from various sources with own interpretation relating to issues discussed.</td><td colspan="2">Some discussion of issues raised in class, drawing on a few sources of information.</td><td colspan="2">Only little discussion of issues raised in class, drawing on few sources of information.</td><td>No or little discussion of issues raised in class.</td></tr>
<tr><td>4. Critical reflection (Ability to evaluate own process of learning to make improvements) 25%</td><td colspan="2">Analyzed and critically reflected upon own learning experience, and found new paths for further development.</td><td colspan="2">Discussed own learning experience with evidence of a critical approach.</td><td colspan="2">Gave a discussion of learning experience, but the account was generally descriptive without critical or alternative comments.</td><td colspan="2">Some attempts to discuss own learning experience, which remains descriptive and superficial.</td><td>Simply recorded the activities done in class without reflection.</td></tr>
</table>

-End of appendix H -

Appendix I: Sample – Data Collection of Phase FIVE [Reflective Journal & Online interview Records]

(1) Self-reflective Journals

	Accounts of AW*	Designer 8
	Name of the participant	Chan Lok Man (Adrian)
	Gender	Female
	Contact	booohemian@hotmail.com 852-64276268
Avatar [Mankare]	Date of retrieving data	12 October 2007
Self Reflective Journal		
Other design tasks need brainstorming. Brainstorming exercise helps me to explore more creative possibilities. Better ideas usually come in the middle to the end of the exercise. Interacting with other people, I can further develop other people's primitive idea into my own idea. Also, during the exercise, I automatically ask myself to identify the problem and redefine it, as I have to give as many ideas as I can, so I must think about how I can "playing around" with the question. For example, in the task, it doesn't mention the how to collect the juice, we have just simply squeeze a lemon, so I can be more concentrated on the problem that I have to solve and eliminate extra limitations. Brainstorming is the freest part of a design process, so it allows more creativity and less limitation. The more the ideas, the more creative idea will appear. Although the idea may be a bit rough at the beginning, it probably is the "closest" answer of the problem at that stage.		
Data Analysis [Researcher]		

(2) Post-lesson Online Interview

Scenario-Interview		
	Accounts of AW*	Designer 8
	Name of the participant	Chan Lok Man (Adrian)
	Gender	Female
	Contact	booohemian@hotmail.com 852-64276268
	Date of the interview	
Avatar [Mankare]	Duration of the interview	

Interview-Conversation	Interview-Emotion Display	Data Analysis [Researcher]

-End of appendix I -

Appendix J: Semi-structured Interviews Questions for the Post-lesson Online Interviews

(1) Aims and Objectives of the Post-lesson Online Interviews

The semi-structured post-lesson online interviews will be carried out for all participants in order to collect their feedback and reflections regarding their online learning experiences in the selected shared virtual reality.

(2) Sampling of the Post-lesson Online Interviews

Eight Participants from Designer1 to Designer8 in the Shared Virtual Reality (AW)

(3) Duration and Venue of the Interviews

15 minutes per interviewer

(3) Semi-structured Questions for the Interviews

Code	Type of Question	Questions
Q1	Virtual Identity	What is the name of your avatar?
Q2	Virtual Identity	Why did you choose this avatar?
Q3	Virtual Identity	Do you like to use an avatar instead of your real personal identity inside any virtual platform?
Q4	Environmental stimulation	Where do you want to conduct this interview inside virtual reality? Which Café?
Q5	Environmental stimulation	Why did you choose this café?
Q6	Environmental stimulation	Do you like to work in virtual reality? Or prefer traditional face-to-face conversation?
Q7	Environmental stimulation	What would you think if the exercise were conducted in MSN, discussion forum or other internet applications?
Q8	Environmental stimulation	Did you check emails, browse webpages or listen to music during the process?
Q9	Environmental stimulation	I saw someone was flying in the sky inside the virtual reality, What you think about this action?
Q10	Environmental stimulation	Do you like the emotion displays inside the system? If you could add more functions of the emotional display, what would you like?
Q11	Virtual Identity	Did you feel more relaxed and free by using avatars during the brainstorming exercise?
Q12	Virtual Identity	Do you think, to a certain extent, you changed your personality or learning behavior inside the virtual reality?
Q13	Learning experience	In what way do you think virtual reality can facilitate your creative thinking process?
Q14	Learning experience	You had learnt the brainstorming technique before in the classroom. Please comment about using this technique again inside the virtual reality?
Q15	Learning experience	Did you face any learning problem during the process? What were they?
Q16	Learning experience	If one of the design modules could be totally conducted in virtual reality, what do you think, which subject is appropriate?
Q17	Learning experience	What is your overall learning experience inside the virtual reality? Do you like it?

-End of appendix J -

Appendix K: Details of the participants and their avatars

PICTURE REDACTED DUE TO THIRD PARTY RIGHTS OF [redacted]

Details of the Participants	
Accounts of AW*:	Designer1
Names of Avatars:	Navi
Sex:	M
Symbol:	<S01>
Accounts of AW*:	Designer2
Names of Avatars:	Godfather
Sex:	M
Symbol:	<S02>
Accounts of AW*:	Designer3
Names of Avatars:	Pharaoh
Sex:	M
Symbol:	<S03>
Accounts of AW*:	Designer4
Names of Avatars:	Gary
Sex:	M
Symbol:	<S04>
Accounts of AW*:	Designer5
Names of Avatars:	Luke
Sex:	F
Symbol:	<S05>
Accounts of AW*:	Designer6
Names of Avatars:	MeSmEr
Sex:	F
Symbol:	<S06>
Accounts of AW*:	Designer7

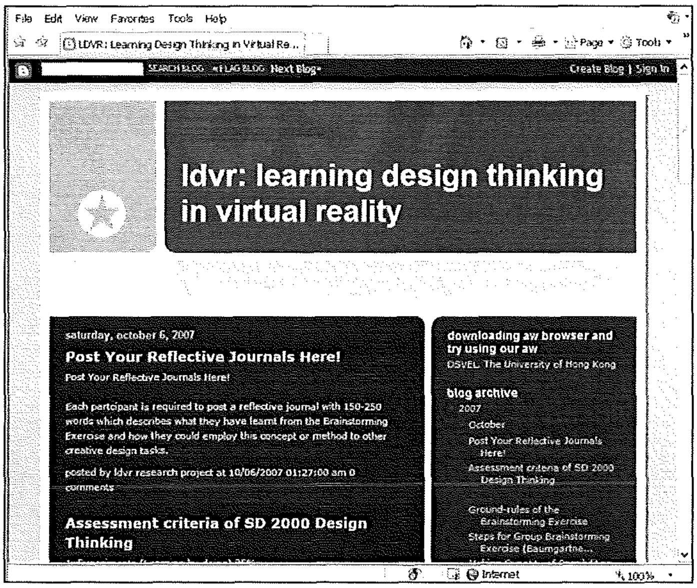
PICTURE REDACTED DUE TO THIRD PAR

[redacted]

Names of Avatars:	Bingo
Sex:	F
Symbol:	<S07>
Accounts of AW*:	Designer8
Names of Avatars:	Mankare
Sex:	F
Symbol:	<S08>

-End of appendix K -

Appendix L: Content of the Web blog LDTVR (Learning Design Thinking in Virtual Reality)



Post Your Reflective Journals Here!

Each participant is required to post a reflective journal with 150-250 words which describes what they have learnt from the Brainstorming Exercise and how they could employ this concept or method to other creative design tasks.

Assessment Criteria of the Design Thinking Exercise

1	Experiments (Learning by doing)	25%
2	Versatility of thinking (Ability to solve problems by using different styles of thinking	25%
3	Independent learning (Self-motivation in furthering knowledge, skills and interests)	25%
4	Critical reflection (Ability to evaluate own process of learning to make improvements)	25%

The details of the criteria will be distributed to participants individually by hardcopies.

The Task: Design Thinking Exercise

Participants are required to explore 101 ways to squeeze a lemon by posting the solutions here. And discuss the possibilities of designing a creative juicer for squeezing lemon.

Ground-rules of the Brainstorming Exercise

The basic structure and ground-rules of undertaking a sound brainstorming exercise:
(1) judicial judgment is ruled out. Criticism of ideas will be withheld until the next day;
(2) Wildness is welcomed. The crazier the ideas, the better; its easier to tone down than to think up;
(3) Quantity is wanted. The more ideas we pile up, the more likelihood of winners; and
(4) Combination and improvement are sought.

Steps for Group Brainstorming Exercise (Baumgartner, 2002)

(1) Step One - A positive approach to problem identification and exploration
(2) Step Two - 25 minutes for every participant to do brainstorming exercise

(3) Step Three - Everyone presents his/her ideas without any explanation and judgment
(4) Step Four - Select five possible ideas from all concepts
(5) Step Five - Compromising for a fine criterion towards the problem
(6) Step Six - Create a score system (0-5 points) give points to selected ideas
(7) Step Seven - Implementing the idea with highest score

Making Quantity of Possibilities

Making quantity of possibilities: This category of creativity methods is helping participants to generate numerous ideas and possibilities which may or may not resulted as solutions. This kind of tools are not going to solve problem directly but generating more alternatives for further consideration. Tools like The Brainstorming Techniques and The Random Access are in this category.

Arranging Appropriate Learning Activities for Creative Thinking

An appropriate learning activities for creative thinking could be identified into FOUR stages (1) the preparation stage, which students have to build up their knowledge by gathering versatile information in this stage; (2) the incubation stage is the accent of the entire learning process which involves the use of various creative thinking skills that allows students to explore possible solutions to address problems; (3) the evaluation stage allows students to look at their explorations and creative thoughts deliberately in order to determine the most appropriate solution from hundreds of possibilities; and students are giving opportunity to examine their selected solution in (4) the implementation stage.

LDTVR: Learning Design Thinking in Virtual Reality

This study attempts to deepen the understanding of the learning experience of design students in undertaking design thinking exercises in a shared virtual reality. the investigation aims to identify the areas of an appropriate pedagogy for E-Learning and the use of shared virtual environment for students in tertiary design education in Hong Kong. Other questions, arising from this research are (1) in what ways can the virtual space release creative potentials of design students; (2) how the virtual space affects the students' learning experience; and (3) how computer plays a role as a learning partner in design education. The virtual reality can assist design students to learn design thinking skills effectively with the help of designing an appropriate pedagogy as well as reinforcing the nutrition of creative climate. This research aims at (1) looking at design students' learning experiences in the module Design Thinking in a shared virtual reality; (2) exploring the implications of using a shared virtual reality in design education; and (3) studying the design students' learning experience and emotional display in virtual learning community.

-End of appendix L -