THE PHYSICAL ENVIRONMENT AS A THREE-DIMENSIONAL TEXTBOOK FOR ENVIRONMENTAL EDUCATION IN MALAYSIAN PRIMARY SCHOOLS

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ABSTRACT

Environmental education (EE) for primary schools in Malaysia is often linked to abstract representation in a featureless classroom. What has often been overlooked is the potential use of physical environment to enrich the EE experience. Instead of focusing on what is taught and how it is taught, equal attention should be given to the physical environment in which EE occurs. With the increased recognition that EE should find a special consideration in educational facilities design, a small, growing literature about the subject is emerging. Practitioners and scholars attempt to bond architecture and EE by designing physical environment as a three-dimensional (3-D) textbook. Although the notion of a 3-D textbook promises a lot of benefits to the teaching and learning of EE, research on this subject is relatively scarce in the literature. To date, there has been no systematic effort to formulate an effective design model for the 3-D Textbook.

This study sets out to explore two knowledge gaps. Firstly, ‘what are the design features for the 3-D textbook?’ Although previous researches illustrate some of the content and benefit of the 3-D textbook, the scholars have not explicitly elaborated on the design features. The answer to the first question would provide a series of design features for further testing and validation. It leads to the second enquiry: ‘Can the 3-D textbook enhance EE outcomes?’ Although some scholars claimed that the 3-D textbook is a useful educational tool, the effectiveness of this architectural intervention has not been evaluated in the literature.

To achieve these goals, a two-phase, sequential exploratory mixed methods had been employed. The purpose was to develop and test a design model for the 3-D textbook. Phase 1 was a two-week qualitative case study in Green School, Bali. The reason for collecting qualitative data initially was that the design features were not known and that these variables needed to be identified based on a case study. Data was collected through a series of interview and on-site observation. Through content analysis, four design features emerged: ‘Transparency’, ‘In One with Nature’, ‘Creativity & Imagination’ and ‘Active Setting’. From the results of the qualitative study, the author further developed the tentative hypotheses which emerged out of literature review. Subsequently, a quasi experiment involving two groups of standard five students (i.e. comparison & participant) was used to test the hypotheses and generalize the design features. The participant group took part in the design, build and operate of a physical model which evolved from the findings of Phase 1. ANCOVA tests revealed that the 3-D textbook had a significant ($p<.05$) positive effect on EE outcomes. The participant group demonstrated an improvement in pro-recycling knowledge, attitudes and behaviour as compared to their peers who had not interacted with the 3-D textbook. This study offers significant contribution to both theory and practice related use of architecture in EE. It serves as a catalyst for further research on academic architecture.

Keywords: 3-D textbook; Architecture; Environmental education; Children; Sustainability

ABSTRAK

Pendidikan alam sekitar (*environmental education*, EE) bagi sekolah rendah di Malaysia sering dikaitkan dengan perwakilan abstrak dalam kelas yang tidak kreatif. Apa yang sering diabaikan adalah potensi penggunaan persekitaran fizikal untuk memperkayakan pengalaman EE. Selain memberi tumpuan kepada apa yang diajar dan bagaimana ia diajar, perhatian harus diberikan kepada persekitaran fizikal di mana EE berlaku. Dengan pengiktirafan bahawa EE perlu diberi pertimbangan khas dalam reka bentuk kemudahan pendidikan, satu sastera tentang subjek ini telah muncul dan sedang berkembang. Pengamal dan cendekiawan cuba untuk mengaitkan seni bina dan EE dengan membentuk persekitaran fizikal sebagai buku teks tiga dimensi (*three-dimentional*, 3-D). Walaupun buku teks 3-D ditanggap menjanjikan banyak manfaat dalam pengajaran dan pembelajaran EE, penyelidikan mengenai perkara ini adalah agak terhad dalam sastera. Sehingga kini, tidak ada usaha sistemik untuk merumuskan satu model reka bentuk yang berkesan untuk buku teks 3-D.

Kajian ini dibentangkan untuk meneroka dua jurang pengetahuan. Pertama, apakah ciri-ciri reka bentuk buku teks 3-D? Walaupun penyelidikan sebelumnya menggambarkan beberapa kandungan dan manfaat buku teks 3-D, cendekiawan tidak menghuraikan ciri-ciri reka bentuk dengan jelas. Jawapan kepada soalan pertama akan menyediakan satu siri ciri-ciri reka bentuk untuk ujian lanjut dan pengesahan. Ia membawa kepada siasatan kedua: Bolehkah buku teks 3-D meningkatkan hasil EE? Walaupun sesetengah cendekiawan mendakwa bahawa

buku teks 3-D adalah alat pendidikan yang berguna, keberkesanan penciptaan seni bina ini tidak pernah dinilai dalam sastera.

Untuk mencapai matlamat ini, kaedah penyelidikan bercampur yang dijalankan secara penerokaan dalam dua fasa yang berurutan telah digunakan. Tujuannya adalah untuk membentuk dan menguji model reka bentuk buku teks 3-D. Fasa 1 adalah satu kajian kes kualitatif selama dua minggu di Green School, Bali. Data kualitatif dikumpulkan pada permulaan kerana ciri-ciri reka bentuk tidak diketahui dan pembolehubah-pembolehubah ini perlu dibentuk berdasarkan kajian kes. Data telah dikumpulkan melalui beberapa siri temuduga pelajar dan pemerhatian di tapak. Melalui analisis kandungan, empat ciri-ciri reka bentuk muncul: 'Ketelusan', 'Satu dengan Alam', 'Kreativiti & Imaginasi' dan 'Tempat yang Aktif'. Dari hasil kajian kualitatif, pengarang membetulkan hipotesis tentatif yang muncul daripada kajian kesusasteraan. Selepas itu, satu eksperimen kuasi yang melibatkan dua kumpulan pelajar tahun lima (iaitu perbandingan & peserta) telah digunakan untuk menguji hipotesis dan mengkaji ciri-ciri reka bentuk. Kumpulan peserta mengambil bahagian dalam kerja reka bentuk, pembinaan dan operasi model seni bina yang berkembang daripada Fasa 1. Keputusan ujian ANCOVA mendedahkan bahawa buku teks 3-D mempunyai kesan positif yang nyata ($p < .05$) terhadap hasil EE. Kumpulan peserta menunjukkan peningkatan dalam pengetahuan, sikap dan tingkah laku pro-kitar semula berbanding dengan rakan-rakan mereka yang tidak berinteraksi dengan buku teks 3-D. Kajian ini menawarkan sumbangan penting kepada penggunaan amalan seni bina dalam bidang EE. Ia berfungsi sebagai pemangkin untuk penyelidikan senibina akademik pada masa depan.

Kata kunci: Buku teks 3-D; Seni Bina; Pendidikan alam sekitar; Kanak-kanak; Kemapanan

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SYMBOLS/ABBREVIATIONS	
ANCOVA	Analysis of covariance
DBO	Design, Build and Operate
EA	Environmental Attitudes
EB	Environmental Behaviour
EE	Environmental Education
EK	Environmental Knowledge
EBD	Evidence Based Design
EFS	Education for Sustainability
ERD	Eco-Revelatory Design
ENSI	Environment and School Initiatives
ERGS	Exploratory Research Grant Scheme
ECEFS	a synthesis of ‘Early Childhood Education’ and ‘Education for Sustainability’
FEE	Foundation of Environmental Education
GPPT	Greenschool Partnership Project in Taiwan
ITBS	Iowa Test of Basic Skills
MSW	Municipal Solid Waste
NGO	Non-Governmental Organization
QUAL	Qualitative
QUAN	Quantitative

SYMBOLS/ABBREVIATIONS

TOPB	Theory of Planned Behaviour
USGBC	United States Green Building Council
3-D	Three-Dimensional
3Rs	Reduce, Reuse and Recycle

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter provides a context for the research by introducing academic architecture and environmental education (EE) in Malaysia. It identifies the gap of knowledge and attempts to improve EE outcomes by designing physical environment as a pedagogical tool. Additionally, the research questions, objectives, aim and the methods are presented. Structure of the thesis is described at the end of this chapter.

1.2 RESEARCH BACKGROUND

‘We teach how to build, but what we build teaches us how to live’

Richard Register, Founder of the global EcoCity Movement

(Graham, 2003, p. 11)

‘We shape our buildings and afterwards our buildings shape us’

Winston Churchill

(Deasy, 1974, p. 5)

It is noted from the quotes above that architecture has the power to shape the life and behaviours of mankind. An interesting comment on this interaction is given by a renowned architect, Frank Lloyd Wright. He claimed that architectural design of house can cause divorce of a married couple within weeks (Orr, 2000). Buildings are not merely machines as Le Corbusier would have it, they are a form of pedagogy that never fails to instruct (Orr, 2000). Public spaces like schools have huge potential of becoming an instrument for education – “buildings that teach”. For example, rainwater harvesting or renewable energy could be something more than reading material if a creative design shows these wonders first hand (Innovative Design Inc, 2009). More importantly, students are not merely studying static knowledge under contrived conditions. Instead, they are part of an innovative school environment that serves as a 3-D textbook where the physical environment and the real-world objects within it are utilized as teaching and learning tools for understanding phenomena now studied from textbooks (Taylor & Enggass, 2009).

This study argues that the current school design in Malaysia is unable to support EE, especially in terms of behaviour change. Till now, the design of primary schools in Malaysia is still based on the “Factory Model” as described by Leland and Kasten (2002). Classrooms are designed to shelter the act of teaching and learning that happens within its four walls (Ford, 2007). While the textbook preaches the importance of water conservation, the students are flushing school toilets with drinking quality water everyday. While the students learn about energy crisis and global warming, their classrooms are dependent on non-renewable energy sources from the national grid. How then do we expect the students to understand the true meaning of living sustainability with the earth in a “concrete box”?

Apparently, implementation of EE syllabus and program alone is not sufficient in moulding pro-environmental attitudes and behaviour. School environment does play a vital role in supporting EE. Instead of focusing on what is taught and how it is taught, equal attention should be given to the physical environment in which education occurs (Sanoff, 2009).

1.2.1 EE and Architecture in Malaysian Schools

Malaysia National News Agency reported that 75% of the world's plant and animal species are found in 12 countries including Malaysia (Daniel, et al., 2006). Being a tropical country, Malaysia has been entrusted with the responsibility to conserve the natural heritage in their march forward to be a developed nation by the year 2020. However, Malaysia is facing tremendous challenges in ensuring sustainable development by keeping pace with rapid urbanization and industrialization. In Eighth Malaysia Plan (Economic Planning Unit, 2001), the following key environmental problems are identified:

1) about 73% of Malaysian rivers are polluted;
2) a serious solid waste crisis as a result of a very low recycling rate of 5% for a generation rate of 1.0 kg/day per person;
3) air quality problems mainly in the urbanized places associated with particulate matter and other pollutants;
4) an increate in the quantity of poisonous and dangerous waste disposed by industries.

Although the Malaysian Government and other non-profit organizations have embarked upon EE among school students since 1983, the success of these strategies have been very limited. This is reflected in a survey by Said et al. (2007). This survey was conducted in the state of Johor, Malaysia to gauge levels of environmental understanding, awareness and knowledge and the involvement of secondary school students in sustainable consumption practices. The collected data showed that students were only moderately concerned with the environmental problems although they were aware of these issues. Merely 10% of the students were capable of defining environment in terms of a relational concept as opposed to an object. Furthermore, the data discloses that the respondents had minimal EE experience ‘in’ and ‘with’ nature. Surprisingly, EE was ineffective in altering action and behaviour patterns of students, but had only improved their environmental consciousness. Similar findings were also obtained by Lim (2005) in two public schools in the Klang Valley. Lim found that students’ and teachers’ basic environmental knowledge was high, however when it involved actual application or practices, the respondents only favoured conservation actions, such as switching off fans, which required minimum skill and effort.

A similar findings as school student, also have been noted among households in Malaysia where sustainable practices were found to be modest (Aini, et al., 2002; Othman, et al., 2004). For instance, Daniel et al. (2006) documented that the environmental citizenship level in Malaysia is not adequate for a country that is heading towards a developed status by year 2020. They noted that Malaysian citizens had good factual knowledge of environmental problems, moderate level of understanding of environmental issues and low level of positive environmental action. Haron et al. (2005) research concurred with the above-mentioned. They investigated the level of environmental knowledge among the Malaysian households. The findings indicated that respondents performed satisfactory on fundamental environmental knowledge. However, the respondents possessed merely a low level of complex environmental knowledge, which may not promote their pro-environmental behaviour.

While there are a number of causes for the failure to achieve the EE goals, major blame has been attributed to the outdated school design (Taylor & Enggass, 2009). Sustainable development issues in Malaysia have been directed towards high-end residential and commercial buildings rather than public institutions. Green architecture that enables support for EE in government funded public schools has received minimal attention. The current design of public schools in Malaysia is often linked to the "factory concept" with a sterile assembly of components. Like most of the countries in South East Asia, the modern typology that emphasizes on a more industrial-like architecture has dominated the educational architecture in Malaysia (Tajuddin, 2007). The school buildings are merely designed to meet floor area and budget requirements. They deprive the students of a pleasant and imaginative learning environment. While countries like Japan, United States and Germany are looking at different possibilities and innovation in school architecture (Walden, 2009a), the public schools in Malaysia are still constrained by the "Factory Model". As Tajuddin (2007) described:

> "…The standard JKR (Jabatan Kerja Raya, or Public Works Department) rigid frame construction is built up to four storeys with no elevators; if there are multiple blocks, they are arranged either in a row or in an open-ended square around a central courtyard containing an empty padang (field). Some of the more recent school designs have slightly more interesting forms but the same regimentation still pervades."

Furthermore, Yaman (2006) noted that the school architecture in Malaysia is still under the shadow of the colonial influence after 50 years of independence from the British rule. Yaman also documented that the planning, design and construction of educational facilities have not undergone much evolution since the colonial period. The current prevailing "Factory Model" in Malaysia is deeply rooted in the Industrial Revolution. It was dedicatedly done in response to prepare young people for factory jobs that required them to perform some relatively simple task repeatedly during industrial age of western countries (Leland & Kasten, 2002). The school design reflected and confirmed the industrial model of education. The overall architecture is guided by uniformity and conformity. Repetitive and identical classrooms with passive configuration are part and parcel of the learning environment (Taylor & Enggass, 2009). This “Factory Model” is then brought into Malay Peninsula during British colonial period and it continues to subjugate the fields of education and school architectural design until today (Figure 1.1).

Figure 1.1: Recently completed primary schools under the 9th Malaysian Plan.
(Source: Development Department Ministry of Education, 2010)

Although the "Factory Model" has received numerous criticisms (Leland & Kasten, 2002), no high quality design solutions have been developed (Tajuddin, 2007). EE persisted to be planned around the "concrete box" and learning continues within its four walls. Housing the EE within the "Factory Model" lead to a disturbed harmony between architecture and EE as both disciplines are forcefully adapted to each other. For instance, EE has the revolutionary purpose of transforming the values that underlie decision making, from the current ones which assist and abet environmental degradation to those which support a sustainable planning in which all people live with equivalent human dignity (Tanner, 1974). This contrast with the existing school design that is structured to present basic information to maintain existing social conditions and relations (Stevenson, 2007). In addition, EE treats students as active thinkers and generators of knowledge (UNCED, 1992; UNESCO, 2003). The repetitive and featureless classrooms place them in the passive position of spectators and recipients of other people's knowledge and thinking. The mastery of relevant knowledge and skills is demonstrated in EE by students' actions in real-situations, not by students writing about theory of artificial situations which leads to the deficit in direct learning experiences. For example, reading the concepts of composting will never be the same as actually practicing it in the school garden. However, if gardening space is not planned for in the earlier design stage, students can only marvel at the composting through texts and images in their books. As H'Doubler (2002) has noted, "to know is the essential first step, but it is the expression of what we know that develops character and a sense of value" (p. 11).

1.2.2 Physical Environment as a 3-D Textbook

EE is getting more recognition in educational facilities design as indicated by the growing numbers of literature in this subject. Practitioners and scholars attempt to bond architecture and EE by designing physical environment as a 3-D textbook (Orr, 1993; Taylor & Enggass, 2009), thus transforming the school into an ecological learning hub for students (Rauch, 2000). Treating the physical environment as a teaching tool enables the topics such as "rainwater harvesting", "renewable energy", "ecosystem" and the like to be conveyed through direct experience (Duerden & Witt, 2010). More importantly, students are not studying static knowledge under contrived conditions (Chuan, 1996; Kong, et al., 1995; Sharma, 2009); instead they are part of an interactive learning environment which serves as an instrument for pedagogy (Malone & Tranter, 2003b).

Orr's (1993; 1997) thought-provoking theory, 'Architecture as Pedagogy' highlighted that buildings and landscape carry pedagogical value and these are power tools that influences the act of teaching and learning. Orr (1997) emphasized that the physical environment and EE are not two separate identities. In fact, a school's architecture can be argued to be a kind of crystallized pedagogy. Thus Orr propositioned that buildings have their own hidden curriculum which effectively takes part in teaching process as any lessons that are usually taught in classrooms. Similar approaches were implemented in many other projects such as the Smart Green Schools (Newton, 2010), Design for Learning (Featherston Archive, 2013), Whole School Approach to Sustainability (Ferreira, et al., 2006; Fien, 1997), Eco-Schools in England (Eco-Schools England, 2013), Sustainable Schools in Australia (Department of Sustainability Environment Water Population and Communities, 2011) and Green Schools in Mainland China (Wu, 2002). These projects explored the link between architecture, pedagogy and sustainability to create new learning environments that support and enhance EE (Wang, 2004).

Additionally, the concept of Reggio Emilia identifies three educators in a classroom at anytime, namely the teacher, the child and the environment (Strong-Wilson & Ellis, 2007). It provides a unique idea that link early childhood education to physical settings such as childcare centres and kindergartens (Edwards, et al., 2012; Thornton & Brunton, 2007; Wurm, 2005). The concept of Reggio Emilia also suggests that the early childhood environment offers children vital messages and cues. In other words, the physical setting communicates with children - about what they can do, how and where they can do it and how they can work together (Fu, et al., 2002; Rinaldi, 2006). It is not usual to think of the environment as a live mentor, however, the work of Anne Taylor (Taylor, 1993; Taylor & Enggass, 2009) can lend us a sight into how school environment can teach. Taylor has been working together with her colleagues for the past forty years interpreting philosophy and curriculum into architectural programs which are subsequently transformed to actual physical designs. Her writings resonated with Orr's (1993) recommendation that buildings and landscape can be used to reflect teachings similar to what we are educating through books (Taylor, 1993). Taylor documented that the physical environment communicates to us many messages if we are ready and willing to read them. In other words, the elements in the built environment and natural environment are representational with messages that are worthy of further exploration. Awareness of the opportunities offered by the designed or natural world can help educators to turn 'objects' into 'thoughts' for students' learning (Taylor & Enggass, 2009). Thus, Taylor (1993) concluded that when a school serves as a 3-D textbook, the EE curriculum is the school's environment.

Educators and scholars noted that utilizing academic buildings as a 3-D textbook promises a number of benefits in the process of design, construction and operation. Orr (1993) highlighted that the design of a school is an opportunity to further explore the relationship between environmental impact and costing. For example, students in the Davidson Elementary School learned how to create a new school building that would complement and support the ecosystem within the budget constraint (Sanoff, 2009). They were exposed to issues such as energy consumption, maintenance cost, embodied energy and life cycle assessment where they strived to achieve a balance between ecology and economics (Environment and School Initiatives, 2012). Additionally, Mitchell (2005) and Lynam (2007) documented that the physical environment carry pedagogical value that reinforces the lessons taught in the classroom. For instance, rainwater harvesting or renewable energy is ideal in an educational setting because it can engage students' imaginations and spur learning about sustainability (Innovative Design Inc, 2009; Nair, et al., 2009). Buildings can also be constructed to inform and support the learning of energy and resource use within the campus (Badarnah 2009). Lastly, Ford (2007) and Rauch (2000) noted that school buildings can extend ecological competence by inviting the participation of students in the maintenance and operation of their schools. New knowledge and skills would be constructed through the students' hands-on activities. Therefore, students in eco-schools are encouraged to take charge of their surroundings, education and making decisions about how to improve their home and their school environment (Foundation for Environmental Education, 2012).

1.2.3 The Research Gap

Although the notion of 3-D textbook promises a lot of potential to the benefits of teaching and learning EE (Higgs & McMillan, 2006), research done on this subject is rather limited in the literature review (Taylor & Enggass, 2009). There is much to be done to further reveal the road from theory to practice. To date, there has been no systematic effort to explore students' responses and perceptions towards this emerging trend in school design (Barr, 2011; Ford, 2007). Thus, it remained unclear what attributes that characterize a 3-D textbook from the students' point of view. More importantly, practitioners were unable to formulate or invent an effective design model for 3-D textbook, due to the limited feedback from the users (Deasy, 1974). Furthermore, Mitchell (2005), Taylor and Enggass (2009) noted that empirical evidence is required to identify learning outcomes which are specific to the 3-D textbook. Therefore, further studies are needed to scrutinize the contributions of the 3-D textbook in promoting pro-environmental knowledge, attitudes and behaviour, particularly how the child-environment interaction could be a possible source of environmental learning (Dresner, 1990; Linn, et al., 1994; McNeill & Wilkie, 1979; Padua & Jacobson, 1993; Ramsey, 1993).

This background information has now highlighted two potential areas of research. Firstly, 'what are the design features for a 3-D textbook'? The first enquiry is raised because the lack of information and investigation in this area of study (Orr, 1993; Tanner; 2008). Although previous researches illustrate some of the content and benefit of a 3-D textbook, the scholars and designers have not explicitly described all of the design features (Ford, 2007; Kong, et al., 2012; Orr, 1997; Taylor & Enggass, 2009). From the review of literature, it appears that passive design and green technology are relevant factors, but other criteria and tactics may also shape the 3-D textbook (Higgs & McMillan, 2006). The answer to the first question would provide a series of design features for further testing and validation. It leads to the second enquiry: ‘Can a 3-D textbook enhance EE outcomes’? Although some scholars claimed that 3-D textbook is a useful educational tool, the effectiveness of this architectural intervention has not been evaluated in the literature (Fink, 2011; Tanner, 1974; Taylor, 1993). Thus, the impact of a 3-D textbook on students’ environmental knowledge, attitude and behaviour is unknown.

1.3 RESEARCH PROBLEM

1.3.1 Aim

The obvious untapped potential of 3-D textbook and its undefined attributes in architectural design provokes further investigation. The aim of this research is to explore the design of the 3-D textbook and determine its effectiveness to improve the environmental knowledge (EK), environmental attitudes (EA) and environmental behaviour (EB) among primary school students. It intends to develop a design model which could be used as a tool for those seeking to establish 3-D textbook, thus transforming the physical environments into pedagogical tools. This research will benefit the architectural practice through identification of the design features that correlate positively with desirable EE outcomes.

1.3.2 Objectives

The objectives for this research as follows:

1 To examine the design features of the 3-D textbook.

2 To investigate the students’ responses and perceptions towards the 3-D textbook.

3 To investigate the impact of the design features related to the 3-D textbook on the EK of primary school students.

4 To investigate the impact of the design features related to the 3-D textbook on the EA of primary school students.

5 To investigate the impact of the design features related to the 3-D textbook on the EB of primary school students.

6 To investigate participants' experiences during the intervention trail.

1.3.3 Research Questions and Hypotheses

The research background reveals that there is a dearth of investigation on the design features of the 3-D textbook and the effectiveness of this architectural intervention is unknown. Research questions and hypotheses that structure the research and define these variables are therefore:

Research Question 1 (RQ1)

What are the design features of a 3-D textbook?

Hypothesis 1 (H1):

Students would demonstrate an improvement in environmental knowledge (EK) when they interact with the 3-D textbook than when they receive no treatment.

Hypothesis 2 (H2):

Students would demonstrate more pro-environmental attitudes (EA) when they interact with the 3-D textbook than when they receive no treatment.

Hypothesis 3 (H3):

Students would engage in more pro-environmental behaviour (EB) when they interact with the 3-D textbook than when they receive no treatment.

Research Question 2 (RQ2)

How do students perceive the impacts of the 3-D textbook on their environmental knowledge, attitudes and behaviour?

1.4 RESEARCH METHOD

The research processes were guided by the principles of mixed methods as recommended by Creswell and Clark (2007). The research processes included two main phases (Figure 1.2). In Phase 1, an extensive literature review and a qualitative case study was carried out. The data collected from students' interview and on-site observation were utilized to establish the design features for the 3-D textbook. After that, the author brought together research findings from Phase 1 to refine the theoretical framework and develop a physical model to satisfy the needs of the subsequent quasi experiment. Phase 2 aimed to test the design features on real life students. It utilized a pretest-posttest nonequivalent comparison group design (Babbie, 1992) to address the hypotheses and research questions. Particularly, it gathered numerical information and figures with statistical support to strengthen the findings from Phase 1. The author assessed the effectiveness of a short duration use of the physical model that acts as a 3-D textbook. It was expected that students would demonstrate improved EK, more pro-EA, and engage in more pro-EB after interacting with the full-scaled model.

The sequential nature of the methodology allow a pragmatic approach to follow the development of an architectural intervention is well-suited to the exploratory nature of this thesis. There is no previous study on educational architecture that integrates EE and test out its effectiveness. Thus, the purpose of the research is to establish the design features for the 3-D textbook and identify its consequences. The emphasis of this thesis, as with sequential mixed methods, is on the journey of discovery and interpretation of all the data that is revealed, rather than relying on the pure analysis of primary data. This is in line with the evidenced based design (EBD) framework which conceptualizes and formulates design concepts and then evaluates and test these ideas through a succinct, organized process. Scholars noted that EBD is grounded in the scientific method of quantitative and qualitative research, thus it can be implemented along with the mixed methods design to create a highly robust research (Brandt, et al., 2010).

1.5 STRUCTURE OF THE THESIS

Two characteristics of this research affect the structure of the thesis. Firstly, Creswell and Clark (2011) noted that the structure of a mixed methods research should relate to its design. In the current study, the principle of sequential exploratory design emphasizes that the results of Phase 1 shape the development of Phase 2. Particularly, the initial qualitative phase produces specific design features which are then used to direct the data collection in the second, quantitative phase. Thus, Phase 1 findings ought to be reported prior to the commencement of Phase 2. As a result, the two main phases are presented in different chapters with its own sections for result and discussion. The rationale for this approach is that the qualitative data and their subsequent analysis help to identify important variables for further testing. Secondly, the exploratory nature of the research requires non-biased research endeavour towards presumption free new findings. To remain truthful to the methodology, the thesis is structured into a few parts each of which reflects different phases of the research.

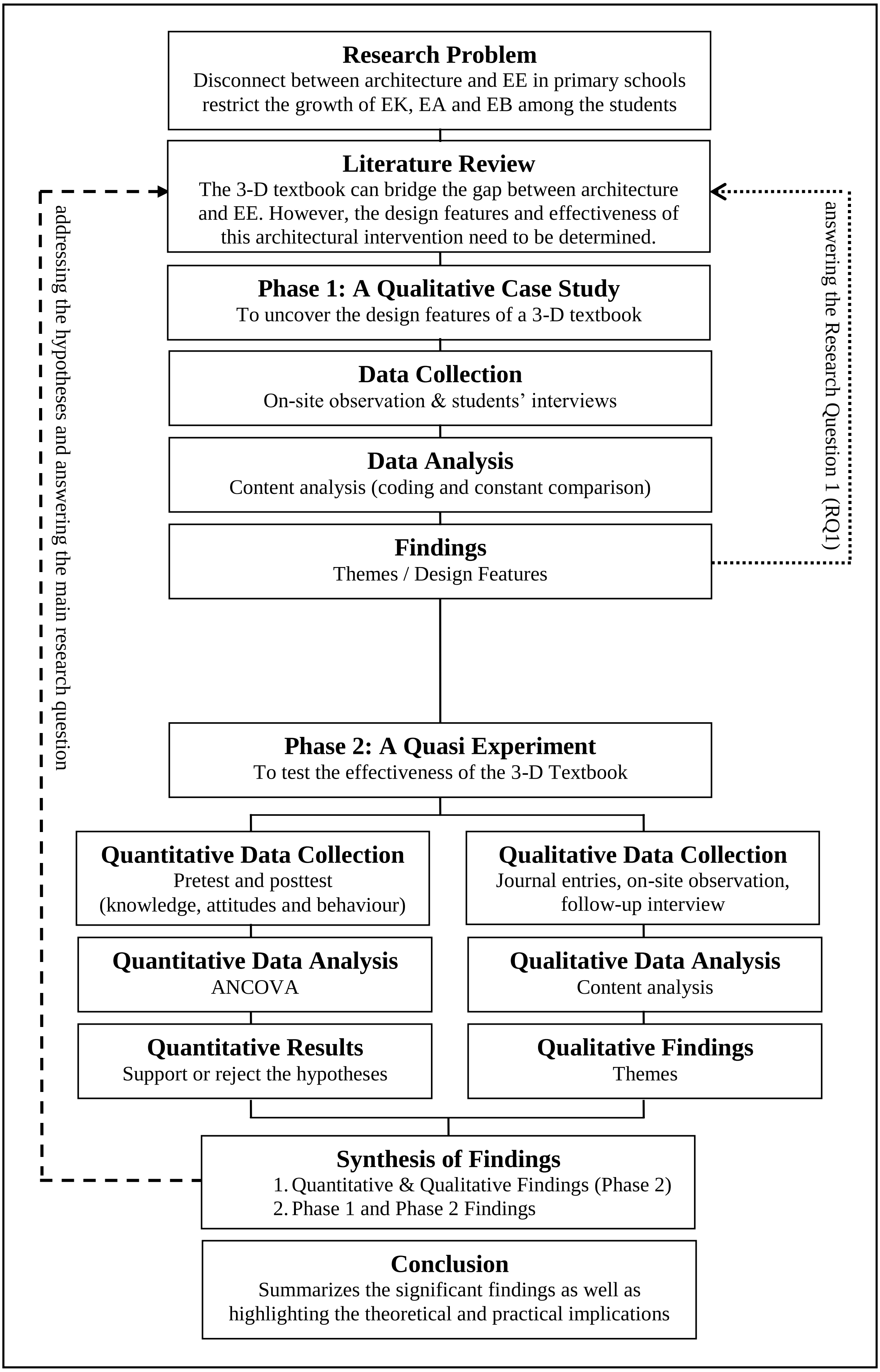


Figure 1.2: The research procedure

Chapter 2 of the thesis reviews the literature relevant to the research. In particularly, it highlights the previous studies and theories used to formulate the tentative theoretical framework. It also helps to strengthen the argument of filling a knowledge gap through this research. Chapter 3 describes the methodology used to answer the research questions and test the hypotheses. The methods adopted for Phase 1 and Phase 2 are presented here. Chapter 4 collates the result and discussion of Phase 1. It discusses and concludes the Phase 1 of the research. Chapter 5 explains how the findings from Phase 1 will be investigated during Phase 2. It also presents the result of a quasi experiment to test the effectiveness of the 3-D textbook. Finally, significant findings are discussed and summarized as the conclusions. Responses to research questions and hypotheses are presented here. It also identifies the theoretical and practical implications as well as a few research gaps for future research.

1.6 SUMMARY

EE in Malaysia is often linked to abstract representation in a featureless classroom. What has often been overlooked is the potential use of the physical environment to complement the formal EE in enriching the learning experience. The notion of a 3-D textbook brings physical environment and EE into collaboration and through this cooperation, architecture is utilized to advance the environmental learning. However, the author noted that the literature provides very little information on the design features of the 3-D textbook. Furthermore, the impact of this architectural intervention on the EE outcomes (i.e. EK, EA and EB) needed to be tested on real life students. Thus, the procedure to be followed here to fill up these gaps seems to be qualitative followed by quantitative. In view of this situation, the author adopted the sequential exploratory mixed methods to examine this phenomena in depth (Creswell & Clark, 2011). Firstly, the author conducted a qualitative case analysis which describes and interprets the 3-D textbook from the students' perspective. It concurred with Deasy's suggestion (1974) that design solutions should be understood by studying the reactions of the users rather than concentrating on the intentions of the designers. Subsequently, a quasi experiment was carried out to test and validate these variables and relationship.

This research adds on to the current body of knowledge on the concept of 3-D textbook, with a focus on a tropical country with vast biodiversity, namely Malaysia. The research outcomes are significant in various ways. Firstly, it examines the notion of 3-D textbook in the developing nations in Southeast Asia. Thus, this study serves as a catalyst for the educational facilities reformation in the region. Secondly, the research provides novel findings to identify the patterns and design of 3-D textbook and its constituent parts to assist students' environmental learning. It offers an entirely new perspective to educational facilities design by merging the disciplines of architecture, EE and sustainability. The qualitative and quantitative findings are instrumental to create powerful ideas or innovations that could influence environment-friendly development, in light of the forward march to create future sustainable communities.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Chapter 1 introduces the disconnection of school architectural design and EE in Malaysia. It also identifies the gaps in knowledge for the current research. An elucidation of the literature in Chapter 1 has shown the notion of a 3-D textbook could bridge the gap between architecture and EE. However, there is a scarce of practical guidance about how to actually design a 3-D textbook that capable of enhancing EE outcomes (i.e. knowledge, attitudes and behaviour). Therefore, an in-depth study is required to further open up the road from theory to practice.

In this chapter, the related concepts of 3-D textbook including the design, practices and benefits is critically evaluated and explored. Subsequently, current literature related to the impacts of traditional (e.g. classroom) and non-traditional (e.g. schoolyard) settings on environmental knowledge (EK), environmental attitudes (EA) and environmental behaviour (EB) are presented. The author used this as a basis to establish the effectiveness of the 3-D textbook to improve EE outcomes.

2.2 DEFINITIONS

The commonly occurring terms are adopted and defined as follow for the purpose of this thesis:

- ***Building systems***

  plumbing, electrical, heating, ventilation and air conditioning (HVAC), structures and building skin (building envelope)

  (Baird, 2001; Taylor & Enggass, 2009; Yeang, 2006)

- ***Education for sustainability***

  a process of transformative learning which equips all the concerned students, teachers and school systems with the original and new knowledge by enhancing the ways of thinking which is indispensable to speed up economic affluence and to build up answerable citizenship while recasting and upgrading the environment of health system upon which our lives rely on

  (Davis, 2009; Li & Williams, 2006; Nixon, et al., 1999; Tilbury, 1995)

- ***Environmental education***

  a learning process that augments and broadens the mental faculty of people replete with knowledge and responsiveness about the surroundings and connected confronts, enhances the essential talent, proficiency and know-how and expertise to successfully and valiantly triumph over the challenges by cultivating positive approaches, enthusiasms and dedication with unflinching commitment to make up to date decisions and take responsible accomplishment

  (Howie, 1974; Stevenson, 2007; Tanner, 1980; UNESCO, 1978)

- ***Educational facility***

  the physical elements of the school environment, including school building, technology, grounds and gardens

  (Gislason, 2009; Higgs & McMillan, 2006; Orr, 1993)

- ***Operations***

  indicates the activities and accomplishments prepared to maintain the schools' physical systems functioning, including amenities safeguarding, maintenance, ground work, protection, waste management by reduction, recycling, cooking and cleaning

  (Dyment & Bell, 2007; Higgs & McMillan, 2006)

- ***Physical environment***

  all the material elements within school settings, not just architecture and landscape architecture, but inclusive of equipment, furniture and the context within the school is located

  (Dudek, 2000; Owens & Valesky, 2007)

- ***Sustainable design***

  it's a design therapy seeking to get the most out of the quality of the erected atmosphere while diminishing or doing away with the negative impacts to the natural environment

  (McLennan, 2006; Van der Ryn & Cowan, 1996; Yeang, 2006)

- ***Three-dimensional (3-D) textbook***

  the physical environment and the real-world objects within it that can be utilized as teaching and learning tools for understanding phenomena now studied from textbooks

  (Brkovic & Milosevic, 2012; Taylor, 1993; Taylor & Enggass, 2009)

2.3 EE IN MALAYSIAN SCHOOLS

With the intention of addressing the environmental problems in Malaysia and the tenets of Chapter 36 of Agenda 21, government and NGOs have put a lot of efforts into promoting EE, public awareness and training. The Ministry of Education developed a curriculum for EE and promoted various teaching and learning strategies in formal education. Other NGOs such as World Wildlife Fund and Tzu Chi Foundation have participated in the promotion of EE to the students and to the public at large. Lateh and Muniandy (2010) documented the importance of EE within the national education system as a result of the Education Planning Committee to introduce EE across curriculum at primary level (for 7-12 years old). For instance, a subject named ‘Man and his Environment’ was officially implemented to all students in the upper primary school curriculum (for 10–12 year olds) in year 1986 (Said, et al., 2007). Currently, EE is introduced within the Malaysia school system through the infusion and integration approach, in relevant subjects such as Science, Civic and Citizenship.

Additionally, the schools encourage their students to participate in the extra-curricular activities that introduce the concepts of EE through activities such as environmental clubs, landscaping projects and school decoration works. Other EE activities, such as environmental debates, camps, clean-up projects (*gotong-royong*), essay writing competition and quiz are also implemented on an ad-hoc basis (Fathahi, 2006). In year 2005, a sustainable school award (*Sekolah Lestari*) has also been implemented to sustain and enhance the functioning of EE within the campus. A school will be labelled ‘*Sekolah Lestari*’ if it is found to infuse EE and promote environmental values through school organization, syllabus, co-curriculum and greening activities and incorporate these activities with the neighbourhood, local authority and other institute (Jabatan Alam Sekitar, 2004).

The Eco-School programme was soon introduced by the WWF Malaysia in 2011. The programme focused on nine key environmental themes (i.e. water, waste/litter, energy, nature/biodiversity, school grounds, transportation/sustainable mobility, healthy living, Local Agenda 21 and climate change). However, it is not compulsory to work on all the nine themes simultaneously. Interested schools are encouraged to focus on easier themes in the beginning and move progressively into more challenging thematic areas (Eco-Schools Malaysia, 2013). The Eco-School programme acknowledges the importance of school grounds in EE. It encourages the participating schools to utilize their surroundings as educational opportunities for formal and informal learning. However, it does not provide a clear guidance on how to transform the school grounds into learning tools. Participating schools would have to rely on their own initiative and creativity in designing their school grounds for EE.

Some private and international schools in Malaysia have also demonstrated their interest and commitment towards sustainability. For instance, the Melaka International School has provided a 2 acres organic farm to teach their students about recycling of wastes, preparation of organic fertilizers and environmentally friendly pesticides. The school emphasizes on the learning of healthy life style and the development of responsible and mature citizens. Additionally, the Matahari School in Johor Bahru has shown similar commitment towards EE by using collected rainwater for general cleaning and providing a recycling centre in their school with regular environmental preservation or cleaning campaign. The school combines the national curriculum with their own educational program based on communication, values, humanities, science, technology and personal development.

Although these private institutions have demonstrated some sustainable ideas for their schools, they have not fully explore the potential use of the physical environment as a 3-D textbook for EE as suggested by some scholars (e.g. Orr, 1997; Taylor, 1993; Taylor & Enggass, 2009).

2.4 LINKING ARCHITECTURE AND ENVIRONMENTAL EDUCATION

Several scholars from architecture, ecology, geography and environmental psychology have examined the notion of a 3-D textbook (e.g. Barr, 2011; Brkovic & Milosevic, 2012; Mitchell, 2005; Orr, 1993; Taylor, 1993; Taylor & Enggass, 2009). However, as the architecture and EE disciplines are so enormous, no single book has thoroughly elucidated an all-inclusive assessment. In spite of that, some journal articles (e.g. Orr, 1993; Taylor, 1993), book chapters, and monographs have made an endeavour to present a synopsis of the concept as well as numerous case studies (e.g. Higgs & McMillan, 2006). These studies also provide insight into the linkage between school and sustainability. Additionally, they illustrate some of the content and benefits of a 3-D textbook. Thus, the author reviewed the following literature as a foundation to formulate an initial theoretical framework for the current research.

Broadly identifying, five key theories endorse the exploit of the physical environment as a 3-D textbook: 1) Architecture as Pedagogy, 2) Teaching Sustainability through Educational Facility, 3) Whole-School Sustainability, 4) The Third Teacher and 5) Place-Based Education. While closely related, an understanding of the uniqueness of each theory may provide a useful starting point to this research. Thus, each theory will be briefly discussed below including its approach, development and limitation. Table 2.1 recaps some of the similarities and difference of each.

2.4.1 Architecture as Pedagogy

Orr's (1993; 1997) thought-provoking theory – "Architecture as Pedagogy" highlighted that buildings and landscape carry educational value and these are power tools that influence the teaching and learning of EE (Barry, 2009; Peatross & Peponis, 1995; Tanner, 2000). He suggested that the EE can be embedded into the architectural form and thus every building is a pedagogical tool (Abercrombie, 1986). Additionally, the act of structure and building, as pointed out by Orr, is a prospect tool to elongate the educational know-how across disciplinary margins. Orr emphasized that physical environment and EE are not two separate identities (Ford, 2007; Orr, 2000; Taylor & Enggass, 2009). In fact, school architecture can be a kind of crystallized pedagogy to manipulate the surge of thoughts and ideas and the superiority of learning. With creativity in planning and design, students can learn passively toward the built environment (Brubaker, 1998; Ford, 2007; Orr, 1993; Rauch, 2000; Taylor, 1993; Walden, 2009b).

There is a set of courses found in applied ecology contained by the built environment (Innovative Design Inc, 2009; Lackney, 2009). For instance, buildings can be planned to recycle waste water through minute ecosystem that would be studied by the students. This ecologically engineering system combines the traditional wastewater technology with the decontamination processes of natural wetland to expose students to the essential lessons of biology and sustainability. The treated water can be utilized for toilet flushing and landscape irrigation where it acts as a practical and tangible demonstration to students of the benefits of recycling and water conservation (Nair, et al., 2009). The minute ecosystem can also extend ecological competence by inviting the participation of students (Lackney, 2009; Taylor, 1993; van Weenen, 2000). New knowledge and skills are constructed through the students' involvement in the maintenance and operation of the waste water treatment system. It helps to build environmental consciousness through the active engagement of students in the treatment, purification, recycling and reuse of the waste within the campus.

Additionally, Taylor and Vlastos (Taylor, 1993; Taylor & Vlastos, 1983) described the physical environment as a pedagogical tool, well-designed art type, place of splendour and motivational hub for learning. Educational spaces turn out to be value-driven design (Holloway & Valentine, 2000), and this places the architect in the role of smoothing the progress of designer and educator in lieu of a embellishing or designing mechanic (Taylor & Enggass, 2009). It also empowered the students to play an active role in the process of design, build and operate (DBO), where they gain meaning from their participation (Walden, 2009b). For instance, the school principal and teacher of a primary school in Nigata, Japan used the DBO of a project of solar greenhouse for hands-on mathematics and science for 5th grade students. As an incorporated educational tool, the solar greenhouse assists children to foster life naturally, comprehend botany and alternative energy systems and put side by side structural systems to body systems. The exposed mechanical and electrical system can also provide a lesson in input and output environment, alike to the arteries and veins available in human bodies.

The use of architecture as a pedagogical tool supports real-world problem solving (Fusco, 2001; Korsmeyer, 1999; Pallasmaa, 2005) as conceptualized by experimental learning theory (Dewey, 2005; Orr, 1994). Nieto (1994) acknowledged that what students gain as knowledge in science has deficit and lacks its importance to their real lives and this insight is rather marked in the field of EE. As a result, Barnett et al. (2006) theorized and put into practice a field-based municipal ecology science program. Their empirical study reveals that physical environment can be an educational tool because it involves students in actions positioned in real-world perspective to boost their local relevance and significance (Fusco, 2001; Orion & Hofstein, 1994; Weston, 1996). Taken together, campus can be used as a pedagogical tool by building 'place-based learning' and 'situated learning' concept based on the research on education (Vogelgesang & Astin, 2000). It has the similar tone with Savanick's (2006) idea to use campus to put up the contents of courses on a geographical area known to the students well (Astin & Sax, 1998; Learning through Landscape, 2012). In addition, Mitchell's (2005) study demonstrated that buildings having their own concealed core curriculum instructs as fully and as strongly as any course educated in it. She conducted a qualitative research to explore whether high calibre green buildings can passively communicate a pro-environmental message to their occupants. Her qualitative data reveals that to varying degrees green buildings can passively communicate a pro-environmental message to their occupants. Green design solutions can act as "triggers" by capturing an occupant's attention and causing them to link the strategy with a pro-environmental construct. Mitchell (2005) concluded that green buildings can be heuristic learning tools if they are designed with an aesthetic that challenges existing constructs.

The originality and the significance of this theory - 'Architecture as Pedagogy' is that it contributes a conceptual foundation to reunite architecture and EE in creating 3-D textbook for teaching and learning. It advocates the idea that green buildings can active instruments to communicate a pro-environmental message to its occupants (Zandvliet, et al., 2012). More importantly, it provokes the suggestion that students should play an active role in the process of DBO. By bridging the gap between architecture and education, everything within the environment can be a potentially interactive learning tool (Rauch, 2000; Wu, 2002). Not only the space, but also the colour, texture, size and placement of every object might be the groundwork of an experience that considerably promotes the learning process (Orion & Hofstein, 1994; Peatross & Peponis, 1995; Rapoport, 1982). This approach acts as a catalyst for the development of general design principles with EE in mind. However, a major limitation with this approach is that it is conceptual in nature rather than applied. While this approach may not be a holistic solution, it has led to the development of an understanding of important concepts underlying a 3-D textbook where architecture and EE are united.

2.4.2 Teaching Sustainability through Facilities and Operations

The concept of teaching sustainability through facilities and operations grew out of the work of Higgs and McMillan (2006). They examined how four innovative schools (i.e. Arthur Morgan School, Common Ground School, The Island School and Lakeside School in the United States) model sustainability practices to their students. They conducted interviews, observed daily life of students and reviewed school documentations. Their findings divulge that modelling through amenities and operations is an important approach to sustainability education, upholding both learning about sustainability and acceptance of sustainable behaviours among the students. Thus, schools should ensure that the ecological, social and economic impacts of the facilities are obvious to students and others (Karliner, 2005; McLennan, 2006; Van der Ryn & Cowan, 1996; Zachariou & Kadji-Beltran, 2009).

Apparent, tangible and sustainable facilities can teach or model sustainability effectively to the students (Gentry, 1990; Higgs & McMillan, 2006; Kolb, 1984). Mitchell (2005) explained that there are three different methods to make sustainable facilities more visible to the children, namely, exposed building systems, experiential building systems and uncovering hidden cycles. Firstly, exposed building systems are an active strategy that creates opportunities to view the building systems that are normally hidden behind walls (Van der Ryn & Cowan, 1996). This can be accompanied by eliminating finishing details such as dropped ceilings that usually hide mechanical equipment and providing windows to view building assemblies and mechanical equipment. Secondly, the experiential building system is an active strategy involves the creation of opportunities for an occupant to understand experientially the purpose behind the building system (Baird, 2002; Petersen, et al., 2007). Typically, experiential building systems aim to create a fast, effortless and automatic learning opportunity through the reliance on sensory experience (Mitchell, 2005). Thirdly, sustainable buildings can illuminate hidden cycles through technology that makes these connections visible (Winter & Cotton, 2012). Ways in which green buildings can uncover hidden cycles include: treating wastewater on-site using a solar aquatic system, producing energy from renewable means, capturing rainwater for use within the building and incorporating a composting program that provides nourishment for landscaping (Helphand & Melnick, 1998).

In addition to making green facilities apparent, Higgs and McMillan (2006) noted that some schools used maintenance and operation to promote sustainability within the campus. Involving students in the operation of the school makes the waste, consumption, inequities, governance and economics of the school more tangible (Abrahamse, et al., 2007; Bandura & Houston, 1961; Foster, 2001). Students' involvement in operations made them feel more ownership and responsibility for their local place and school (Rauch, 2000; Schelly, et al., 2011). For instance, the students and teachers at the Island School and Arthur Morgan School are in charge of the school operations instead of the custodial staff. The students and faculty serve as school takers, cleaning, collecting trash, recycling, tending gardens, composting, preparing food and caring for school animals. Students at both schools are responsible for about 30 minutes of chores per day, as well as longer work projects that involve ongoing maintenance, building construction and gardening. It can be concluded that sustainable facilities and operations teach and promote EE by modelling sustainable practices (Schunk, 1987; Schunk, et al., 1987; Wagstaff & Wilson, 1988), reducing the need to preach to students (Berryman & Breighner, 1994; Cangemi & Kahn, 1979; Frayer & Klausmeier, 1972), creating a context for conversations about sustainability (Short, 2009), providing hands-on opportunities to try sustainable practices (Abrahamse, et al., 2007; Gentry, 1990) and increasing student ownership and stewardship of their environment (Kadji-Beltran, et al., 2012; McKenzie-Mohr, 2000; Schelly, et al., 2011; Sterling & E. F. Schumacher Society, 2001).

A recent study by Schelly et al. (2012) suggests that teaching through facilities and operations can also occur in large public schools in the context of a district committed to sustainability. Schelly et al. (2012) conducted a case study research to observe how energy management efforts in one public high school (i.e. Rocky Mountain) contributed to both sustainability education and the adoption of sustainable behaviour within educational and organizational practice. Qualitative data reveals that building facility can serve up an educational function. For instance, in the Rocky Mountain, a space was constructed for recycling to instruct students about the recycling program and its significance. The space was planned as a pedagogical tool to inspire and motivate students towards sustainable waste management. It was designed as a recycling hub where it provided the required setting to support collection and segregation of waste within the campus. Schelly et al. (2012) recognized that through facilities design, operations and school clubs, Rocky Mountain models a dedication to energy conservation, and use of resources with higher responsibility and fiscal management as well as environmental sustainability (Bogner, 1998; Orr, 2006). Their study demonstrates that conservation efforts can simultaneously and synergistically meet up the goals of conservation and sustainability education when modelled effectively in a public school setting (Berryman & Breighner, 1994).

The originality and the significance of this theory - ‘Teaching Sustainability through Facilities and Operations’ is that it contributes important case studies that promote the use of apparent green facilities as a 3-D textbook to model sustainability. It also generated data about the meaning and use of architecture to enhance EE. The act of modelling helps students to transfer the concepts of sustainability from abstract ideas to personal and tangible applications. Direct observation of sustainable practices also equips students with the knowledge needed to carry out the behaviour themselves (Frayer & Klausmeier, 1972). Furthermore, the operations of the school can be an educational tool and source of multi-directional learning, as students, teachers, and other groups learned from and modelled for one another (Tilbury, 1995). One can expect that students who have seen sustainable practices being carried out first-hand will be better prepared to lead more sustainable lifestyles. However, a major limitation with this approach is that it tends to focus more on student’s learning and less on the school design. It gives a restricted interpretation of research from an architectural perspective. Nevertheless, this approach provides important data and inputs from the fields of psychology and education which can be translated into architectural design (Lawrence, 1983). Particularly, it promotes design that support active learning through the maintenance and operation of green facilities within the campus.

2.4.3 Whole School Sustainability

Whole School Sustainability has its early roots in Owens’ and Valesky’s (2007) School Climate Model (Figure 2.1). The model is a meshing of four primary components, namely, ecology, culture, milieu and organization. Ecology refers to the physical qualities of the environment, such as site, architecture, equipment and technology. Culture refers to the values and behaviours of the members of the school community with milieu describing the social patterns and psychosocial dynamics among students. Organization encompasses teaching pedagogies and the social hierarchy within school. Overlaps of these four dimensions demonstrate symbolic aspects of these relationships, with each component influencing the others. This model remains unique as the only school environment model holistically addressing the students learning experience by including the built environment as a primary factor (Gislason, 2009). The Whole School Sustainability addresses all the components in the School Climate Model (Australia Department of the Environment and Heritage, 2005). In this approach, schools incorporate sustainability into all aspects of their organization, manifested in school governance, pedagogical approaches, curriculum, resource management, school operations (Figure 2.2) and grounds (Henderson & Tilbury, 2004; Shephard & Furnari, 2012). Thus, the mission of Whole School Sustainability is to educate students for sustainability by placing emphasis on active engagement (Fairfield, et al., 2011; Walshe, 2008). It acts as a catalyst for the growth of "sustainable", "eco" or "green" orientated school that consider physical environment as training grounds for environmental management, as well as sites to showcase good practice in EE for the community (Dewey, 2005; James & Bixler, 2008; Reed, 2009; Zwahlen, 1995).

Figure 2.2: Maintenance of school ground
(Source: Henderson & Tilbury, 2007, p.1)

Figure 2.1: School Climate Model
(Source: Owens & Valesky, 2007, p. 192)

A sustainable school has been defined as an organization that:

1. is guided by the principle of care for one self, care of each other and care for the environment (Great Britain Dept for Children Schools and Families, 2008; Scott, 2011);
2. integrates changes to the practical operations of the school with sustainability issues in the curriculum and helps to build links to local communities (Gough, 2005, p. 340).

These definitions imply that developing sustainable schools requires fundamental restructuring of the school on a pedagogical, organizational, technical and social level. Transitioning a school towards Education for Sustainability (EFS) requires a holistic reform of a school's operation, including its curriculum, teaching, culture, resource management and collaboration within and outside the school boundaries (Jensen, 2005). These whole school approaches to sustainability that characterize a sustainable school have broadened the educational agenda from school improvement and student achievement concerns to school development that encompasses not only curriculum and pedagogical issues but also school governance and the management of resources (i.e. energy, waste and water reduction) and school grounds (for biodiversity) (Ferreira, et al., 2006; Ferris, et al., 2001). Embedding sustainability principles and values across all curriculum areas, expanding pedagogical approaches to include experiential, outdoor and action learning, and creating participatory and democratic decision-making structures that engage the whole school community are ideals that have been identified as part of whole school sustainability approaches (Kadji-Beltran, et al., 2012; Sward, 1999).

Henderson and Tilbury (2004) reviewed several whole-school sustainability initiatives, namely, *Enviroschools*, New Zealand; *Green School Award*, Sweden; *Green Schools*, China; FEE *Eco-schools* and ENSI *Eco-schools* to document their experiences, achievements and lessons learnt. Their study revealed that whole-school approaches to sustainability have an important contribution to make in shifting local communities towards sustainability. Additionally, there is some evidence which points to a number of critical success factors for whole-school sustainability programs (Waters, et al., 2008; Wilson & Tomera, 1980). These include: alignment with national government priorities; access to expertise in EE or EFS during program design and implementation; significant and continuous funding; alignment with EFS approaches; investment in professional development of program team as well as school partners; creating links with EE initiatives already in operation; and establishment of multi-stakeholder partnerships. In addition, Henderson's and Tilbury's study provided numerous case studies to link physical surroundings and curriculum. For instance, *Enviroschools* in New Zealand uses ecological and participatory design of school surroundings as a living curriculum to integrate the informal curriculum of all areas of school life with the formal curriculum. On the other hand, *Green Schools* in China are necessitated to accept effectual, ecologically welcoming management practices for environmental protection, and make stronger teamwork between schools and communities (Wu, 2002). Additionally, *Green School Award* in Sweden includes physical environment (e.g. materials and products, food, waste, water, energy, air, local environment, transport and buildings) as an important criteria in the curriculum and certification assessment.

Whole School Sustainability is not merely a means of redefining the role of teacher and student, but it is also a means of generating educational criteria for school design (Dudek, 2000; Woolley & Kimmins, 2000). It interprets architecture as a socially rather than a personally valid process of decision making. The design process is bound by the curriculum and culture, rather than to rely upon intuition (Barr, 2011). As noted by McClintock & McClintock (1968), “school building becomes architecture when the builder’s arts are used to advance the cultural concerns of the educator” (p. 63). Therefore, the design of physical landscape and resource management has to reflect the goal of EFS as well as the values of the school community. The blending of green school design, green organizational behaviour and aligned educational goals can set the stage for innovation. In short, this approach provides an important basis in creating 3-D textbooks that encompass sustainability, education and architecture. It reveals the value of sustainable design in creating high performance buildings as well as providing a dynamic model to teach construction, conservation, consumption, engineering and environmental science in harmony with nature. It acknowledges that sustainable architecture and building systems are ideal in an educational setting because they can engage students' interest and spur learning about buildings as 3-D textbooks.

2.4.4 The Third Teacher

Education is often seen as the responsibility of parents and teachers. However, Reggio Emilia approach identifies a third teacher between child, teacher, and parent: the environment (Strong-Wilson & Ellis, 2007; Vecchi, 2010). It provides a unique concept that link early childhood education to physical settings such as childcare centres and kindergartens (Edwards, et al., 2012; Thornton & Brunton, 2007; Wurm, 2005). Reggio Emilia suggests that the early childhood environment gives children important messages and cues (Abramson, et al., 1995; Hendrick, 1997; Rinaldi, 1995). In other words, the environment 'speaks' to children - about what they can do, how and where they can do it and how they can work together (Fu, et al., 2002; Rinaldi, 2006). In its attention to how space can be thoughtfully arranged, Reggio Emilia has reconceptualized space as a key source of educational provocation and insight (Kinney & Wharton, 2008). It advocates that teachers pay close attention to the myriad of ways that space can be made to "speak" and invite interaction (Cadwell, 2003; Fraser & Gestwicki, 2002). Kerka and Eric Clearinghouse on Adult, Career and Vocational Education (1999) further explained that an environment that fosters learning provides the necessary resources and time for investigative play and experimentation. Thus, physical space is acknowledged as a medium that nurtures concentration, creativity and the motivation to independently learn and explore (McKellar, 1957).

Davis (2009) noted that ECEFS – a synthesis of ‘early childhood education’ and ‘education for sustainability’ – is finally beginning to emerge as an active new field of interest. She emphasized the importance of using learning environment as the third teacher to bridge the gap between early childhood education and sustainability. Young children can create quality learning experiences through their interactions in rich environments in which nature has a central place (Abbott & Nutbrown, 2001; Finegan, 2001). The ‘forest school’ movement, for example, made obvious that social, educational, health and environmental learning might be affected by multiple impacts of the outside experience across broad learning areas (Borradaile, 2006). Using the environment as a third teacher refers to a ‘transformative’ early childhood education, equipped with greater values encouraging and supporting children not only as problem-seekers but problem solvers and action-takers around sustainability issues and topics connected to their own lives (White, 2004).

The notion of the environment acting as a third teacher also gives the classroom the qualities of a living being (OWP/P Architects Inc, et al., 2010). As such, it must be as open to change and responsive to the students, parents and community as any good teacher would be. This reciprocal, dynamic environment, designed to play the role of a third teacher in the room is a powerful educational tool (Jones, 2002; Lewin-Benham, 2006). In adopting principles of the Reggio Emilia approach, teachers will have to consider more seriously about what kind of environment they endow with for students by examining each component and think about its purpose (Ellis, 2003). For, as Lella Gandini said, “All the things that encircle the people in the school and which they bring into play like the objects, the equipments and the structures are not seen as inactive elements, but quite the opposite are seen as elements that provision and are provisioned by the dealings of children and adults who are dynamic in it" (Edwards, et al., 1998, p. 177).

The originality and the significance of this theory - 'The Third Teacher' is that it develops significant ideas and case studies about what constitutes ideal settings for pre-school children (Lyon & Donahue, 2009; Maynard & Chicken, 2010; New, 2007). The Reggio Emilia approach draws deeply on how children perceive and use space to create meaning (Abbott & Nutbrown, 2001; Cadwell, 1997; Strong-Wilson & Ellis, 2007). Thus, it provides useful ideas about planning with children in mind or to include children in design of environments they use. As previously reviewed, some childhood educators begin to use the environment as a tool to communicate function as well as to express sustainability values (Borradaile, 2006; Davis, 2009; White, 2004). They noted that physical setting carries numerous messages that invite children to engage with the world. Therefore, the Reggio Emilia approach promotes the active involvement of children and other users in the initiation, design and management of their surroundings (Mackey, 2012; OWP/P Architects Inc, et al., 2010; Roe, 2007; Van Wagenberg, et al., 1981). It introduces new ways of thinking about design of school facilities and opens an opportunity for the innovative use of physical environment in early childhood education. For instance, thoughtfully designed, attractive and informative gardens can be utilized as 3-D textbooks for learning of science, art, ecology and stewardship. Children can be given an instrumental role in programming and design of these 3-D textbooks. The hope is that children who comprehend, use and interact with their surroundings will grow into adults who protect and appreciate the environments (Gough & Gould League of Victoria, 1992; New Zealand Ministry for the Environment, 1998).

2.4.5 Place-Based Education

Place-based education has been widely published in journals such as *Environment & Behavior* (Lindholm, 1995; Weinstein & Pinciotti, 1988; Wells, 2000), *Environmental Education Research* (Cook, 2008; Duhn, 2011), *Journal of Environmental Education* (Ernst, 2012; Lawrence, 2012; Powers, 2004), *Journal of Elementary Science Education* (Martin, 2003) and *Journal of Environmental Psychology* (KasalI & Dogan, 2010). It seeks to use the notion of a "place" to advance environmental teaching and learning. It is an area of research made possible by significant advances in environmental psychology (Howley, et al., 2011; Malone & Tranter, 2003a; Malone & Tranter, 2003b; Rauch, 2000; Sobel, 2005). The concept of place-based education has been an evolving curricular and instructional approach that over the years has also been referred to as ecological education, bioregional education and environmental-based education (Woodhouse & Knapp, 2000).

Place-based education is designed to help students learn about the immediate surroundings by capitalizing on their lived experiences (Knapp, 2005). The strategy uses local settings to teach all school subjects in a way that seems to deliver results for everyone interested. The appeal and strength of the place-based education approach is in its adaptability to the learner's context and its process of mending the disconnect between an institution's environment and the learner (Pajak, 2000; Smith & Sobel, 2010). It advocates experiential learning, contextual learning, problem-based learning, as well as other learning theories that share in emphasizing the value of learning from one's own community (Resor, 2010). An overwhelming number of studies in the educational literature describe the potentially positive effects of a place-based education (Arbogast, et al., 2009; Armitage, 2001; Fisman, 2005;

Howley, et al., 2011; Knez, 2005; Malone & Tranter, 2003a; Ozdemir & Yilmaz, 2008; Rauch, 2000; Thomson, 2007; Weston, 1996). These positive outcomes include schools and communities working in conjunction with one another to establish curriculum goals and design strategies that improve student achievement while increasing their interest in their community. Place-based education is designed to motivate learners at all levels of ability to interact with content and supports Dewey's belief that learner's direct experiences are key (Gruenewald & Smith, 2008; Li & Williams, 2006; Walden, 2009b).

To comprehend place-based education and its meaning and implications, one must be aware of the core concept of the pedagogical approach which is the geographical concept of place (Bedwell, 1966; Ellis, 2002; Relph, 1997). A description of three fundamental aspects of place, namely location, locale, and sense of place, can help in distinguishing the technical connotation of place from its ordinary usages (Cazden, 1995; Resor, 2010; Smith, 2007). All places have a complete location usually communicated using latitude and longitude (Cresswell, 2004; Sobel, 2005). The second aspect of place, locale, is the place of living, i.e. the actual setting consisted of real objects - streets, buildings, flora, walls, furniture, windows, or pictures on the wall in which people used in their lives (Duhn, 2011; Smith & Sobel, 2010). The third aspect of place is a "sense of place," which describes the subjective and emotional attachment of a person to a place (Ellis, 2004; Gruenewald & Smith, 2008; Weinstein & Pinciotti, 1988). It is this subjective aspect of place, typically the least investigated and explored although it is most interesting, that is the real shed of Upitis' (2007) study. Her research investigates the development of sense of place through school architecture. She selected a few case studies to exemplify how schools can present students with opportunities to extend ecological mindfulness through realistic and pragmatic activities enhanced by natural and built environments. Further descriptions of these educational institutions are given in below where beauty, loveliness and a sense of place are principal.

The first case study described Shearwater Mullumbimby Steiner School which was positioned at the border of a rainforest close to the northern boundary of New South Wales. The architects and school founders used an imposing white fig tree to serve as a physical and symbolic hub for the school. Classrooms were designed in ways that highlight the physical surroundings as well as reflecting a sense of place. The second case study centred on the Seabird Island Community School, which was planned for Grade 12 students. Patkau Architects of Vancouver added a participatory process in designing the school (Dudek, 2000) by placing a large kitchen as the symbolic centre for the community. After some years, both the architects and community members relate how participating in the construction processes served the young men of the community. It was found that these young men took pride and satisfaction of their work, and in some cases, built their own homes afterward. The third case study involved the Environmental Studies program at Oberlin College. The school community envisioned designing a building that can enhance students' ecological literacy. Therefore, a forum involving twenty-five students and a dozen of architects was held to develop the core ideas for this new building. They determined a set of design criteria for the 14,000 square foot facility which included generating more electricity than it would consume, discharging no negative externalities like waste water, using no materials known to be carcinogenic and promoting ecological competence and mindfulness of place. The design works of the school community resulted in the construction of a building that responded to the site issues, offering sustainable building principles of the uppermost order.

The originality and the significance of this theory - ‘place-based education’ is that it contributed key findings on the use of local environment as an effective means to achieve educational goals. Although place-based education is not practiced widely, but its efforts to encourage a convergence of the environment and EE are attracting growing attention from both architects and educators (Ellis, 2004; Hutchison, 2004; Thompson & Sorvig, 2008). Local contexts (e.g. river, community artwork, wetland, garden, etc) are embodied in the curriculum to develop 3-D textbooks, involving learning through manual or practical skills as suggested by Dewey (1956). It acknowledges that knowledge is not about memorizing abstract facts but about building understanding through physical, intellectual and social engagement. The local contexts are not restricted to permanent buildings or elements. In some cases, a temporary structures itself can a 3-D textbook to teach about “place”. For instance, students at a small school in Bridgehampton built a “tepee” in their garden using local materials. This temporary structure soon became a signature element in the school, acting as a pedagogical tool to provide a memorable place for students to study ecology within the campus (Nair, et al., 2009).

Table 2.1: Theories linking architecture and EE

1. Architecture as Pedagogy	
Approach	• school architecture as a kind of crystallized pedagogy with hidden curriculum • every building is a pedagogical tool • green building as a teaching tool during the design, construction and operation phases
Research Advances	Contributed essential concepts to reunite architecture and EE.
Design Advances	Developed general principles on the design of school with EE in mind.
References / Proponents	Abercrombie, 1986; Badarnah, 2009; Barnett, et al., 2006; Barry, 2009; Brubaker, 1998; Ford, 2007; Innovative Design Inc, 2009; Lackney, 2009; Orr, 1993; Orr, 1994; Orr, 1997; Pallasmaa, 2005; Rapoport, 1982; Rauch, 2000; Savanick, 2006; Savanick, et al., 2008; Taylor, 1993; Taylor & Enggass, 2009; Taylor & Vlastos, 1983; van Weenen, 2000; Walden, 2009b; Weston, 1996; Zandvliet, et al., 2012
2. Modeling Sustainability through Facilities and Operations	
Approach	• using green opportunities and operations to form sustainability to the students • making green facility transparent, visible and tangible • students and teachers in charge of school operations
Research Advances	Contributed important case studies that promote the use of school facilities to teach sustainability.
Design Advances	Generated data about the meaning and use of architecture to advance EE.
References / Proponents	Baird, 2002; Berryman & Breighner, 1994; Bogner, 1998; Cangemi & Kahn, 1979; Foster, 2001; Frayer & Klausmeier, 1972; Higgs & McMillan, 2006; Hopkins & McKeown, 1999; Kadji-Beltran, et al., 2012; Karliner, 2005; McLennan, 2006; Petersen, et al., 2007; Schelly, et al., 2012; Schunk, 1987; Schunk, et al., 1987; Short, 2009; Tilbury, 1995; Van der Ryn & Cowan, 1996; Wagstaff & Wilson, 1988; Winter & Cotton, 2012
3. Whole-School Sustainability	
Approach	• has its early roots in Owens' and Valesky's (2007) School Climate Model • school development that encompasses not only curriculum and pedagogical issues but also school governance and the management of resources and school grounds • acts as a catalyst for the growth of "sustainable", "eco" or "green" orientated school around the world

Table 2.1, continued

Research Advances	Included the design of physical landscape and resource management as a part of the EFS.
Design Advances	Interprets architecture as a collectively rather than an in-person legitimate procedure of decision making. The design process is bound by the curriculum and culture, rather than to rely upon intuition.
References / Proponents	Australia Department of the Environment and Heritage, 2005; Barr, 2011; Birney & Reed, 2009; Edwards, 2006; Ferreira, et al., 2006; Fien, 1997; Gislason, 2009; Gough, 2005; Gough & Gould League of Victoria, 1992; Great Britain Dept for Children Schools and Families, 2008; Henderson & Tilbury, 2004; Jensen, 2005; Kadji-Beltran, et al., 2012; McClintock & McClintock, 1968; Nixon, et al., 1999; Pajak, 2000; Shephard & Furnari, 2012; Tilbury & Wortman, 2005; Wang, 2004; Wang, 2009; Williams & Brown, 2011
4. The Third Teacher	
Approach	• echo Reggio Emilia approach which links early childhood education to physical settings • physical environment as a tool to communicate function as well as to express sustainability values • the environment ‘elucidates’ to children - about what, how and where they can contribute, as well as how they can work together
Research Advances	Developed significant ideas and case studies about what constitutes ideal settings for children.
Design Advances	Provided useful ideas about planning with children in mind or to include children in design of environments they use.
References / Proponents	Abbott & Nutbrown, 2001; Abramson, et al., 1995; Cadwell, 1997; Cadwell, 2003; Danko-McGhee, 2009; Davis, 2009; Edwards, et al., 1998; Edwards, et al., 2012; Ellis, 2003; Ellis, 2004; Ellis, 2005; Finegan, 2001; Fraser & Gestwicki, 2002; Fu, et al., 2002; Hendrick, 1997; Hendrick, 2004; Kinney & Wharton, 2008; Lewin-Benham, 2006; Lewin-Benham, 2008; Lyon & Donahue, 2009; Mackey, 2012; Maynard & Chicken, 2010; Millikan, 2003; New, 2007; OWP/P Architects Inc, et al., 2010; Rinaldi, 2006; Roe, 2007; Scheinfeld, et al., 2008; Strong-Wilson & Ellis, 2007; Thornton & Brunton, 2007; Van Wagenberg, et al., 1981; Vecchi, 2010; White, 2004; Wien, 2008; Wurm, 2005

Table 2.1, continued

5. Place-Based Education	
Approach	• environment as an indispensable connecting context for education • place serves as an inspiration for lesson content • utilizing environment to promote interdisciplinary, collaborative, hands-on and engaged learning
Research Advances	Contributed key findings on the use of environment as an effectual way to accomplish educational targets.
Design Advances	Provided case studies that embrace local contexts and education.
References / Proponents	Arbogast, et al., 2009; Armitage, 2001; Cazden, 1995; Cook, 2008; Duhn, 2011; Ellis, 2004; Ernst, 2012; Fisman, 2005; Ford, 2007; Gruenewald & Smith, 2008; Howley, et al., 2011; Hutchison, 2004; Johnson, 2011; KasalI & Dogan, 2010; Knez, 2005; Lawrence, 2012; Li & Williams, 2006; Lindholm, 1995; Malone & Tranter, 2003a; Malone & Tranter, 2003b; Martin, 2003; Ozdemir & Yilmaz, 2008; Powers, 2004; Rauch, 2000; Resor, 2010; Smith, 2007; Smith & Sobel, 2010; Sobel, 2005; Thompson & Sorvig, 2008; Thomson, 2007; Upitis, 2007; Walden, 2009a; Walden, 2009b; Weinstein & Pinciotti, 1988; Wells, 2000; Weston, 1996

2.5 LEARNING FROM THE 3-D TEXTBOOK

The 3-D textbook fosters a dynamic relationship between the students and environment (Day & Midbjer, 2007; Orr, 1993; Taylor, 1993). In this type of setting, students learn through their interaction with the physical surroundings (Khalil, 2011). Caine and Caine (1991) documented that regardless of what we are doing, we are always operating in a physical context in space. Thus, human’s natural ability to learn is directly linked to constant interaction with the environment (Peatross & Peponis, 1995). Caine and Caine (1991) concluded that leaning does not occur in a vacuum or by rote memorization, but through active interaction with the subject under study. At the same time, Maxwell (2007) noted that proficiency from an environmental viewpoint is the capability to act together efficiently with the surroundings one faces (p. 230). The interactive effects of physical parameters can notably improve or slow down learning (Amedeo & Dyck, 2003; Dyck, 2002). Effective interaction thus is defined as the utilizing opportunities within the specific milieu to thrive the physical and cognitive development of a person (Bronfenbrenner, 1980; Trancik & Evans, 1995). The ability to interact knowledgeably with the environment is an essential foundation for students’ learning. In other words, learning can be ensured by the students from their interactions with physical surrounding and from the people whom they communicate in their daily lives (Aho, et al., 1993; Baines, 2008; Malone & Tranter, 2003a).

To understand how learning is derived from child-environment interaction, it is first necessary to explore the methods by which people make sense of the world (Rapoport, 1982). Hershberger (1974) identified two categories of meaning that can be derived from architecture – representational and responsive (Figure 2.3). Representational meaning refers to the identification of objects, design features or spaces and the recognition of their function. This involves matching sensory experience with personal constructs (Abercrombie, 1986; Lynam, 2007). For example, distinguishing a rectangular plank of wood with a circular handle as a door and its purpose of partitioning two separate spaces would be representational meaning. Responsive meaning is a secondary reaction to the identified object that might be affective, evaluative or prescriptive in nature (Hershberger, 1974). Through representational and responsive meaning, students can understand the built environment and use that information to direct their behaviour accordingly (Rapoport, 1990).

Stimulus Object		**Representation**		**Response**		**Behavioural Response**
(rectangular door)	→	(image of door) (idea of passing through)	→	(feeling of welcome) (judgment of beauty) (decision to use)	→	(open and pass through door)

Figure 2.3: Representational and Responsive meaning of architecture
(Source: Hershberger, 1974, p. 149)

Building upon the works of Hershburger and Rapoport, Shapiro (2012) suggested that everything within the learning setting holds the potential for learning and teaching. In addition to listening and reading texts, learning takes place through daily interaction with building and communication structures (Schacter, 1999; Tuan, 1977). These structures are representations of cultural values that are read by all who inhabit learning settings (Lui, et al., 2004). In the Alberta Energy program, *Energy Sleuth*, for example, students examine energy education principles using the material structures of the physical learning setting to understand and develop the concepts, energy and heat (Shapiro-Zimnicki, 1989). With this knowledge, students then become energy loss activists. They track down heat loss and energy waste in learning environments and share their findings with fellow students and teachers. In addition, buildings might be used in a study of sound through featuring the sound barrier qualities of walls in the study of acoustical principles. Or students may examine the interrelationships between plants and animals by investigating schoolyard ecology (Blair, 2009; Brody, 2005; Chansomsak & Vale, 2008). In these ways, the physical features of learning environments function as a form of curriculum 'text' to build and enhance concepts, skills and attitudes (Thrill, 2009; Wang, 2004; Wang, 2009; Wu, 2002). The term 'text' used in this way refers not to the printed pages of a book, but to potential readings of the interwoven sets of messages that are read as cultural rules about how communication and learning will proceed (Bowers, 1995; Cadwell, 2003).

Additionally, Taylor (1993) used the term "knowing eye" to explain how students may learn from their interaction with the 3-D textbook. The knowing eye is defined as a type of visual literacy that enables architects to see and critically analyze the physical world (Taylor & Enggass, 2009). Architects undergo special training that sharpens their perception, increases their discernment and helps them to form an aesthetic sense of the environment (Demirbas & Demirkan, 2003). However, the knowing eye is not a sole privilege architects possess (Arnheim, 1997; Grandin, 2006; Northern & Downs, 2002). In fact, students can develop knowing eye when they occupy and use spaces designed expressly to stimulate their natural curiosity, where architecture is not a vacuous space but a learning tool. The knowing eye is not solely a sensory mechanism, but rather "an organ of wisdom, a mind's eye that allows us to read the environment with deep understanding" (Taylor & Enggass, 2009, p. xvii). For instance, the Integrated Learning Centre at Queen's University in Kingston, Ontario is described as a "living building" that students will not only learn in but also learn from. The exposed structures and monitoring sensors allow students to gain an in-depth understanding on how a green building is constructed and how it functions over time. In their attempt to explain how students learn from green design of schools, Taylor and Enggass (2009) documented that, "building systems and carefully designed outdoor environments can be used to teach the cyclical, dynamic order in the universe such as the changing state of matter or properties of water, biology and the life cycle, Earth science, or other ecological concept" (p. 359).

2.6 3-D TEXTBOOK AND EE OUTCOMES

For better or worse, physical settings contribute to shaping perception, performance and behaviour of the students (Boeve-de Pauw & Van Petegem, 2011; Dresner & Gill, 1994; Leeming, et al., 1993). Beyond a functional backdrop enveloping activities, the design of learning environment can be harnessed as a tool to manifest teaching and learning values. Through thoughtful design, architects can aim to change students' behaviour for the better and make it, for instance, more sustainable (Dietz, et al., 2009; Duerden & Witt, 2010). Such design, aimed at enabling, inducing or motivating students to behave in a more sustainable manner, is the interest of a 3-D textbook (Orr, 1993; Taylor & Enggass, 2009). It deals with the intersection between the disciplines of architecture, psychology and education. This intersection constitutes a research area that has grown considerably in recent years especially amongst the environmental psychologists (Abrahamse, et al., 2007; Arbogast, et al., 2009; Halpenny, 2010; Kaiser, et al., 2007; KasalI & Dogan, 2010; Ozdemir & Yilmaz, 2008).

Scholars identify the outcomes of EE as improved environmental knowledge (EK), attitudes (EA) and behaviour (EB) (Dresner, 1990; Dresner & Gill, 1994; Linn, et al., 1994; McNeill & Wilkie, 1979; Padua & Jacobson, 1993; Ramsey, et al., 1981; Ramsey, 1993). Zelezny (1999) noted that the effectiveness of any EE interventions should be evaluated in terms of EK, EA and EB. He defines EE intervention as "planned strategies that provided information and/or training to modify or achieve a predicted pro-environmental outcome" (p. 6). Leeming el at. (1993) also included EK, EA and EB in their review of the psychological studies that focused on the effectiveness of EE. They noted that the primary goal of EE should be to encourage students to engage in more pro-EB. However, it is important to assess the EK and EA change, which ultimately improves EB (Kuhlemeier, et al., 1999). Their statement is supported by Duerten and Witt (2010), who incorporated the theory of planned behaviour (TOPB) to evaluate EE interventions. The TOPB suggests that an individual's intention to engage in a particular behaviour is the best predictor of actual behaviour (Tonglet, et al., 2004; Valle, et al., 2005). However, the behavioural intentions are influenced by an individual's knowledge about and attitudes towards the behaviour in question (Kruse & Card, 2004; Kuhlemeier, et al., 1999; Martin, 2003).

In short, measurement of EK, EA and EB gives a more holistic understanding on the impact of a 3-D textbook on EE outcomes. However, the use of a 3-D textbook as an educational tool and catalyst to improve EE outcomes has not been evaluated in the literature. Although the lack of empirical evidence hampers efforts to assess the effectiveness of this intervention, existing studies which investigate the impacts of traditional (e.g. classroom) and non-traditional (e.g. wilderness) settings on EE outcomes may assist research efforts in this area. Although aspects of it have been covered in the extant literature earlier, the specific impacts of the physical environment on EK, EA and EB are presented below.

2.6.1 Environmental Knowledge (EK)

EK can be understood as the capability to make out and evaluate the impact of society might be on the ecosystem (Cegarra-Navarro, et al., 2010; Gambro & Switzky, 1996). The Tbilisi Declaration stresses that EE should help individuals and their communities to understand the complexity of the natural and built environments resulting from the interaction of the biological, physical, social, economic and cultural aspects (UNESCO, 1978). This is a broad definition of EK and hints at how many ways knowledge interacts with other factors, which govern the success of EE (Ramsey & Rickson, 1976; Robelia & Murphy, 2011). EK can also be investigated as species knowledge (plants and animals), ecological concepts, action-specific environmental knowledge and system knowledge (Bögeholz, 2006). However, only a few empirical studies have explored the link between physical environment and EK. These studies have moved beyond a focus on conventional textbook education to document a relationship between physical settings and knowledge systems.

Tanner (2000; 2008) was one of the first to investigate the influence of architecture on academic achievement. Although his research does not address the issue of EK directly, but it provides empirical evidences that suggest a link between physical environment and cognition. Tanner (2000) noted that students' interactions with physical surroundings often turn out to be their primary mode of learning. Thus, the study conducted by him was to find out how design factors of school architecture might control and determine the achievement scores of students in their elementary schools. A total of 39 patterns, including “green areas”, “climate control”, “natural light”, “context” and “external views”, were identified from literature review. These patterns were incorporated into an instrument for measuring the impact of design on students' academic achievement. In tune with the Alexander et al. (1977), the design patterns as articulated in the study referred to the structural and changeable architectural elements and natural components of a school. The findings revealed that schools with higher ITBS (Iowa Test of Basic Skills) scores were equipped with computers in several locations, arranged in spaces accessible to students and teachers. ITBS scores also correlated positively with broad and well-lit indoor spaces which allowed freedom of movement. Additionally, Tanner (2000) found that schools which were favourable to nature succeeded to have their students earned high ITBS score. These findings motivated Tanner (2008) to conduct another study to look into the possible effects of chosen school design patterns (i.e. movement and circulation, group meeting places, day illumination and views & instructional neighbourhoods) on third-grade students' academic accomplishment The finding showed the positive output in each case, having the positive correlation among all the school designs variables with student achievement. It paved the way for positive relationship between design patterns and learning outcomes in the selected elementary schools.

Edwards (2006) investigated the relationship between sustainable design and learning outcomes. The research used both empirical and observational techniques based upon comparing qualitative and quantitative data from a number of harmonizing 'green' and 'ungreen' primary schools (Bernardi & Kowaltowski, 2006; Cohen & Trostle, 1990; Schahn & Holzer, 1990). Edwards found that school buildings designed on green principles can offer a number of benefits and facilities for the students. First, linking sustainable design with the education ethos present possible learning advantages, and this advantage presents most obvious in younger age groups of students (Aho, et al., 1993; Farmer, et al., 2007). Second, the excellence of the classroom surroundings emanating from green design approaches reduces students absenteeism (approved and unapproved) and suggests greater satisfaction with the school as a place for learning leading to improved examination results (Peatross & Peponis, 1995). Third, student performances are related to the level of daylight in the classroom involving other significant factors such as ventilation system, the temperature and noise levels. By taking full advantage of students' exposure to daylight, green schools offer educational advantages apart from reducing energy consumption (Kats, et al., 2010).

Mirrahmi et al. (2011) proposed that outdoor learning environment provide opportunities to improve EK. They noted that natural environment helps students to create new knowledge and thus renders a positive impact on the cognitive development (Kruse & Card, 2004; Leeming, Dwyer, & Bracken, 1995; Sandell & Öhman, 2010). Their statement is supported by Bordy (2005) who conducted a study to explain how people learn in natural settings. He proposed a learning theory in nature that relates knowledge systems to physical settings. He noted that for meaningful learning to take place the individual must be aware of the actual experience through the senses (McKenzie-Mohr, 2000). The learner will perceive regularities in nature such as similarities and differences in the characteristics of various species or geologic formations. This leads to concept formation and differentiation related to the setting and experience (Jensen, 2002). Harvey's (1990) study concurred with Bordy's suggestion. He investigated the use of landscape as a teaching resource for botany and EE. His study evaluates the impact of the landscape upon students at 21 junior schools in England. Past and present experiences of 8- to 11-year-old students (N = 845) with vegetation, their botanical knowledge, and their environmental dispositions were measured. The results indicate that both past and present experiences make a small but significant contribution to the students' development of EK and environmental dispositions.

Fančovičová and Prokop (2011) examine whether outdoor education influence participants' knowledge of plants. Participants from one urban school participated in the study. All students were fifth graders (ages 10 and 11) and they were randomly divided into quasi-experimental (N = 17) and control group (N = 17). The quasi-experimental group together with forest experts planted new stocks of trees and visited a meadow that was adjacent to the experimental school. Pre-test, post-test and re-test procedures were applied to measure changes in students' knowledge of plants as a result of the outdoor education. It was found that mean scores of participants' attitudes and knowledge of plants significantly increased after the outdoor programme. These effects remained significant even after three months' post-testing. In addition, Martin (2003) examined the effects of participation in regular outdoor schoolyard EE activities on EK of fourth- and fifth-grade students. A quasi experimental, pretest/posttest, nonequivalent group design was used. The students in the treatment group participated in schoolyard activities to observe trees, conduct inventories of soil samples, or compare plots in sunny and shady locations. ANCOVA analyses revealed that the fifth-grade treatment group showed statistically significant differences in the measures of EK when compared to the control group.

After reviewing the above-mentioned literature, it is anticipated that students who interact with a 3-D textbook would demonstrate an improvement in EK. Empirical research from the field of environmental psychology supports the link between physical environment and students' cognitive development (Rissotto & Tonucci, 2002; Robelia & Murphy, 2011; Tanner, 2000; Tanner, 2008). Previous studies also highlighted that design concept with an emphasis on "sustainability", "nature" or "outdoor" would render a positive impact on students' EK (Bögeholz, 2006; Edwards, 2006; Fančovičová & Prokop, 2011; Harvey, 1990; Martin, 2003; Mirrahmi, et al., 2011; Ramsey & Rickson, 1976). Because a 3-D textbook seems to draw from these strategies, there seems to be theoretical grounding to support the possibility of this architectural intervention improving EK. Additionally, an overview of EE literature reveals that all learning appears to be inextricably bound to the environment in which it occurs (Brody, 2005). Thus, the place-bound contexts may help to form cognitive bridges linking settings with EK (Boeve-de Pauw & Van Petegem, 2011; Miles, 1987; Pearson & Ialongo, 1986). This concurs with the aim of a 3-D textbook to utilize environment as an effective tool to advance EE outcomes. The proposed positive effect of a 3-D textbook on EK is depicted in Figure 2.3.

2.6.2 Environmental Attitude (EA)

The EA of students are a major focus of many EE programs (Prestina & Pearce, 2010). EA, which are consisted of sets of beliefs and are defined as "tendencies to evaluate an entity with some degree of favor or disfavor" (Eagly & Chaiken, 1993, p. 155). EA account for 71–91% of individuals' intention to complete the behaviour, along with subjective norms and perceived behavioural control (Kaiser & Gutscher, 2003; Kaiser, et al., 2005). Generally, physical settings predict attitudes toward environmental issues for adults and adolescents (Carlson & Baumgartner, 1974; Zelezny, 1999). In Tanner's (1980) research, for instance, participants cited interaction with natural areas, frequent contact with habitat and environment alteration as the significant variables that impact their EA (Chawla, 1999; Palmer, 1993; Sivek, 2002; Sward, 1999). Research in the field of environmental psychology has also demonstrated a strong link between place settings and pro-EA for adults (Dietz, et al., 2009; Fredrickson & Anderson, 1999; Halpenny, 2010). At the high school level, Duerden and Witt (2010) found that direct experience with nature correlated positively with pro-EA. Another similar study by Eagles and Demare (1999) found that ecological and moralistic attitudes toward the environment correlated with visiting nature park or gardens. Although researches on primary school students are limited, there are empirical evidences that interaction with physical environment (i.e. natural areas, EE centers & school grounds) mediated the attitudes and norms of students (Zelezny, 1999).

There have been studies examining the effectiveness of outdoor education or day trips to natural areas to improve EA (Leeming, et al., 1993; Zelezny, 1999). For instance, a recent study by Ferreira (2011) has found associations between natural settings and EA. She noted that guided visitation to urban national parks with the necessary and appropriate interpretation can greatly contribute towards EE in general and can also be the point of departure towards fostering environmental stewardship among citizens of metropolitan areas bordering urban national parks (Howie, 1974; Maddock, 1991). Ferreira conducted a research to evaluate a three-day nature-learning experience by school children to Table Msountain National Park. Data were collected through pre- and post-visit questionnaires and supplemented by informal discussions with learners and teachers. It was found that the trip to national park had a minimal impact on the learners' EK. However, it had a reasonable impact on the pro-EA. Additionally, Lisowski and Disinger (1991) investigated students' conceptions of ecological concepts and the influence of field trips on their understanding and retention of these concepts. All groups exhibited statistically significant posttest gains and showed evidence of retaining the targeted concepts and EA.

At the same time, Farmer et al. (2007) examined the long-term effects of an EE school field trip on 30 fourth grade elementary students who visited Great Smoky Mountains National Park, a site devoted to preserving biodiversity. Farmer et al. conducted informal, in-depth interviews in the fall of 2002, a year after the trip, to explore the students' long-term memory recollections of the field trip experience. The findings suggest that one year after the experience, many students remembered what they had seen and heard and had developed a perceived pro-EA. The theme of pro-EA was revealed by evaluating several comments found throughout the interviews for 6 of the 15 students. The students constantly expressed their concern over the pollution and suggested to be more careful with the environment and how to treat it. Upon which students also commented that the cities where people work had been polluted from smoke and also killing the workers there. These sort of statements reflect the preservation of long-term knowledge as well as a pro-EA (Price & Hein, 1991).

Residential EE centres present a number of benefits to students, including the opportunity to be "in" nature. Activities may include pond and stream study or doing in-depth investigation of habitats. Dettmann-Easler and Pease (1999) did a study to examine 6 residential EE centres in the upper Midwest to evaluate their effectiveness in fostering positive attitudes toward wildlife. These residential centres, each with their individual unique facilities and program, took part in this study in the spring of 1994 where from each residential centre, one fifth- or sixth-grade class was selected to participate in this study. Student interviews revealed that students have positive attitudes toward wildlife and enjoyed adventure activities the most, which engage child-environment interaction as these are physically involving. Thus the result of this study make obvious that residential EE centres are more resourceful in fostering positive attitude changes toward wildlife than a single, in-class program. A comparison of delayed posttest scores with posttest scores showed that attitude changes generally were retained for at least 2-3 months.

Harvey (1990) promoted the use of school grounds as a site for EE learning. Harvey encouraged the use of school grounds because they can be unremitting (daily), qualitative (if combined with classroom instruction) and of long period (a student's entire school career). Harvey's (1990) research provided evidence of a relationship between environmental attributes of the school grounds and the affective development of children. It confirmed the role of the school landscape as a teaching tool. Harvey concluded that the "developed" school landscapes with functional and educational gardens were more superior to the undeveloped school grounds in fostering beneficial attitudes to the environment. This was concurred by Cronin-Jones (2000) who examined the effectiveness of using the schoolyard as a teaching tool and found that elementary students learn more through outdoor schoolyard experiences than through traditional classroom experiences. Particularly, the school grounds provide a readily available and practical means for achieving the goals of continuous exposure to the outdoors at regular intervals. This helped to lower the novelty of such areas and build a sense of environmental competence (Martin, 2003).

After reviewing the above-mentioned literature, it is anticipated that students who interact with a 3-D textbook would demonstrate an improvement in EA. Empirical research from the field of EE evaluated the impact of different settings on students' EA (Cronin-Jones, 2000; Dettmann-Easler & Pease, 1999; Duerden & Witt, 2010; Ernst & Theimer, 2011; Ferreira, 2011; Harvey, 1990; Lisowski & Disinger, 1991; Ryan, 1991). These studies highlighted that natural areas, EE centres and school grounds help to foster positive attitudes toward environmental issues. Commonalities can be observed in the literature that highlights a link between nature-inspired settings and EA. Because a 3-D textbook can be design to work with nature, there seems to be theoretical grounding to support the possibility of this architectural intervention improving EA. Additionally, an overview of environmental psychology literature discloses that direct contact with built or natural environment correlated positively with pro-EA (Duerden & Witt, 2010; Eagles & Demare, 1999; Eagly & Chaiken, 1993). This concurs with the characteristic of a 3-D textbook that encourages child-environment interaction. Thus, there is a theoretical potential for a 3-D textbook to mediate the EA of students. The proposed positive effect of a 3-D textbook on EK is depicted in Figure 2.3.

2.6.3 Environmental Behaviour (EB)

Deasy (1974) noted that the destruction of planet is caused by the greed, ignorance and neglect of human race. He proposed to use architecture as a medium to alter this destructive behaviour. He is convinced that behaviour-based design is capable of resolving complex human problems in very practical ways and holds the premise of radical improvements in both the planning process and planning product. The notion of designers wanting to change user behaviour in order to improve the world, society, or the life of their users, is not new (Read, et al., 1999, Wever, 2012). Architects have shown tendency in the past to design from their vision for a better world. An example of the rather extreme forms of this may comes from the Amsterdam School, a Dutch architectural movement (roughly 1915-1930) now classified as expressionist architecture. In the catalogue of an exhibition about the Amsterdam School, Venema (1975) describes the debate among architects within the movement about the level of forcefulness with which the designs of working class dormitories could change the way these people lived. Some spoke of the relationship between architecture and behaviour:

> "One teaches the working class how to live. One teaches them where their table should be placed, where their lamp should be hung, where their bed should stand. And in order to really imprint this on the disobedient, one places the window in the corner, to ensure that the table will be placed there and definitely not in the middle of the room. One screws the lamp hook eccentrically in the ceiling, to ensure that the lamp will not be hung in the middle of the room, and one fixes the bed in a particular corner to ensure that the working class man takes his 8 hours of sleep there, and not where-ever he might prefer himself."
> (Venema, 1975, as cited in Wever, 2012, p. 2)

Building upon the works by Deasy and Venema, Taylor and Enggass (2009) documented that there is a greater message behind the spaces that children inhabit and use. They suggested that sustainable settings (i.e. building and landscape) can help to foster pro-EB, and related emotions and behavioural intentions, which is an important goal of EE. Fink (2011) further explained, "the design of the buildings (offices and homes) and urban spaces offers valuable avenues for influencing behaviour through spatial layouts, physical formations, technical systems and accessibility to and contact with the natural environment, all of which can encourage energy savings that carry over into other elements of daily life" (p. 19). Additionally, Higgs and McMillan (2006) documented that school facilities and operations can promote pro-EB by modelling sustainable practices, reducing the need to preach to students, creating a context for hands-on learning and increasing students ownership and stewardship of their environment.

Direct experience with a variety of ecological systems that help to ameliorate environmental problems in non-traditional settings outside the classroom is also important if students are to learn new behaviours (Jensen, 2002; Jordon, et al., 1986; Lawrence, 1983; Newhouse, 1990). Therefore, a few studies have been directed to examine the effectiveness of EE programs in non-traditional settings such as gardens and playgrounds (Anthony, 1987; Askham, 1974; Blair, 2009; Brown & Burger, 1984; Dyment & Bell, 2007; Tonglet, et al., 2004). These studies may give a clearer perspective on how the physical environment influences students' EB. For instance, Dresner and Gill (1994) investigated the influence of natural settings on students' pro-EB. They found evidence of more environmentally responsible behaviour among the students after participating in a nature camp. They also noted that nature camps were an extension of outdoor schools where students learned about natural processes firsthand, gain greater familiarity with nature and achieve greater comfort in the wilderness (Kruse & Card, 2004). In short, it can be concluded that when students learn how ecosystems function and about environmental action strategies that contribute to their maintenance, they develop more environmentally responsible behaviours (Bamberg & Schmidt, 2003).

There are also empirical researches which demonstrated significant correlations between physical environment and pro-EB. For instance, the use of a demonstration facility as an educational tool and catalyst for behaviour change was investigated by Dietz et al. (2009). Their study centred on the Utah House which was designed to showcase environmentally friendly building techniques, shedding light on sustainable use of resources, energy and water conservation. Survey questionnaires were sent to visitors to determine whether their visit to the house influenced their level of knowledge or more importantly their behaviour. Significant increases in self-reported knowledge were found and the house was a catalyst for behaviour change as per a large percentage (63%) of visitors. Another study by Carrier (2009) explored the relationship between the schoolyard and EB. Particularly, she compared EE conducted in the schoolyard with traditional classroom activities involving the boys and girls of elementary schools. A quasi-experimental, along with pretest–posttest, nonequivalent group design was used. One fourth-grade class and one fifth-grade class from a school with low-to-middle income families were included in the traditional (i.e. classroom) and experimental (i.e. schoolyard) groups. Students from both groups participated in 14-week EE programs. The traditional group's program included indoor classroom activities, while the treatment group's program included outdoor activities. By investigating and analyzing the gain scores (self-reported EB) of the boys and girls independently, the findings reveal that both groups increased their EB scores in the treatment (outdoor) condition when in comparison with the traditional (classroom) condition.

Another recent study by Lawrence (2012) builds on past research linking outdoor recreation and environmentally responsible behaviour (Chawla, 1999; Martin, 2003; Moore & Graefe, 1994; Ozdemir & Yilmaz, 2008; Teisl & O'Brien, 2003) by examining college students' visits to natural areas on campus and how these visits relate to place identity and EB. One hundred fifteen undergraduates (27 men; 88 women) at Guilford College participated in this research. All participants were asked seven items from Vaske and Kobrin's (2001) modification of the Environmentally Responsible Behaviours Inventory (Smith-Sebasto & D'Costa, 1995). The results revealed that involvement in environmentally responsible behaviours had a moderately strong correlation with frequency of visits to the natural areas on campus. The results also supported the hypothesis that spending more time in natural areas on campus was related to stronger identification with these areas as well as more environmentally responsible behaviours. It revealed that even brief encounters with the outdoors through a structured course can have positive environmental outcomes. This is supported by Sandell and Öhman (2010), who suggest that direct experiences with the outdoors encourage students to see themselves in relation to their surroundings, and this relational perspective plays a critical role in the development of EB. Similarly, Vaske and Kobrin (2001) found that experiences with a particular natural area might result in a person coming to see that area as part of their identity, which in turn may lead to greater environmental responsibility.

In general, previous studies provide convincing logic and evidence that the design of physical environment affects pro-EB. Thus, it is anticipated that the 3-D textbook would give an impact to the students' EB. Empirical research from the field of environment-behaviour and EE evaluated the impact of non-traditional settings (e.g. demonstration facility, schoolyard and natural areas) on students' EB. These studies highlighted that physical environment with an emphasis on sustainability or ecology can help to foster environmentally responsible behaviour. Because a 3-D textbook builds upon eco-friendly ideas that integrate man-made and natural environment, there seems to be theoretical grounding to support the possibility of this architectural intervention improving EB. Additionally, an overview of EE literature discloses that school facilities and operations provided the context to foster learning about sustainability and the adoption of pro-EB without the need to preach. This concurs with the aim of a 3-D textbook that promotes direct observation of sustainable practices and thus helping the students to transfer the abstract EE ideas into personal and tangible applications. Thus, there is a theoretical potential for a 3-D textbook to mediate the EB of students. The proposed positive effect of a 3-D textbook on EB is depicted in Figure 2.3.

2.7 TENTATIVE THEORETICAL FRAMEWORK

In the light of the literature review in the previous sections, the author has identified a theoretical framework that could direct the current research (Figure 2.4). This theoretical framework consists of a priori component based on the existing literature and a posteriori component informed by a qualitative study (see Chapter 4). The author acknowledges that forming a complete theoretical framework preceding all data collection is not possible due to several reasons. Firstly, this field of study is relatively new and unexplored (Taylor & Enggass, 2009). Thus, there is insufficient information to develop the design features from the literature. Secondly, the existing researches on 3-D textbook are mostly based on the Western context. Haron et al. (2005) have expressed their concern on the use of Western literature in the study of EE in Malaysia. Thirdly, Creswell (2008) noted that in any exploratory or inductive research, the literature does not guide and direct the study, but rather becomes an aide once patterns or categories have been identified. The current thesis concurs with his suggestion.

In the sequential mixed methodological research design employed for this study (see Chapter 3), a qualitative exploration defined the design features for a 3-D textbook that is tested in a subsequent quasi experiment. Munhall and Chenail (2008) describe the importance of this “atheoretical” approach to exploratory research and specifically warn that “if you study the theory before collecting data, it could influence your perceptions and interpretations” (p. 9). In other words, the data analysis of a qualitative case study in Phase 1 helps to develop and complete the theoretical framework. Therefore, the initial theoretical framework based on existing concepts and theories serves as the foundation for the complete study, while the undefined theoretical components informed by the qualitative study are treated in Phase 1.

Section 2.4 describes five important and credible conceptual orientations that can help to link architecture and EE. All these approaches provide a theoretical foundation that supports the use of physical environment as a 3-D textbook for EE. Such studies are very valuable, but the sociology, education and psychology scholars have not fully explored the potential role of design. Although previous studies illustrate some of the content and benefit of a 3-D textbook, the scholars have not explicitly described all of the design features. Despite these limitations, these existing literatures provide a theoretical lens to view physical environment as a pedagogical tool, thus placing a 3-D textbook as an independent variable that govern the success of EE.

Section 2.5 outlines the learning opportunity offered by a 3-D textbook. In this type of setting, students learn through their interaction with the physical surroundings. Previous studies documented that leaning does not occur in a vacuum or by rote memorization, but through active interaction with the subject under study (Caine & Caine, 1991). Consequently, students' learning can be enhanced and ensured by the ability to interact knowledgeably with the environment. This is proved by the EE literature that all learning process is imperatively bound to the surroundings in which it occurs. Thus, the place-bound contexts may help to enhance EE outcomes, encouraging the development of EK, EA and EB. In short, existing literature discloses that "learning" is an intervening variable that could explain the relationship between a 3-D textbook (independent variable) and EE outcomes (dependent variable). Students appear to learn from a 3-D textbook which in turn affect their EK, EA and EB.

Even though the deficit experimental proof slows down efforts to identify with the control of a 3-D textbook on EE outcomes, the existing studies in environment-behaviour, EE and environmental psychology may assist research effort in this area. Section 2.6 provides a review of literature which suggests a theoretical potential for a 3-D textbook to mediate the EK, EA and EB of students. Looking at these previous studies, the author predicted that a 3-D textbook will positively influence students' environmental performances. As a result, EE outcomes are treated as dependent variables in the quasi experiment where the author gathers numerical information and figures with statistical support to test his hypotheses. The quantitative specifics of this relationship are explored in Chapter 5.

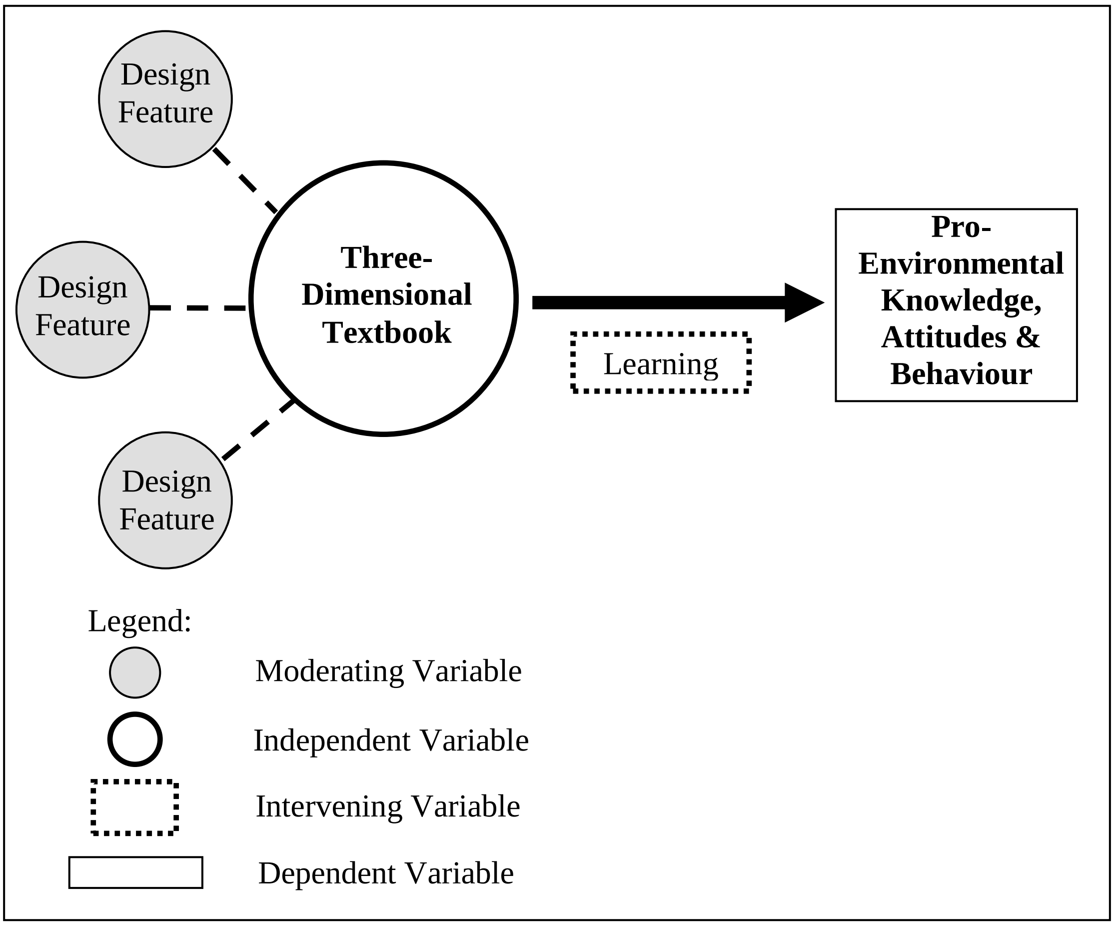


Figure 2.4: Initial theoretical framework

2.8 SUMMARY

Chapter 2 describes five important conceptual orientations that can help to link architecture and EE, providing a theoretical foundation for the current study. However, writings about 3-D textbook are, in general, scattered in many disciplines and are conceptual and theoretical in nature rather than applied. The approach adopted by scholars in architecture, geography, ecology and environmental psychology has been piecemeal. Despite these limitations, the existing literatures provide a theoretical lens to view the physical environment as a pedagogical tool, thus placing a 3-D textbook as an independent variable that govern the success of EE. Additionally, an overview of EE literature reveals that all learning comes out to be significantly bound to the atmosphere within which it functions. Students appear to learn from the physical settings which in turn affect their environmental performances (i.e. knowledge, attitudes and behaviour). Even though the lack of empirical evidence hampers efforts to understand the influence of the 3-D textbook on EE outcomes, existing studies suggests a theoretical potential for a 3-D textbook to mediate the EK, EA and EB of students. In the light of the literature review in this current chapter, the author has identified a theoretical framework that could direct the current research. The data analysis of a qualitative case study in Phase 1 will helps to develop and complete this initial framework. This is in line with in the sequential mixed methodological research design employed for this study.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Chapter 2 discussed the current knowledge that embraces architecture and EE. The research questions or hypotheses presented in Chapter 1 provide a basis for exploring the concept of "3-D textbook" in relation to the desirable EE outcomes – pro-environmental knowledge (EK), environmental attitudes (EA) and environmental behaviour (EB). This chapter will map the research questions and hypotheses with the research process. The current study has been arranged in two sequential phases. The first phase aims to explore the design features of the 3-D textbook. A second phase is then required to measure the effectiveness of this architectural intervention. This two-phase method is known as the exploratory sequential mixed methods design (Creswell, 2009). Chapter 3 draws upon works by Creswell and Clark (2011), Tashakkori and Teddlie (2003), etc to discuss the holistic principles of the mixed methods adopted.

3.2 Rationale for Using Mixed Methods Research

The apparent untapped potential of 3-D textbook and its undefined design features invites further investigation. The complexity of the problem and issues beg for a blending of qualitative and quantitative data (Buck, et al., 2009; Clark, et al., 2013; Fielding, 2012). Mixed methods research is identified as the preferred design due to the following reasons.

In the current study, qualitative information is required before doing quantitative research for the intervention to take shape. Creswell (2007) noted that mixed methods research provides a good method for this type of problem that needs to be explored qualitatively at the beginning. Nastasi et al. (2007) proposed that the process of intervention development research is best characterized by a sequence of qualitative and quantitative data collection. In this process, the intervention development is guided by qualitative methods in order to generate formative data, followed by quantitative evaluation that tests the effectiveness of the intervention. Therefore, the present research process begins with collecting qualitative data to identify and define the design features specific to a 3-D textbook. Collection and analysis of qualitative data help to uncover environmental conditions that support and enhance EE.

The intention to generate and test the design features for 3-D Textbook also begs for the blending of qualitative and quantitative approaches. One type of evidence may not tell the complete story and thus using only one approach to address the main research question would be deficient. Combining qualitative and quantitative data gathering techniques, the author can clarify subtleties in the data, cross-validate the findings and can reason on efforts to plan, implement and assess the design strategies. Particularly, the mixed methods design enabled the author to integrate the data and write up the research in a way that both components were mutually illuminating (Kington, et al., 2011). This is in line with methodological literatures which suggest to adopt a stance centred on the conceptualization of a problem and a ‘‘fitness for purpose’’ approach to the selection of methods (Bryman, 2007). Combining the various methods provides stronger evidence for the conclusions through convergence and corroboration of findings (Johnson & Onwuegbuzie, 2004). It also reveals the key factors that influence the design of 3-D textbook and the relationship between architecture and EE.

In the current study, the author attempt to offset the weakness of both quantitative and qualitative research by adopting a mixed methods design. For instance, the author acknowledged that the qualitative research in Phase 1 is seen as deficient because of the personal interpretations made by him, the ensuing bias created by this, and the difficult in generalizing findings to a larger group because of the limited number of interviews in a single case study. Thus, a quantitative approach has been adopted in Phase 2 to make up for these weaknesses. Additionally, the author embedded qualitative data within a quasi experiment in Phase 2 to examine the intervention qualitatively in addition to the quantitative results. Qualitative data was collected during and after the intervention trial in order to clarify the results of the intervention. By examining participants’ perspectives during their intervention trial, the author can better realize the findings of the intervention study. In short, the combination of qualitative and quantitative data provides more comprehensive evidence for studying the 3-D textbook. This is in line with methodological literatures, which promote the mixture of qualitative and quantitative methods to minimize the risk of over reliance on one method of data collection (Pintrich & Schunk, 2002).

3.3 Selecting a Type of Mixed Methods Design

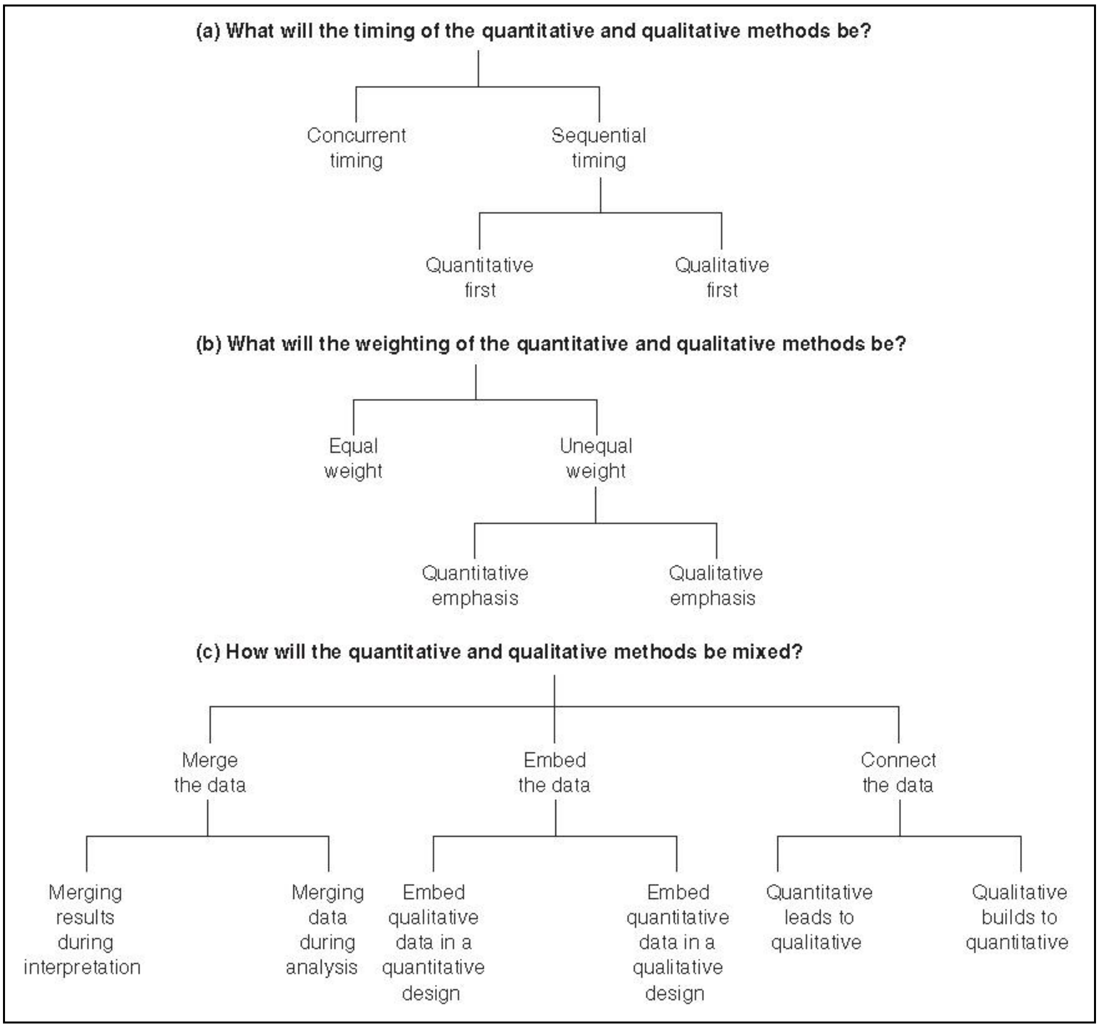


Figure 3.1: Decision tree for mixed methods design criteria
for timing, weighting and mixing
(Source: Creswell & Clark, 2007, p. 80)

The research problem and literature present a strong evidence to adopt both qualitative and quantitative approaches. Creswell and Clark (2007) documented that when a researcher has selected mixed methods approach for his or her study, the next step is to decide on the specific design that best addresses the research problem. They noted that there are four major mixed methods design, namely triangulation, embedded, explanatory and exploratory. Each design types can be further classified into a few variants according to the decision tree in Figure 3.1. They highlighted the importance of selecting a type of mixed methods design that best matches the research problem so that the study is more manageable and simpler to implement and describe. The three important considerations when choosing an appropriate design are:

1. the timing of using the collected data
2. the relative weight of the qualitative and quantitative methods
3. the approach to mixing the two datasets

The Timing Decision

Timing refers to the temporal relationship between the quantitative and qualitative components within a study (Greene, et al., 1989). In the present study, two issues are highlighted in the literature review. Firstly, the literature provides very little information on the design features of a 3-D textbook. Secondly, the impact of this architectural intervention on EE outcomes is uncertain. Thus, the procedure to be followed here to fill up these gaps seems to be qualitative followed by quantitative. The first issue is about discovering new design features, so the suitable approach would be qualitative. While the second issue is about proving whether a 3-D textbook impacts EE outcomes, so the suitable approach would be quantitative. As a result, the sequential timing (that starts with the collection and analysis of qualitative data followed by the same on quantitative data) is most appropriate for this present study.

The Weighting Decision

Weighting denotes the relative importance or priority of the quantitative and qualitative methods to answer the questions in the study. The main goal of this research is to identify important design features that were not known beforehand and then test its effectiveness. Thus, the author uses the research questions and hypotheses to shape the mixed methods design. At first, qualitative data is collected which then begins the next quantitative phase. The qualitative component in this type of design is clearly not an adjunct. Because the design starts qualitatively, data gathered from the method is considered to bear great importance. (Creswell & Clark, 2007). Qualitative data is used to generate theories or variables that are grounded in the viewpoints of the participants that is subsequently tested or refined using quantitative methods (Bryman, 2004; Creswell, 2003). Therefore, quantitative data plays a less dominant role by acting as a supplement to qualitative research (Creswell, et al., 2006). Particularly, the quantitative data helps to enhance the generalizability, replication, reliability, and validity of the mixed methods research.

The Mixing Decision

Mixing denotes the relating of the two data sets explicitly. In this present study, the author starts with qualitative findings, which provides the basis of subsequent collection and analysis of quantitative data. Thus, mixing occurs by connecting these data types. Decisions are made prior to the commencement of Phase 2 about how the findings from qualitative methods will be used to influence quantitative data collection and analysis. Furthermore, qualitative approach is “embedded” within a quasi experiment in Phase 2 to merge elements of two methods within one study. It takes advantage of the benefits of singular methodology as well as to consolidate the phasing of triangulation (Robinson & Mendelson, 2012). In short, the mixing of the qualitative and quantitative data in the current research is both “connected” (from Phase 1 to Phase 2) and “embedded” (Phase 2).

3.4 RESEARCH DESIGN

Research design is important in guiding the research to answer the research questions. In addition, research design provides a logical sequence that connects between questions and conclusion through data collection, analyses and interpretation (Yin, 2003). Creswell and Clark (2007) documented that research designs are measures to collect, analyse, interpret and report data in research studies. They noted that rigorous and high-quality studies result from well-planned research procedures.

The taxonomy development model is a variant of the exploratory sequential design (Figure 3.2 and Figure 3.3). It is identified as the most appropriate design because it matches the timing, weighing and mixing decisions as outlined in Section 3.3. The taxonomy development model adopted for this present study is characterized by:

- Timing - sequential (qualitative data followed by quantitative data)
- Weighting - a greater emphasize is placed on qualitative data
- Mixing - “connected” (from Phase 1 to Phase 2) and “embedded” (qualitative data within quantitative research in Phase 2)

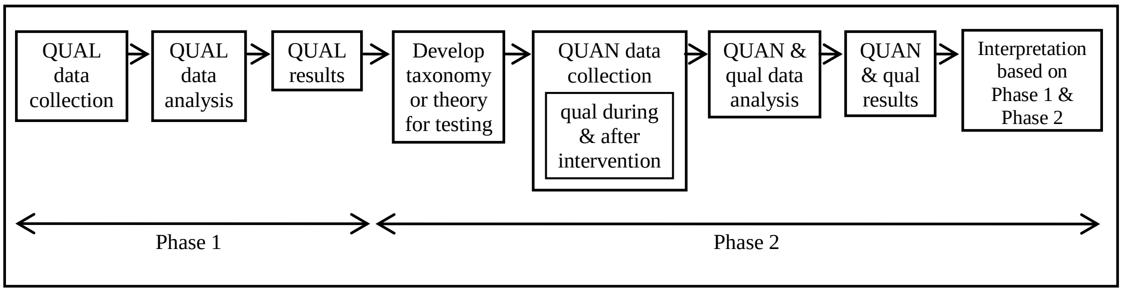


Figure 3.2: Exploratory design: taxonomy development model
(Adapted from Creswell & Clark, 2007)

The EBD framework is a useful guide to the current research design. EBD promotes the conceptualization, evaluation and testing of design concepts through a succinct, organized process. Scholars noted that EBD is vital in any design-orientated research that aims "to reduce uncertainty and or error when designing environments for human occupation and aid in making crucial design decisions" (Kopec, et al., 2012, p. 3). EBD is grounded in the scientific method of quantitative and qualitative research, thus it can be implemented along with the mixed methods design to create a highly robust research. The present study combines the evidence gathered from the physical modelling and social science methods as recommended by Brandt et al. (2010). These techniques help to create access to data that the author can understand, interpret and act on to inform his study.

The research is implemented in three stages in accordance to a EBD framework (Lippman, 2010; Louw & Forlizzi, 2004). The 'discovery' stage (i.e. Phase 1) involves a broad search for inspiration and ideas supported by site, users and subject of research. The author also examines the existing literature to establish an initial theoretical framework. The 'development' stage (i.e. Phase 2) brings together insights, intuitions and research findings from the discovery stage and defined the constraints of the problem in order to generate the initial design solutions. The 'evaluation' stage (i.e. Phase 2) established the subsequent nature and details of the design through modelling and user testing. It helps to track the implications of the design implementation. Table 3.1 maps EBD framework to the research questions, hypotheses and the sequential mixed methods phases proposed.

Phase 1 utilizes a case study to uncover the design features of a 3-D textbook. Groat and Wang (2002) defines case study as "an empirical inquiry that investigates a phenomena or setting" (p. 346). In the current research, the case study focuses on the exploration of the 3-D textbook in its real-life context. This is in line with Zeisel's (1981) writings, "A case study is appropriate when investigators are interested mainly in information specific to the particular study object and context, rather than information easily generalizable to a large population" (p. 65). Thus, the context of the case becomes virtually inseparable from the definition of the 3-D textbook (Yin, 2003). Particularly, it provides multiple sources of evidences for the development of this architectural intervention (Kopec, et al., 2012). These evidences come from two main sources, namely interviews and observation. This echoes Yin's (2004) writings that when any finding or conclusion in a case study is based on several different sources of evidences, it is likely to be much more convincing.

Phase 2 adopted a quasi experiment to provide empirical evidences on the effectiveness of the 3-D textbook in enhancing EE outcomes. This is in line with Zeisel's (1981) writings, "An experimental design is appropriate when investigators want to measure the effects that an action has in a particular situation" (p. 69). A physical model is used as a pivotal medium to test the relationship between architectural design and EE outcomes. It reveals to the author potential findings that could not have been understood without testing a physical representation of the 3-D textbook. The deductive approach of the experimental research is utilized to create evidence that applicable to the design of educational facilities. It adds tangible value to the end users and makes a case for a new design solution, thereby enhancing innovation. The quasi experiment also offers the author the unique opportunity to observe participants in natural surroundings that a contrived setting could not re-create. Thus, the author is capable of collecting additional evidences to compare effects before-and-after the intervention trial.

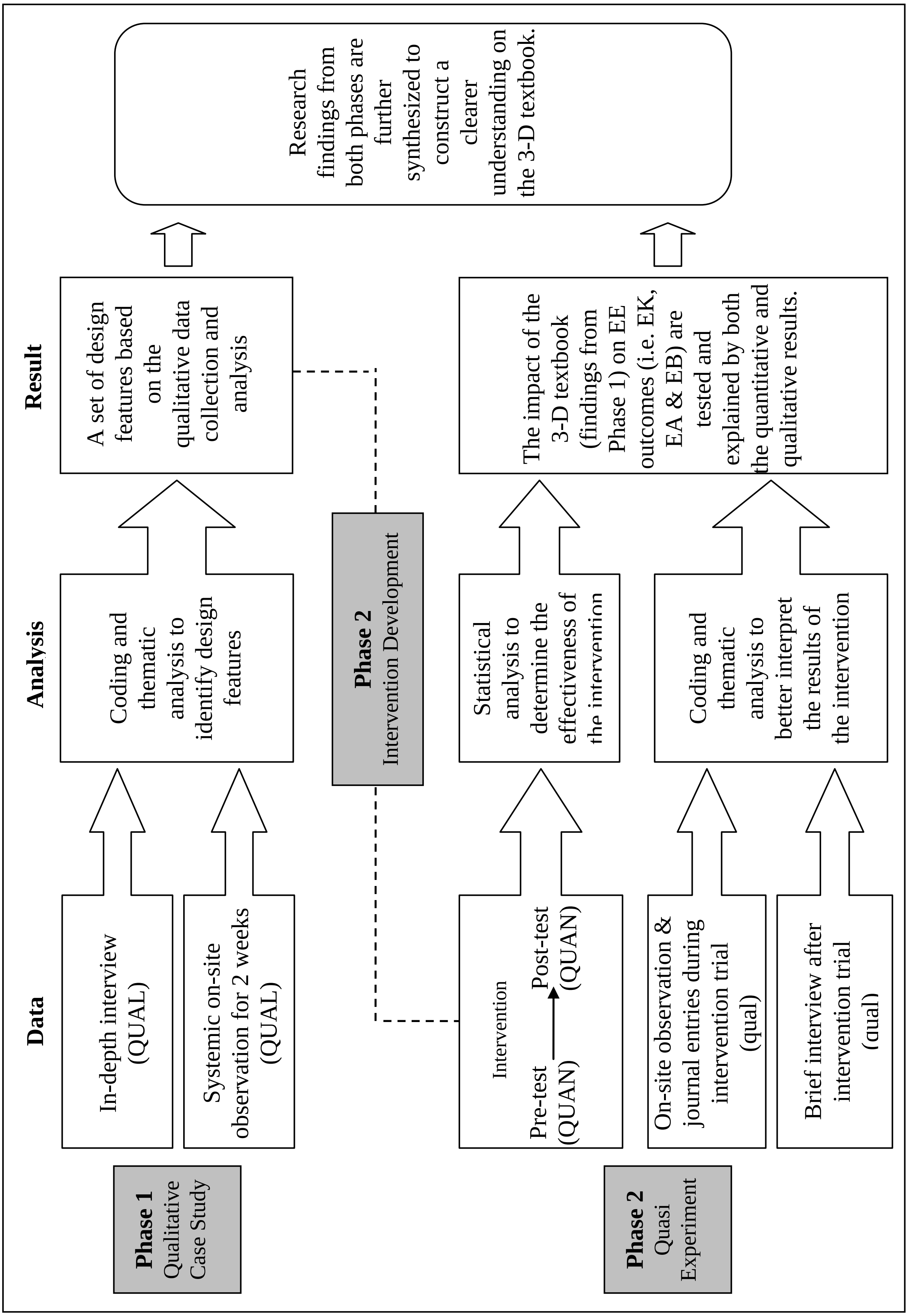


Figure 3.3: Research Design

Table 3.1: Mapping of the research questions/hypotheses, EBD framework and sequential exploratory design

	Research Questions / Hypotheses	Sequential Exploratory Design		EBD Framework	
Phase 1	**RQ1**: What are the design features of a 3-D textbook which encompasses architecture and EE?	Qualitative	To uncover the design features of a 3-D textbook.	Case Study	Evidences from interviews and observation.
Phase 2	**RQ2/H1**: Students would demonstrate an improvement in environmental knowledge (EK) when they interact with the 3-D textbook than when they receive no treatment.	Quantitative	To test the effectiveness of the 3-D textbook to improve pro-environmental knowledge.	Quasi Experiment	Evidences from statistical analysis.
	RQ3/H2: Students would demonstrate more pro-environmental attitudes (EA) when they interact with the 3-D textbook than when they receive no treatment.	Quantitative	To test the effectiveness of the 3-D textbook to improve pro-environmental attitudes.	Quasi Experiment	Evidences from statistical analysis.
	RQ4/H3: Students would engage in more pro-environmental behaviour (EB) when they interact with the 3-D textbook than when they receive no treatment.	Quantitative	To test the effectiveness of the 3-D textbook to improve pro-environmental behaviour.	Quasi Experiment	Evidences from statistical analysis.
	RQ5: How do students perceive the impacts of the 3-D textbook on their environmental knowledge, attitudes and behaviour?	Qualitative	To explore what participants actually experienced during the intervention.	Quasi Experiment	Evidences from journal entries, observation and interviews.

3.5 PHASE 1

The aim of Phase 1 was to determine the design features of the 3-D textbook. It required data to be collected from a case study (Figure 3.4). The reminder of this section detailed the processes of research which constitutes Phase 1.

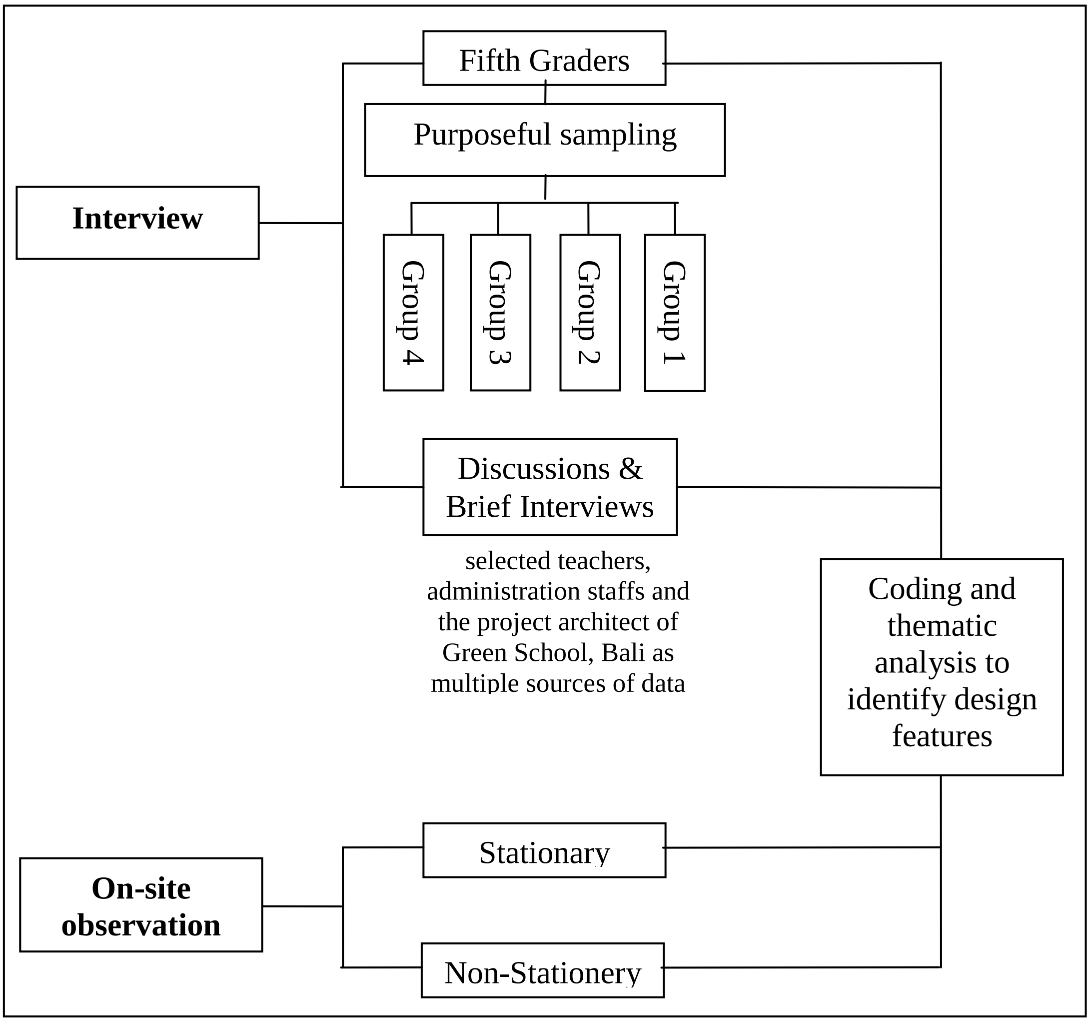


Figure 3.4: Phase 1 – qualitative case study

3.5.1 Case Selection and Description

In the beginning of this study, the author identified the possible choices of a case study through the review of literature on school design, analysis of visual and audio materials in a library, asking the opinion of colleagues, EE experts and design practitioners and an internet search using keywords like ‘sustainable learning environment’, ‘ecological school’, ‘green educational facilities’, etc. Subsequently, the author contacted the short-listed schools via email correspondence or informal phone interviews to gain a better understanding of the school design in relation to EE. After a series of reviews and discussions, the Green School in Bali, Indonesia had been identified as the ideal case study due to its exceptional approach in greening its campus. Unlike the conventional schools that merely made a few token gestures toward sustainability, the Green School was designed from a sensitive understanding of the educational and ecological contexts. The school design reflected an excellent illustration of the term ‘3-D textbook for EE’.

The Green School nestling deep in the tropical rainforest, is an international school that echoes cofounder John and Cynthia Hardy’s vision in creating a future sustainable community (Figure 3.5). Commencing in 2008, the Green School has attracted both local and international attentions, including press coverage by the global communication media such as CNN, BBC and CNBC. On April 20th, 2012, Green School was awarded the 2012 “Greenest School on Earth” award by Rachel Gutter from the Center for Green Schools at the USGBC (U.S. Green Building Council, 2012). Additionally, the school was named as a finalist in the 2010 Aga Khan Award for Architecture, which honoured projects that exhibit architectural excellence as well as improve people’s overall quality of life. It was described as a holistic green community that seek to inspire students to be more curious, more engaged and more passionate about the environment and the planet (The Aga Khan Development Network, 2007). The school serves to cater to the different educational needs and levels of students from nursery to secondary school, combining the Cambridge International Curriculum with Green Studies and creative arts. When the author conducted the case study visit, there were more than 200 children from 40 countries enrolled in the school. 20 percent of this cohort consisted of the local Balinese children with their school fees being sponsored by scholarships.

The Green School offers an unprecedented learning environment that attempts to bind the two disciplines of architecture and EE together. Additionally, the school signifies a total departure from the industrial-like educational facilities. In order to fulfil the school's vision to inspire and lead the world of education and sustainability (Green School, 2011), the school as a whole is designed as a real life example of sustainable living. The buildings in the Green School are constructed out of bamboo, *alang-alang* (blady) grass, mud and other local materials (Figure 3.6). The use of chemicals, toxic or non-sustainable materials is avoided to minimize pollution and energy expenditure in the building production. For example, bamboo is widely adopted in the process of design and construction due to the material's attributes as a low-impact and rapidly renewable material.

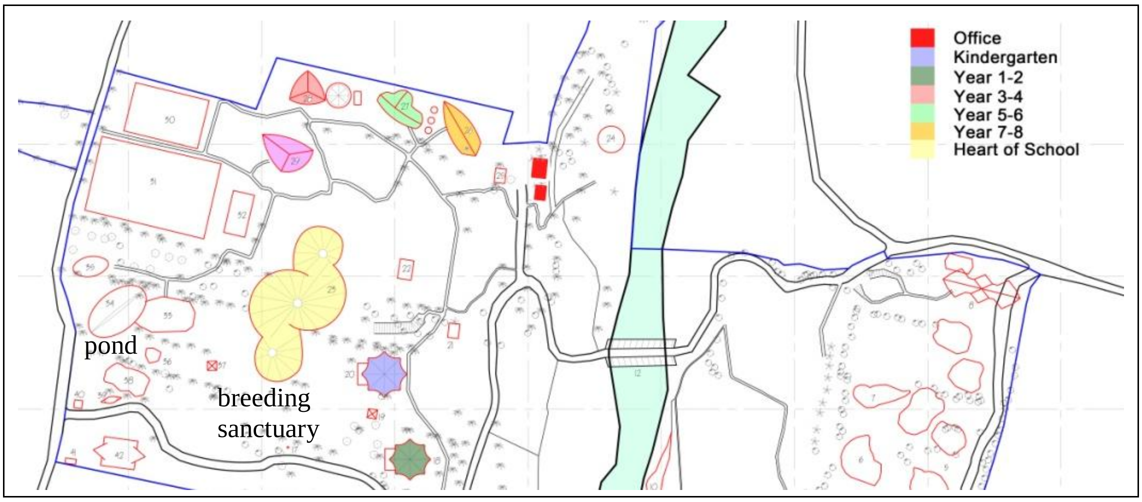


Figure 3.5: Site plan of Green School, Bali

Figure 3.6: School buildings constructed with local materials

The classrooms are completed with no walls, allowing for natural ventilation to occur while assisted with the ceiling fans. The open concept of the classroom creates a closer relationship between the student and nature, encouraging the use of the surrounding environment as an interactive teaching material, for example by integrating sight and sound of nature into the learning spaces (Lim, 2010). In addition, the school grounds are utilized as organic planting plots for the students to grow, harvest and consume their own vegetables and fruits. The sustainable building elements and equipment include a 9-metre water vortex power plant, a biogas reactor supplying methane gas from the decomposition of cow manure (Figure 3.7) and composting toilets, which were also components of the EE syllabus. In the near future, the school plans to be completely off the electrical power grid by installing solar panels combined with generating hydroelectric by the water vortex in the adjacent river.

In short, the Green school symbolizes the first of its kind learning facility that presents as a valuable case study for 3-D textbook, by striving to minimize the carbon footprint using experimental and innovative architecture. More importantly, the school reaffirms suggestions for a 3-D textbook (Orr, 1993; Taylor & Enggass,

2009) by utilizing the physical environment (i.e. buildings and landscape) as a pedagogical tool to transmit the message of sustainability directly to the students. This is in line with Zeisel's (1981) writings, "In locating sites to carry out such studies, investigators look for situations, settings and events that reflect theoretically relevant questions" (p.73).

Figure 3.7: Water vortex power plant (left) and
biogas reactor using cow manure (right)

3.5.2 Data Collection

The author began the case study by drafting a research protocol for approval by the Green School administration. He made explicit that he would not disturb the daily routine and learning activities of the students. He also limited his study to the responses of students in primary years, with a focus on fifth graders, rather than expand it to include students in secondary years. Additionally, this study was bounded by time (two weeks) and by a single case (Green School, Bali). This bounding of the study was consistent with an exploratory qualitative case study design (Creswell, 2007), which was chosen because models and variables were not available for investigating students' responses to 3-D textbook in a school setting.

The fifth-graders were identified as the appropriate participants for three main reasons. Firstly, the students were familiar with the school routine and understood the students' role. Secondly, the fifth-graders would be neurologically mature and should establish the required functional levels of literacy, including other basic academic and learning skills by that stage of their academic careers (Tempest, 1987). Thirdly, as the highest grade in the primary school, the fifth-graders were sufficiently knowledgeable due to the five years experience of the learning environments, where they undergone most of the EE syllabus (Tanner, 2000).

The author employed specifically two methods for data collection, namely on-site observation and in-depth interview techniques. The qualitative research methods would elicit meaningful textual and graphical data articulated by individuals expressed feelings about the environment. Thus, the individual interviews were deemed to be more appropriate compared to other qualitative research methods (Gaskell, 2000). The author acknowledged that focus group was not suitable for the present study due to several reasons. Firstly, interviews were conducted during classroom lessons. Thus, permission was granted to interview only one student at a time so that the flow of the lessons would not be disturbed. Secondly, in the author's previous studies, he noted that some of the students tended to be left out during focus group sessions. It was found out later that these students were not comfortable in expressing their opinion in front of their peers. The author had subsequently consulted two associate professors from University of Malaya who specialized in elementary school research. Their advice was to conduct a face-to-face individual interview to build a rampart trust with the students so that they could express themselves better and confidently. Thirdly, as the qualitative data emphasized on personal preferences and opinion about the learning environment, individual interview was a better choice as compared to focus group. Furthermore, the in-depth data and contextual information generated by individual interviews would provide for the depth of inquiry and detailed information required to question and uncovered the underlying attributes of a 3-D textbook which reflected the aim of Phase 1 (Fredrickson & Anderson, 1999).

All students in primary years were included in the on-site observation while the in-depth interviews were only conducted with the selected fifth graders. In addition, discussions and brief interviews were carried out with selected teachers, administration staffs and the project architect of the Green school, Bali, used as multiple sources of evidence to address the limitation imposed by individual interviews. This additional data supported and clarified the information gathered from the students' interviews.

3.5.2.1 On-site observation

On-site observation technique was designed to record particular occurrences and circumstances such as how the students would use the school ground and how they would response to different environmental stimuli (Zeisel, 1981). This collected information served as a point of reference for the in-depth interviews and subsequent data analysis. The on-site observation technique also facilitated an approach to achieve a level of trust with the students in order to promote the open sharing of information and honest response especially during their interview sessions (Fredrickson & Anderson, 1999). The observations were carried out during the two-week visit to the Green School where both physical traces and environmental behaviour were recorded (Table 3.2). Before the final study, the author carried out a pilot case study in one of the primary schools in Kuala Lumpur, Malaysia, which assisted to fine-tune the observation recording technique.

In term of physical traces, both indoor and outdoor spaces in the Green School were examined to understand what design decisions its builders made about the environment, how a place got to be the way it is, how students actually used it, how students perceived their surroundings and in general how different educational settings met the needs of its users. Particularly, the author took photographs of the outdoor traces and indoor traces to generate possible issues for further discussion during the interview sessions. The focus was to understand what a physical setting might reflect and what intend might be behind it.

In terms of environmental behaviour, the author conducted stationary and non-stationary observations to record how students use the physical environment. Particularly, the author looked at how a physical setting supported or interfered with the EE activities taking place within it to generate data about the behavioural opportunities and constraints that environments provide. The author conducted stationary observations at the outdoor spaces (e.g. garden, farming plot, playing field, etc) where there was a wider field of vision; while non-stationary observations were conducted in indoor spaces (e.g. classroom, library, multipurpose hall, etc), which limits visibility (KasalI & Dogan, 2010). The activities, its characteristics (e.g. group, individual, exploratory, etc) and number of participants to the observed activities were recorded along with the location where the activity occurred. In addition, the author spent a considerable amount of time with the fifth-graders as a passive observer during their formal lessons. The author collected an extensive number of field notes, sketches and photos to record on the spatial information relating to students' activities. The author was also invited to join as a facilitator for the fifth grader's "Chicken Coop" project where he contributed his idea and expertise in the design and build processes. This helped to reduce the Hawthorne effect (that subjects who knew they were being observed often changed the way they acted) because the fifth-graders were able to spend time and work with the author to get used to his present in the classroom so that they regarded him as a facilitator instead of a stranger or an outsider (Zeisel, 1981).

Table 3.2: Daily observation schedule

	Time	**Places**
Before School	8.00am-8.10am	Garden, Farming Plot
	8.10am-8.20am	Heart of School, Gym
	8.20am-8.30am	Walking around campus
During Recess	10.20am-10.40am	Heart of School, Playing Field, Gym
	12.30pm-12.50pm	Heart of School, Playing Field, Gym
	12.50pm-1.15pm	Walking around campus
After School	2.15pm-2.25pm	Playing Field, Gym, Garden
	2.25pm-2.45pm	Walking around campus
	2.45pm-3.05pm	Library
During Formal Lessons	8.35am-9.25am 9.30am-10.20am 10.45am-11.35am 11.40am-12.30pm 1.20pm-2.10pm	The author served as a passive observer in Grade Five Classroom, Art Studio, Mepantigan, Garden, etc depending on the daily lessons

3.5.2.2 Student's Interview

A general interview guide was developed using Malone's and Tranter's (2003a) interview protocol as a point of reference. Prior to the interview, 23 fifth-graders were encouraged to draw two pictures illustrating their perceptions of the Green School and how they would like their school to be changed (Figure 3.8). Instructions were kept to the minimum and non-prescriptive so that each student could express their thoughts and feelings spontaneously through their drawings. Subsequently, the students selected for the in-depth interview sessions were done according to maximum variation sampling (Creswell, 2007, p. 127). 3 fifth-graders identified to be of 'good, average and weak' according to their examination result in year 2011, were interviewed each day. All interviewees were informed that the intention of the study was to explore the notion of the 3-D textbook and they knew that they could decline to reply any questions and stop the interview at any time. Additionally, the interviewees had assurance that if the interviews were quoted in the research results, their actual names would be replaced by pseudonyms. Typically, interviews were conducted for 25–35 minutes, face-to-face and audio recorded. It was observed that a total of 12 fifth-graders were interviewed before the saturation of data occurred (arrived at a point where no new information could be gathered) (Lindlof, 1995).

The interview questions were designed to be open ended to encourage the students to express at length their experience as users and occupants of the Green School (Appendix B). Whenever required, the author would ask follow-up questions to construct a clearer understanding on the topic discussed. An example of the interview questions below will clarify on how the interview was conducted:

1. Please briefly describe the Green School to me.
2. Looking at your first picture, can you please explain it to me and label the important places on it?
3. Can you please list all the places that you use in your school? What activities do you usually do at these places? Do you learn anything from these places?
4. Tell me how you feel about your classroom and other school buildings. What you like and dislike about it?

Figure 3.8: Drawing of pictures as part of the interview protocol

3.5.3 Data Analysis

All interview data underwent the transcription process where the audio information was converted into written text and stored in a computer database (Creswell, 2008). Verbatim transcription was done manually without using software. The analysis for Phase 1 served to answer the research question concerning the design features of the 3-D textbook. Adopting Glaser and Strauss's (1967) method of constant comparison, and Miles and Huberman's (1994) suggestions for coding qualitative data, the author and two coding staffs identified and classified all experiences that the interviewees indicated or referred to in the interviews that related to the use of physical setting as pedagogical tool. The analytic process was based the grounded theory approach, characterized by the immersion in the data involving repeated sorting, coding and comparison (Morrow & Smith, 1995). This process was completed in several iterations (Strauss, 1987). First, open coding was conducted to examine sections of text made up of individual words, phrases and sentences (Creswell, 2009). Particularly, the transcriptions were read to gain a general essence of the interviewees' replies. Labels were generated next to each sentence or paragraph to reflect initial coding (Lindlof, 1995; Merriam, 2009). From these labels, an overall grouping system of the interviewees' responses was developed.

Second, the initial scheme was classified into concrete categories and sub-categories in order to identify themes. The categorization represented similarity of responses (in regard to the design of educational settings) and frequency of responses. An initial theme was only included if at least half the interviewees had identified it. At the same time, axial coding was employed where data was put "back together in new ways by making connections between a category and its subcategories" (Creswell, 1998, p. 290). Next, the transcripts and field notes were read to search for regularly occurring terms and unanticipated counterintuitive material that gave atypical proof of interviewees' experiences (Denzin & Lincoln, 1994). The students' drawing, photo, sketches and field notes were used as indicators of consistency throughout the process of analysis (Creswell, 2008; Huberman & Miles, 2002). Furthermore, these indicators offered prospective insights that might not had been vocalized by the combined interviews (James & Bixler, 2008). The responses were categorized according to several initial themes, such as green technology, site-specific features, reused components and adaptable spaces.

Third, these themes were reviewed to find out how they fit into existing design theory or how they might enhance the understanding of the 3-D textbook. During this step, two criteria was employed (Patton, 2002): Does the information confirm the five theories in Section 2.3 (See Chapter 2), and does it offer new insights into the interpretations of the 3-D textbook? At the same time, selective coding was adopted where the core categories were systematically linked to other categories, validating these relationships with existing studies and filling in categories that needed additional fine-tuning and improvement (Merriam, 1998). Progressing with this third step, the author also thought about students' reaction to different physical settings and how these actions may have fulfilled the objective of the 3-D textbook. Codes and categories were continuously sorted, compared and contrasted until a saturation occurred – that is, until all of the data were accounted for in the core categories and analysis could no longer generate any new codes or categories (Morrow, 2007; Munhall & Chenail, 2008). As a result, the initial categories were combined and renamed into four main themes. Finally, the responses were reread and categorized into one of the four themes to make sure goodness of fit. After this step, the author determined that the resulting four themes sufficiently reflected the responses given by the students.

3.5.4 Validity and Reliability

In qualitative research, the need for validity, reliability and generality had been the subject of debate, particularly their appropriateness in the qualitative paradigm as opposed to quantitative paradigm (LeCompte & Goetz, 1982). Many perspectives existed regarding the importance of validation in qualitative research, the definition of it, terms to describe it and procedures for establishing it (Creswell, 1998). The current research augments validity through adopting some of recommendations by Creswell and Miller (2000). Firstly, the author employed prolonged engagement and persistent observation in the field included building thrust with interviewees, learning the daily routine of the Green School and checking for misinformation that stems from distortions introduced by the author or interviewees (Glesne & Peshkin, 1992; Merriam, 1998). Predominantly, the author made decisions about what was salient to the research, relevant to the aim of Phase 1 and of interest for the 3-D textbook in the field. This concurred with Fetterman's (1998) suggestion to work with the study samples day in and day out in a reasonable periods of time to establish the validity and vitality of a qualitative research. Secondly, the research made use of multiple and different sources of information as a triangulation technique to provide corroborating evidence (Glesne & Peshkin, 1992; Merriam, 1998; Miles & Huberman, 1994; Patton, 2002). Particularly, this process involved corroborating evidence from students' interviews, field notes, drawings, sketches, photos and brief interviews with selected teachers, administration staffs and the project architect to shed light on the themes and perspective.

Thirdly, the author verified the descriptions and interpretations by conducting peer review sessions (Creswell, 2003; Glesne & Peshkin, 1992; Lincoln & Guba, 1985) with interested colleagues and practitioners including an architect and a primary school teacher. These reviewers examined the coding and data analyzed during the ‘peer debriefing sessions’ to confirm emerging themes and findings. They checked and verified the research process by asking critical questions about methods, findings and conclusions.

In the current research, reliability was addressed in several ways (Silverman, 2005). Firstly, the author enhanced the reliability by acquiring detailed field notes, employing a good quality audio recorder with verbatim transcription. Thus, interviews were transcribed to indicate the trivial, as well as crucial, pauses and overlaps (Creswell, 2003). Additionally, coding was done “blind” with two coding staffs without prior knowledge of the expectations and questions of the project direction. Creswell (1998) noted that reliability in qualitative research often referred to the stability of responses to multiple coders of data sets. Therefore, the author implemented an intercoder agreement based on the use of multiple coders to analyze and transcript data (Armstrong, et al., 1997; Miles & Huberman, 1994). To achieve this goal, the three coders (the author and two coding staffs) read through several transcripts independently coded each manuscript. Next, the coders met and examined the coding after they coded four transcripts. As a result, a preliminary qualitative codebook of the major codes was developed, containing a definition of each code and the text segments that assigned to each code. The three coders then each independently coded four additional transcripts and met again to compare their codes. The focus was to have agreement on the text segments they were assigning to codes than to have the same, exact passages coded. The author sought to establish a majority agreement upon codes for the passages. Thus, a minimum of two persons out of the three coders must agree on the assignment of a code word to the text segment in order for the coding to be accepted. After the process continued through several more transcripts, the initial codebook was revised. The coders conducted anew assessment of passages that they all coded and determined if they had used the same or different codes.

3.6 PHASE 2

This phase brought together research findings from Phase 1 to refine the theoretical framework and develop a physical model for the subsequent quasi experiment. In conjunction with a sequential exploratory design, the scope of investigation was refined upon the completion of Phase 1. Particularly, the author drew on Phase 1 findings to refine his research questions and hypotheses. Additionally, the qualitative findings from the Green School, Bali were translated into a physical model for further validation and generalization. The full-scaled model was treated as a simplified representation of the 3-D textbook. It was the key linking Phase 1 findings to Phase 2 testing. Working with the interdisciplinary partners, the author developed an initial scheme for the physical model based on the design features identified in Phase 1. This scheme would be further developed during the "Design, Build and Operate (DBO) Workshop". Participating students (i.e. the participant group) would be given opportunity to contribute their opinion and view to formulate a final design.

Phase 2 aimed to test the effectiveness of the 3-D textbook on real life students. It was a quasi experiment that gathers numerical information and figures with statistical support to strengthen the findings from Phase 1 (Figure 3.9). The reminder of this section detailed the processes of research which constitutes Phase 2.

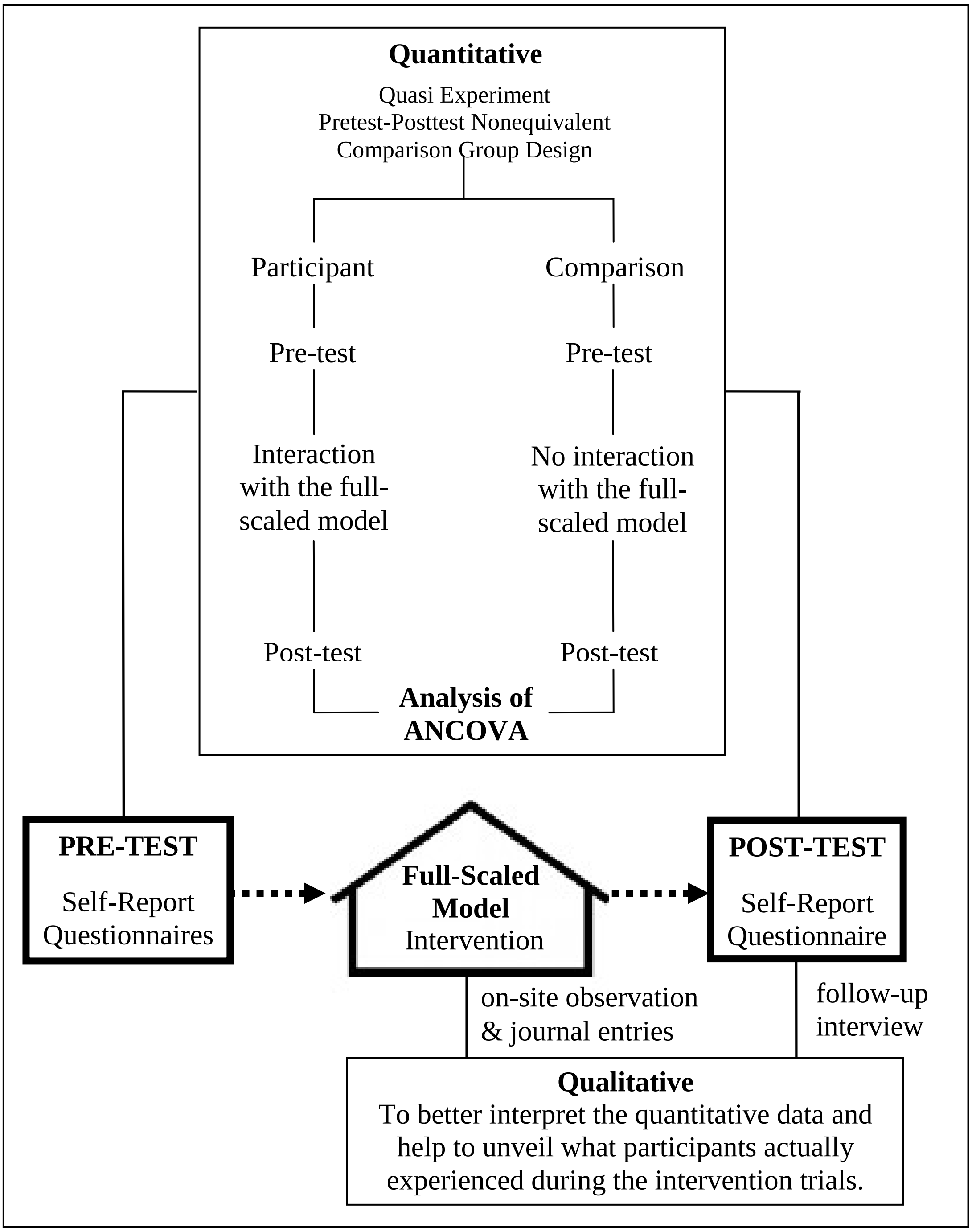


Figure 3.9: Phase 2 – quasi experiment

3.6.1 Study Sample

The hypotheses were tested with standard five students at the Section 6 Primary School in the State of Selangor, Malaysia. Standard five students were found to be suitable for the present study because they were regarded to be neurologically mature (Tempest, 1987). They were also adequately informed about the school routine due to the five years experience of the learning environments. Additionally, approval was granted by the Ministry of Education to involve standard five students in the quasi experiment because they were not sitting for any national examination. The participant group consisted of 42 standard five students who signed up voluntarily for the DBO Workshop. These students agreed to take part and had parental consent through the approval process implemented by the school. Additionally, 42 standard five students from the same school who did not participate in the DBO Workshop were selected to serve as the comparison group. The author requested the school principal and teachers to form the comparison group that was as similar as possible to the participant group in terms of gender, ethnicity and academic performance (i.e. final exam average score). The author acknowledged that the match between participant and comparison groups would not be perfect, thus a pretest was adopted to control for any variance between these two groups due to their initial level of knowledge, attitudes and behaviour. The pretest and posttest sample comprised of all the 84 students in the participant and comparison groups.

Sample size was often seen as a problem in experimental research because the final size was often determined by practical issues such as the number of participants who actually volunteer for the study and the number available to the researcher (Strehler, 2008). Thus, Lipsey (1998) proposed a statistical power framework to address the above-mentioned. The statistical power was defined as "the probability that a statistically significant difference will be detected, given that a treatment effect really exists" (Haberman & Bush, 1998, p. 189). It was determined by three factors, namely alpha level, sample size and effect size. The alpha level was the probability that a null hypothesis was rejected when, in fact, it was actually true. The alpha or *p*-value for the present study was set at 0.05 (Huitema, 2011; Lipsey, 1990; Shadish & Cooke, 2011). In addition, 42 participants signed up for the DBO Workshop, thus the sample size for the present study was 84 (42 participants and 42 comparisons). The effect size (*ES*) was the magnitude of response to which there was some real pre-specified difference between the therapeutic conditions. The *ES* was set as 0.7 for the present study because ANCOVA tests were adopted and relatively small sample size (42 in each group) was used (Haberman & Bush, 1998; Lipsey, 1990; Lipsey, 1998). Using the power analysis table by Lipsey (1998), the resultant statistical power was 0.90. This was considered as satisfactory because the value fall between 0.80 and 0.95 as suggested by Haberman and Bush (1998). Therefore, it could be concluded that the sample size was sufficiently large to detect a statistical difference between the treatment and control conditions.

3.6.2 Quantitative Procedure

3.6.2.1 Instruments

Prior to the commencement of the quasi experiment, the author had refined his scope of investigation to focus on the issue of recycling (see Section 5.2). Due to a lack of existing instrumentation, the author designed an instrument to assess participants' knowledge, attitudes and behaviour towards recycling (Appendix C). The author-designed instrument was based on the Children's Environmental Attitudes and Knowledge Scale (CHEAKS) (Leeming, Dwyer, & Bracken, 1995).

The CHEAKS subscales measured self-reported levels of environmental affect, verbal commitment and actual commitment. However, it was designed to be a measure of “general” environmental performances and not purposely focused on recycling (Leeming, et al., 1997). Therefore, for the purposes of this study, the affect items were modified to measure recycling attitudes and the actual commitment items measured recycling behaviour. Furthermore, scholars noted that it was not feasible to use the existing instruments developed based on Western literature in the local context (Haron, et al., 2005). Thus, various adaptations had been carried out to suit local experience and EE perspective. For instance, the author modified the CHEAKS through a review of local literature, EE curriculum and Phase 1 findings. Particularly, the survey questionnaires developed by Daniel et al. (2006) to explore the environmental performance of Malaysian students were used as a guide. Additionally, the content validity of the instrument was established through a review by two architectural and educational associate professors from University of Malaya. Each reviewer supported the content with minor amendments.

The author-designed instrument was available in English and Malay to the respondents. The Attitude scale included 24 items that measured attitudes toward recycling. It contained statements such as “It makes me upset if waste water in a building is not recycled into fertilizer” and “I get angry when I think of the things people throw away that could be recycled”. On the other hand, the Behaviour scale consisted of 24 items that related to recycling behaviour. It contained statements such as “I separate my family trash for recycling” and “I have asked others to recycle instead of throwing away”. Lastly, the Knowledge scale included 24 items to evaluate participants’ knowledge toward recycling. It included questions such as “which of the following is an organic waste” and “why is recycling important”.

The 24 items included in the Attitudes scale were presented in a 4-point Likert response format (i.e. strongly disagree, disagree, agree or strongly agree). The most pro-recycling response to each item was credited 4 points, and the least pro-recycling response received 1 point credit. Thus, scores on the Attitudes scale could range from 24 to 96, inclusive. Similarly, the 24 items included in the Behaviour scale were presented in a 4-point Likert response format measuring the occurrence of the behaviour ranges from ‘not at all’ (entitled for 1 point) to ‘very often’ (entitled for 4 points). The Behaviour scale was scored by creating a sum of the 24 items, with the possible total scores ranging from 24 to 96. Higher scores indicated more frequent recycling behaviour as compared to the lower scores. Lastly, correct responses to the 24 knowledge questions were each credited 4 points. Thus, scores on the Knowledge scale could range from 0 to 96.

A pilot study was carried out with a convenience sample, comprising of an intact class of 35 standard five students not taking part in the quasi experiment to measure the test-retest reliability of this author-designed instrument. Thus, each test was administered to the pilot group twice, without treatment and with a four-week interval between test administrations. The Pearson correlation was utilized for analysis, resulting in a coefficient in Table 3.3, suggesting acceptable levels of test-retest reliability (Field, 2009). Additionally, Cronbach’s coefficient alpha was utilized for computing test score reliability. The internal consistency scores were 0.77, 0.88 and 0.89 for knowledge, attitude and behaviour respectively. The results suggest acceptable level of internal consistency reliability (Field, 2009).

Table 3.3: Reliability scores for pilot test.

Scale	Test-Retest (Pearson Correlation)	Internal Consistency (Alpha Coefficients)
Knowledge	0.711	0.768
Attitude	0.753	0.876
Behaviour	0.856	0.886

The contrasted-group validity for the instrument was also established by asking teachers to identify high and low environmentally conscious students. Evaluation of these groups' scores disclosed expected and significant differences. Generally, high environmentally conscious students had higher scores in knowledge, attitude and behaviour, as compared to low environmentally conscious students (Table 3.4). Furthermore, the result of t-tests revealed that these differences were significant for knowledge (t=2.25, df=68, p<.05), attitude (t=6.92, df=68, p<.05) and behaviour (t=8.67, df=68, p<.05).

Table 3.4: Mean and standard deviation for two contrasted groups

Scale	Group	N	Mean	Std. Deviation	Std. Error Mean
Knowledge	High	35	55.31	15.992	2.703
	Low	35	47.31	13.625	2.303
Attitude	High	35	74.71	10.529	1.780
	Low	35	59.46	7.698	1.301
Behaviour	High	35	63.09	8.357	1.413
	Low	35	42.89	10.970	1.854

High = high environmentally conscious
Low = low environmentally conscious

3.6.2.2 Data collection

The design of the quasi experiment required the instrument to be administered twice to each of the participant and comparison groups. The pretest administration occurred before the DBO Workshop where as the posttest administration happened after the operational stage when the treatment was completed. The tests were administered as close as possible to the beginning and ending of the DBO Workshop and the participant and control groups provided their responses to the tests on a similar timeline (Ernst & Theimer, 2011). Furthermore, both tests were administered to participant and control groups during regular school hours. The author read the scales to all students and instructed them to raise their hands if they could not comprehend any of the sentences or how to answer any section of the scales.

3.6.2.3 Data analysis

To test the three hypotheses, a series of analyses of covariance (ANCOVA) were carried out to compare participant and comparison group scores on the knowledge, attitudes and behaviour. Given the voluntary nature of the DBO program and that students could not be randomly assigned to participant and comparison groups, the collected data represent a quasi-experimental design that Cook and Campbell (1979) referred to as an untreated control group with pretest and posttest. Consequently, the author used pretest score as a covariate in the ANCOVA tests in order to control for pre-existing differences between the participant and comparison groups on the pretest (Field, 2009; Girden, 1992).

3.6.2.4 Validity and reliability

In experimental studies, there were two contexts in which to think about validity and reliability (Creswell & Clark, 2011). The first related to scores from previous uses of the instruments and whether the scores were reliable and valid. This had been addressed in Section 3.7.2.1 where the author conducted pilot tests to check for the reliability of scores (through statistical measures of internal consistency), test-retest comparisons, content validity and contrasted-group validity. Additionally, the author conducted assessments of validity and reliability of data collected (i.e. power analysis, homogeneity of variance, homogeneity of regression slopes and reliability test) prior to data analysis (see Section 6.3.1). The second related to the internal validity and external validity of the quasi experiment. The author adopted the pretest-posttest nonequivalent groups design for the current research. Although this design lack of the random assignment to participant and comparison groups, it did support some degree of internal and external validity (Cook & Campbell, 1979). For instance, the quasi experiment took place in a natural setting. Thus, it was quite strong in controlling for threats to external validity and it had wide applicability to other similar settings in Malaysia (Huitema, 2011). However, the selection bias poses a threat to the internal validity. The participants for the DBO program were self-selected, instead of assigned by the author. There was considerable evidence that non-random assignment often (but not always) yielded different results than random assignment did, more so when participants self-select into conditions than when others made the selection decision (Shadish, et al., 2001). Thus, the author adopted a few strategies to reduce the plausibility of validity threats in this study (Table 3.5).

Firstly, matching through cohort controls was implemented. The term 'cohort' designates the groups that move through an institution (e.g. school) in cycles (e.g. a new standard five class each year) (Creswell, 1994). The author used cohorts as the comparison group because they were considered to be less nonequivalent than most other non-matched groups would be (Field, 2009). Additionally, the gender, ethnic, age and academic performance (i.e. final exam average score) of the comparison group were comparable to the participant group. Secondly, cohort control was improved by adding a pretest. The pretest allowed exploration of the possible size and direction of the selection bias by comparing cohort pretest means (Cook & Campbell, 1979). The pretest also increased statistical power by enabling the use of within-subject error terms. It allowed a better evaluation of regression and maturation, and it entered into better statistical adjustment for nonequivalent groups design (Shadish, et al., 2001). Thirdly, internal control was implemented by drawing samples from the same pool of populations (i.e. from students in the same school). Scholars noted that non-random comparison to an 'internal' (i.e. same school) rather than an 'external' (i.e. different school) group can sometimes yielded more accurate results (Shadish & Cooke, 2011; Shadish & Heinsman, 1997).

Table 3.5: Summary on reliability and validity

Reliability	Validity
• Conducted a pilot test to assess the reliability coefficients and test-retest comparisons of the instrument • The author checked for reliability of data collected through statistical procedures	• Cohort control and matching to increase group similarity (i.e. gender, ethnic, age, education) • Use of pretest as a covariate in ANCOVA tests • Implement internal control by drawing samples from the same school • Assessment of normality, homogeneity of variance, homogeneity of regression slopes prior to data analysis • Establish the content validity of the instrument • Establish the contracted-group validity for the instrument

3.6.3 Qualitative Procedure

3.6.3.1 Data collection

Although statistical analysis could help to establish the relationship between the 3-D textbook and recycling performance, the author intended to unveil what participants actually experienced during the intervention trial. The author therefore was not only in a better position to interpret the quantitative data more accurately, but also able to construct a deeper understanding on the participants' perceptions towards different setting attributes (Creswell & Clark, 2007; Fredrickson & Anderson, 1999). These insights were utilized in concurrence with the quantitative findings, to generalize and expand the influence of Phase 1 findings. As a result, the qualitative investigation was only carried out with the participant group. Qualitative data collected involved on-site observations, personal journal entries and follow-up interviews.

The author conducted on-site observations during the DBO Workshop. He took extensive field notes regarding all aspects of the child-environment interaction such as how the participants responded to a variety of physical elements including the composting walls, exposed rainwater harvesting system, reclaimed components, sun-screen and collage wall. Particularly, the author intended to explore whether or not the physical model significantly affected the behaviour of the participants and their overall recycling experience. Although on-site observations had restricted value with regards to recording the cognitive or emotional aspects of the participants' experience, this technique was essential for developing a certain rapport with the workshop participants (Zeisel, 1981).

Additionally, all the 42 participants were required to keep journal entries as a running account of their experience (Table 3.6). General instructions were given in order to reduce research bias. Therefore, the participants were merely told to record the opinions and feelings they had in response to the design, construction and operation. In addition, they were asked to write down any thoughts they had towards the physical model. Participants were reminded that the layout or length of the journal entries was not important, as long as they were developing an on-going conversation with themselves regarding their experience during the intervention trial.

Table 3.6: Frequency of journal entry

Activity	**Duration**	**Journal Entry**
Design	Two days	Daily Basis
Build	Four days	Daily Basis
Operate	Two months	Weekly Basis

Upon the completion of the operational stage, the author conducted follow-up interviews with all participants. Typically, interviews were 20–30 minutes, conducted face to face, individually and audio recorded. All participants had given their prior permission to having their dialogue recorded. The information that was gathered from the participants' journals and from the observation field notes was used as a general guide for each interview. Particularly, the interviews included several basic questions about design, construction and operation along with the following three key questions. These questions were intended to be open-ended in nature, promoting participants to express at length about the totality of their experience.

1. What do you do in the DBO program?
2. Which parts of the physical model do you like best?
3. Do you perceive the physical model as having an impact on your knowledge, attitudes and behaviour?

3.6.3.2 Data analysis

All interviews were recorded and transcribed. The transcripts were content-analyzed together with field notes and journal entries. The analysis process was guided by the Phase 1 findings and grounded theory methodology as suggested by Corbin and Strauss (2008). This procedure included reading of relevant sections of the transcripts, filed notes and journal entries to identify recurring words, phrases or sentences. This open coding procedure reduced the database to a small set of themes, allowed for the development of salient categories of information supported by text. Commonalities between these themes enabled the emergence of a central phenomenon under which associated sub-categories were grouped (Creswell, 1998). This procedure was recognized as axial coding. Particularly, the database was reviewed to offer insight into specific coding categories that related or explained the central phenomena. Axial coding was carried out simultaneously with open coding. When the fairly developed themes was revealed, the author moved to selective coding (Strauss & Corbin, 1990), whereby the key interest of the analysis was to generate statements and propositions that interrelate these themes.

The last stage of the analysis procedure included the integration of themes and relations between the themes into a comprehensive reply to the research question and findings of Phase 1. The participants were invited to review the analyses, codes and the emerging themes throughout the analysis procedure to ensure that all analyses reflected their lived experience and the raw data. The opportunity to discuss emerging themes with participants offered the author an extra guidance concerning the qualitative inquiry. It also transformed the data collection process into a more organic and flexible procedure.

3.6.3.3 Validity and reliability

This study implemented four validation techniques for the qualitative study, namely extensive time spent in the field with the subjects, the use of multiple forms of data (i.e. field notes, journal entries and follow-up interviews), member checking and peer review (Creswell, 2003). The author acted as a marginal participant (Zeisel, 1981) where he spent significant amount of time with the participants to build a rapport with them to promote the open sharing of information during the interviews. Although the author had taken a facilitating role in the design, build and operate processes, he remained unbiased throughout the data collection by taking care not to exclude any potential findings from the participants. Thus, his involvement in the workshop only had minimum influence on the outcome of the research. Additionally, multiple and different sources of data were used to provide corroborating evidence to the emerged themes, in line with the triangulation method as advocated by Creswell (2003).

The raw data, analyses, interpretations and findings were also reviewed by the participants so that they can evaluate the credibility and accuracy of the content. This member-checking strategy was documented by Lincoln and Guba (1985) to be “the most critical technique for establishing credibility” (p. 314). In addition, the author adopted peer review or debriefing as an external check of the research procedure. An interested peer was invited to review the methods, meanings and interpretations to ensure that the author was unbiased and honest throughout his investigation. Furthermore, reliability of the qualitative data was established through the use of multiple coders, a good-quality audio recorder and verbatim transcription. Coding was done “blind” with two coding staff without knowledge of the expectations and questions of the project directions. This was in line with Creswell’s (1998) suggestion to ensure stability of responses to multiple coders of data sets.

3.7 OVERCOMING CHALLENGES IN MIXED METHODS RESEARCH

The previous sections highlight the construction of a mixed methods design along with the EBD framework for this current research. Sequential exploratory design was adopted because of the complexity of the factors involved in exploring the design features of the 3-D textbook and associated implications of using this architectural intervention on EE outcomes. A few challenges associated with the use of the mix methods have arisen. However, certain strategies were employed to resolve some of these challenges.

Challenge 1: There was a need to determine how to link Phase 1 and Phase 2, particularly identifying which data to choose from the qualitative phase to make into the quantitative phase and how to utilize these data to produce quantitative measures.
Key resolution: The authors refined his scope of investigation and developed a full scale physical model prior to the commencement of Phase 2. Decisions were made during this stage about how the qualitative results would be used to influence the quantitative data collection and analysis.

Creswell and Clark (2011) noted that in the sequential exploratory design with an objective of developing and testing an intervention, the issues arise as to what information is most useful in designing and developing a treatment and what procedures should be used in this process. Therefore, the author had to refine his scope of investigation and develop a physical model between the two data collections to address the above-mentioned. The intent was to enable the author to determine and select the most useful information for follow-up. It also enabled the author to weigh the options and determine what approach was best to address the research questions and hypotheses. As noted by Creswell and Clark (2007), "the initial qualitative phase produces specific categories or relationships. These categories or relationships are then used to direct the research questions and data collection used in the second, quantitative phase" (p. 77).

Challenge 2: The act of combining qualitative and quantitative approaches raised potential validity issues.
Key resolution: In the beginning of the study, the author considered many types of validity in both qualitative and quantitative research. Additionally, the study on the validity in mixed methods research (e.g. Creswell & Clark, 2011; Tashakkori & Teddlie, 2003) was consulted to ensure that a process was employed to validate mixed methods design.

In mixed methods design, it was extremely important that validation procedures were integrated within the different stages of data collection and analysis. Tashakkori and Teddlie (2003) identified validity as the most vital aspect of any research project. Creswell and Clark (2011) noted that researchers ought to report and discuss validity within the context of both qualitative and quantitative research in a mixed methods study. Thus, validation procedures were employed over the course of the present study in order to validate the qualitative findings as well as the quantitative results. As outlined in Section 3.5.4, Section 3.6.2.4 and Section 3.6.3.3, procedures for validation were explicitly stated. For example, Phase 1 of the project involved a qualitative case study. The author verified the text analysis and interpretation by conducting peer review with interested colleagues and practitioners including an architect and a primary school teacher (Lincoln & Guba, 1985). In Phase 2, the author noted that the self-selection bias posed a potential threat to the internal validity. Therefore, a few strategies, including the use of pre-test and cohort controls, were adopted to address this problem.

Challenge 3: Determining an effective means of integrating and interpreting the qualitative and quantitative data.
Key resolution: The author drafted a visual diagram of the mixed methods design that includes data collection and analysis procedures. Subsequently, other research studies that utilized mixed methods design were studied to identify potential strategies that can be used to combine qualitative and quantitative data.

Although the data collection process for this project was sequential in nature, the analysis and interpretation of this data was an iterative process. Particularly, the use of a mixed methods design afforded the opportunity to integrate data at several levels, enabling the creation of a more robust research (Bryman, 2007). The first level of data integration occurred before the quasi experiment with the use of qualitative findings to create a physical model. Additionally, qualitative data collected from Phase 1 was used to further refine the hypotheses and scope of investigation. Furthermore, the author was able to triangulate the qualitative data and the quantitative results to draw additional conclusions about how 3-D textbook contributed to the EE outcomes (Robinson & Mndelson, 2012). The author developed a visual diagram (Figure 3.3) to convey the complexity of current mixed methods designs (Creswell & Clark, 2011). The construction of a visual model of the mixed methods design, including data collection and analysis procedures, was particularly valuable in underlining where and how qualitative and quantitative data would be interpreted and integrated (Vrkljan, 2009). The visual diagram in this study illustrated not only the multiple methods used for data collection but also how these methods might signify the study's purpose. It reflected upon the methodological design by providing a model that may describe the data collection and analysis process (Nastasi, et al., 2007).

Challenge 4: Because of the combination of quantitative and qualitative approaches, researchers were required to develop the skills to conduct both forms of research.
Key resolution: The author learnt about mixed methods research by attending methodological workshops, reading published mixed methods studies, finding methodological literature in which researchers discussed the procedures in this form of research and locating literature syntheses of many mixed methods studies in particular fields.

The author was previously involved with qualitative and quantitative research projects in the fields of architecture and sustainability. Thus, he had acquired the underlying foundations of each type of research and had basic skills at collecting and analyzing qualitative and quantitative data. This concurred with Creswell's and Clark's (2007) recommendation that researchers should first gain experience with both qualitative research and quantitative research separately before undertaking a mixed methods study. The author also attended methodological workshops and seek guidance from three experts in qualitative, quantitative and mixed methods studies.

Syntheses of mixed methods studies were carried out. These methodological literatures included journal article, book chapters or entire books that provide discussions about qualitative and quantitative research. The analysis showed how mixed methods were used across the sample of studies (e.g. Morgan, 1998; Morse, 1991; Vrkljan, 2009). It emphasized on the synthesis of the methods instead of the review of the results. The author learnt about the organization of the writing by reading examples of how other researchers had reported qualitative and quantitative findings in their mixed methods research. These examples also served as important references for how to design mixed methods study, how to analyze and mix the data and how to report the details of the studies within faculty's expectations.

Challenge 5: A mixed methods research requires considerable time and resources to implement. It might not be feasible, especially for a researcher who is working alone.
Key resolution: The author had taken into consideration extra time and resources required to complete a mixed method study. As a result, he applied for research grant from funding agencies early in the planning stage. Additionally, a research time table was developed and implemented.

Time and resources were considered as an important issue in the present study because mixed methods research was complex and thus required extensive effort on the part of the author (Tashakkori & Teddlie, 2003). As a result, an expenses list and a time table were developed to assess the feasibility of the research. The expenses list provided the cost estimation for entire project including transportation, building materials, printing and software programs. The time table, on the other hand, offered a systemic timeline for data collection and analysis. Considering the amount of effort and expenses required to implement a mixed methods study, the author had applied for financial support from local funding agencies.

Creswell and Clark (2007) acknowledged that mixed methods could still be a viable option even if a researcher was working alone. In this present study, the author echoed their suggestion of using an unequal weighting in the research design so that it was more feasible to implement. Quantitative approach was given a less priority. Thus, more time was allocated for qualitative data collection and analysis. Furthermore, the research was implemented in a two-phase approach. Therefore, only one phase was implemented at a time. This was more viable for the author who was working alone.

3.8 SUMMARY

The complexity of the problem and issues beg for a blending of qualitative and quantitative data. The taxonomy development model, which is a variant of sequential exploratory design, has been identified as the most appropriate research design because it matches the timing, weighing and mixing decisions. The present study begins with an exploratory qualitative component followed by a confirmatory quantitative research to generate and test an architectural intervention. Within this design, the pragmatic paradigm is adopted as this best suits the need of the research to remain flexible, allowing the research focus and questions to logically evolve at each phase. Phase 1 uses qualitative case study that involves interview and observation to establish the design features for the 3-D textbook. Phase 2 is defined by experimental design integrating qualitative data (i.e. quasi experiment). The data collected at Phase 2 enables the effectiveness of the 3-D textbook to be revealed and prevalence of Phase 1 findings can be determined. Additionally, EBD is implemented along with the mixed methods design to create a highly robust research. It helps to create access to data that the author can understand, interpret and act on to inform his study. Particularly, it provides multiple sources of evidences for the development and testing of the 3-D textbook. The next chapter describes in detail the analysis and findings specific to Phase 1.

CHAPTER 4

PHASE 1 – QUALITATIVE CASE STUDY

4.1 INTRODUCTION

The overall aim of this research is to explore the design of the 3-D textbook and test out its effectiveness to improve the pro-EK, EA and EB. A sequential exploratory research design is implemented along with EBD framework to achieve this aim. The research question to be addressed by Phase 1 is "What are the design features of a 3-D textbook?" In responding to this question, evidences are gathered from observations and interviews done at the Green School in Bali, Indonesia. The reason for collecting qualitative data initially is that the design features are not known and that these variables need to be identified based on a case study.

The remaining sections of this chapter focus specifically on the first phase of this mixed methods research. The results are presented by relating the findings to the four emerged themes. Additionally, the qualitative findings are summarized as a series of design features for further testing in Phase 2.

4.2 RESULT

The themes were interpreted in categories that best describes the attributes that characterize a 3-D textbook from the students' point of view (Table 4.1). The four themes that emerged from this case study were: (a) transparency, (b) in one with nature, (c) creativity and imagination, (d) active setting.

Table 4.1: Themes, sub-themes and illustrative quotes

Themes and sub-themes	No. (%) of interviewees mentioning this theme/sub-theme (*N*=12)	Illustrative quotes
Transparency	**11 (92%)**	
Exposed materials	9 (75%)	"The construction material is visible throughout the building"
Exposed technologies / services	9 (75%)	"The biogas reactor and water vortex disclose the opportunity for clean energy"
Exposed ecological processes	10 (83%)	"I can observe everything that happens in the pond… it reveals how aquatic ecosystem works"
In One with Nature	**12 (100%)**	
Indoor-outdoor relationship	8 (66%)	"The open classroom connects me to nature. I can enjoy the greenery from my desk"
Outdoor learning spaces	10 (83%)	"The farming plot is my favourite spot. It brings the learning out of classroom"
Site specific features	9 (75%)	"The adjacent river is amazing. My previous school does not have such feature"
Creativity & Imagination	**11 (92%)**	
Artistic & inventive building	9 (75%)	"The buildings are like artwork… The way they use the natural resources are very inspiring"
Reuse of salvaged products	11 (92%)	"The kitchen roof is made from metal barrel while the white board is made from windscreen"
Spaces for experimentation	9 (75%)	"There is an art studio for us to do painting, sculpture or model from waste or natural materials"
Active Setting	**12 (100%)**	
Open-ended spaces	11 (92%)	"The school ground is a multi-purpose space for class or personal exploration of flora and fauna"
Operation & maintenance	11 (92%)	"Every class is given a task in operation or maintenance. I help to water the plants"
Project based activity	10 (83%)	"I am in charge of the rebuilding of chicken coop. It enables me to design and build…"

4.2.1 Transparency

The first theme was termed as ‘transparency’ because the exposed building materials, services and systems in the Green School served as 3-D textbooks to model high performance and sustainability to the students. It could be further divided into three sub-themes: ‘exposed materials’, ‘exposed technologies/services’ and ‘exposed ecological processes’.

sub-theme 1: exposed material

As the daily lessons advocated on the sustainable living, the buildings in the Green School mirrored the same feature by using and exposing bamboo as a rapidly renewable resource (Figure 4.1). Bamboo was considered one of the most sustainable materials in this region due to its ability to grow and reproduce rapidly without the need for pesticides, fertilizers or much water. During interviews, one student stated, “we used bamboo and bamboo is really easy to grow and much faster than trees. It takes, I think, two to three years to grow to its full height. It takes in a lot of carbon dioxide and let out a lot of oxygen”. At the Green School, bamboo was used as a replacement for rainforest timber as a construction material, where it was exposed, expressed and celebrated in each building. The bamboo served as a live example for sustainable living to inspire EE teaching and learning. A student noted, “Here, you can explain it better. Because you know “bamboo” in our school is this. And this is how it helps and you will be like: OK, this is what I got to do…”. Additionally, most of the interviewees expressed their inclination towards the natural bamboo coloured environment because these modern organic spaces were designed to be both functional and aesthetically pleasing. The bamboo furnishings were an extension of Green School’s educational and design philosophy. The furniture explored and expressed the enormous potential of bamboo. For instance, the chairs and desks in the classroom were made entirely of bamboo. This simple yet elegant furniture were light weight, inexpensive and movable for a variety of teaching requirements. In addition, upper floors of buildings like the Heart of School used 100% bamboo floorings and pins without any glue or chemical finishes. These bamboo floorings, as well as bamboo cabinets, bamboo lockers, bamboo benches, bamboo lounge chairs and bamboo whiteboards were used on a daily basis by the school community.

Additionally, the interviewees expressed their amazement at the use of natural materials such as *alang-alang* grass, mud walls, mud bricks and volcanic stones within the campus (Figure 4.2). The Green School used locally available materials to minimize transportation costs and ensured support for local craftsmen and labourers. *Alang-alang* was a tough and durable grass that could grow in harsh conditions or poor ground. It had been used to construct thatch roof for vernacular domestic building on the island of Bali for hundred of years. In the Green School, the roofs of classrooms were covered with *alang-alang* where the grass strips were overlapped and tied to the structural components. The *alang-alang* thatching protected the occupants from direct thermal gain and at the same time improved the acoustic performance by acting as a sound absorber. A student said, "I like the roof very much. It is a traditional roofing system here in Bali. It is very comfortable to study under the *alang-alang* roof even on a hot afternoon". Furthermore, a local volcanic stone was used to provide permeable paving in all pedestrian pathways within the campus. A student noted that these circulation routes, constructed from volcanic rock, were very durable to the hot and humid climate of Bali. Another student further explained, "Stone is used as a substitution for concrete or cement… Grass can grow within the path…".

Figure 4.1: Bamboo buildings and furnishings

Figure 4.2: Use of stone (left) and *alang-alang* (right) within the campus

sub-theme 2: exposed technologies/services

Green technologies and services were integrated into the planning and design of the school environment to minimize the school's carbon footprint and contributed towards the vision of being energy independent. However, the biggest asset of having these features in place was the fact that they carried pedagogical value. Field notes revealed that the green features were not concealed or hidden from view, as described by a student, "what you see is what you get here…". Thus, it was a part and parcel of the design intention to unmask the processes in built environment so that these systems were more visible and accessible to the students. Field notes and interviews documented that students were exposed to various green technologies as part of their EE learning. The Green School was powered by a number of alternative energy sources including a water vortex power plant, solar panels and biogas reactor. The vortex generator diverted water from the adjacent Ajung River to form a vortice which could be tapped to create clean, green and low-impact hydroelectricity. Although this environmentally friendly technology was still in its testing and development stage, it had already attracted a lot of interest and attention among the school community. Students studied about the water vortex power plant to explore value of renewable energy as well as to understand the science and technology that makes it work. Moreover, by making the vortex generator accessible to the students, it offered enormous opportunity for direct experience to takes place. At the same time, solar panels were installed within the campus as a result of the "Getting off the Grid FUNraiser" program. A student noted, "It is the objective of Green School to have all buildings run on renewable energy. So we use solar panels to generate electricity". The Green School was expecting to install more solar panels in future to generate surplus electricity to share with the local villages or to trade back to the national grid.

Instead of using water flushing water closets, composting toilets were utilized throughout the campus (Figure 4.3). These composting toilets could generate biogas and compost using human waste. This was in line with the intention of the school to expose the students to alternative technology in waste management. On the other hand, all liquid waste was filtered by feeding plants and later used for irrigation of vegetation. Furthermore, a biogas reactor was used to produce cooking gas using cow dung as the decomposing material. The biogas system has been integrated into the EE lessons and the school intended to expend this technology to produce electricity as well as gas. A student said, “I learnt how to use a composting toilet here. It is not as bad as I think… Waste has a lot of usage. A biogas reactor can generate gas for cooking as well as compost for gardening”. Apparently, the innovative site infrastructure technologies in the Green School had been transformed into a powerful teaching tool by making these systems visible to the students. It invariably provoked deeper thoughts among the building occupants. More importantly, it rendered a positive impact on the students’ environmental commitments in the long term. This was reflected in the in-depth interview where the students showed their inclination towards future houses with green technology. When asked how his future house would be like, a student answered, “I will install solar panels, wind turbines or other renewable energy… I will also have composting facilities for organic waste”.

Figure 4.3: Composting toilet

sub-theme 3: exposed ecological processes

The exposed ecological processes provided the necessary scaffolding for students to acquire mastery over the abstract EE concept. It helped to move the act of teaching and learning away from abstract representation. For example, a student explained, “Information in textbooks is too abstract… I have to see it to thoroughly understand it… Instead of learning through textbook, I can gain better understanding about ecology by observing the gardens”. The Green School acknowledged the nature’s system as an opportunity for EE. Thus, the students were encouraged to study the ecological processes to understand the environmental cause and effect. For example, an aquaculture pond was constructed to reveal the processes and organisms in an aquatic ecosystem (Figure 4.4). A student explained the impact of climate change on the food chain in the pond, “If the temperature rises too much, the fish will most probably die… It will give a negative impact on the bird that relies on the fish as a source of food. This is a chain effect in nature”. The aquaculture pond also revealed the different parts of an aquatic setting which characterized a pond ecosystem. The interviewees were able to identify the differences between each zone through their daily observation. They described the surface of the pond as a habitat for air-breathing organisms including floating flora and fauna. They also identified a great variety of plant, animal and insects at the edge of the pond. The bottom of the pond was covered with organic debris while the fish could be found in the open water. The students were greatly benefited by the simple yet informative aquaculture pond. Ecological processes and systems were successfully revealed, studied and understood by the students.

Figure 4.4: The aquaculture pond

A local volcanic stone was used for all circulation pathways within the campus. These permeable pathways disclosed the flow of storm water and informed the students about the importance of recharging ground water. Steep hillside and bamboo water channels were also used to drain water to the Ajung River on a typical raining day. A student said, “When it rains, the water flows into the ground or into the river. I can see where the water is going…”. Revealing the flow of storm water enabled the students to not only observe but relate it to the larger ecological cycle. As noted by a student, “this water that reaches the ground will evaporate and falls as rain again”. In addition, the Green School also blanketed by an organic permaculture system as part of its commitment to a small ecological footprint. School ground was utilized as a farming plot to grow a variety of rice, fruits and vegetables. The organic farming mimicked natural ecological processes and offered numerous learning opportunities to the students. For instance, companion planting enabled the optimal use of natural resources and encouraged beneficial insects to create a vibrant ecosystem within the farming plot. Open-pollination helped to preserve genetic diversity while decomposers helped to transform plant material and food scrap into compost. These ecological processes were visible to the students, encouraging them for further exploration. A student said, "A farm has basically everything you need to know about an ecosystem. We can observe and learn about flora, fauna, predator-prey, food chain, pollination, photosynthesis, composting or other ecological processes here".

4.2.2 In One with Nature

The subsequent theme was 'in one with nature' which described the design of Green School that integrated the surrounding environment as part of the educational spaces. It could be further divided into three sub-themes: indoor-outdoor relationship, outdoor learning spaces and site specific features.

sub-theme 1: indoor-outdoor relationship

The buildings in the Green School did not have any walls or doors (Figure 4.5). Bamboo infill panels and single glazing were used to form enclosure for offices and staff rooms. These minimal but climatic responsive structures set a new design threshold for educational facilities. The Green School promoted indoor-outdoor connectivity by providing convenient access to the greenery. Flora and fauna were always close-at-hands, inviting students for further exploration and discovery. When asked about the important or interesting places in the Green School, a student responded:

> "Well, definitely all the outside places …One of the things represent Green School is that there isn't any enclosed place…Because pretty much you feel like you are always outside. And then when you are outside, it feels really good…"

The open perimeter walls helped to maximize access to the natural environments. Classrooms were linked to the garden, rice field or rabbit farm with proper walkways constructed from volcanic rock. A student said, "Green School is special because all classrooms have their own gardens… There are also paths linking classrooms with other places". Additionally, the open walls created visible lines of sight that connected students to the adjacent landscape. The Green School acknowledged the importance of having vistas to nature. Garden and courtyard were planned around classrooms so that most of the students could visually access nature even when they were in the main learning spaces. Field notes indicated that students enjoyed spending time in the outdoor and preferred open classroom with no walls (Figure 4.5). It reunited the outdoor and indoor environments and it had the benefit of linking students to their surrounding environments. A student stated:

> "I like the garden around here because in other schools there is no garden… And you have a view of the nature from your desk. And so, you are like in the nature right now… I like the noise of it."

The interviewer responded, "You like the noise? What noise?" The dialogue continued as followed:

Student:	I like the crickets.
Interviewer:	Oh, you like it as "background music"?
Student:	I like when there are no people speaking and you can listen to the "singing" outside.

Indoor-outdoor relationship was also established through the use of daylight and natural ventilation in the buildings. Energy intensive artificial lighting and mechanical system were not required in the Green School. The generous roof with large overhangs protected the classroom from driving rains and hot sun. The open perimeter walls had the capacity to draw in a considerable amount of fresh air to maintain a healthy indoor environment. The large openings provided high quality, naturally ventilated and cost effective learning environments to the students. Additionally, central skylight was used to facilitate passive cooling as well as allowing diffused natural light to enter the interiors (Figure 4.6). Field notes documented that daylight and natural ventilation promoted a sense of connectedness to the outdoors. By studying in an open classroom, students were once again linked to the local climate. Field notes documented that students were sensitive to the climatic conditions and constantly expressed their attention to the rhythms of natural cycles throughout the interviews. The open classrooms made them more conscious of the order of sun, wind and rain in the nature. As noted by a student, “I am very comfortable in my classroom. Outdoor breezes help to cool our classroom. Whenever possible, we use daylight… It makes me more aware of the weather conditions”.

Figure 4.5: Open classrooms with no walls

Figure 4.6: Skylight in various buildings

sub-theme 2: outdoor learning spaces

Outdoor learning spaces complement the classrooms by allowing learning or activity that could not take place indoors to happen. Located in a lush jungle with native plants along with organic gardens, the Green School provided ideal settings for various activities such as gardening, composting and nature walks (Figure 4.7). A student said, "In Green School, outdoor learning is equally important… We study under a tree, in the garden or the open field". Working with Begawan Foundation, the Green School also allocated a breeding sanctuary for the critically endangered Bali Starling. Bird cages were set up to breed and release the Bali Starling into the wild. These breeding enclosures were equipped with small palms as a source of nest material, tree branches for perches and sprinkles to ensure a daily bath. Young Bali Starlings were kept in a larger socialization enclosure together with Lorikeets, where they would mature, find a mate and moved to a breeding enclosure. The socialization enclosure had been stocked with live trees to emulate the outside world. As these trees grew, they would also provide fruits for the birds. A small pool and overhead sprinkles provided the daily water. There was planning for additional bird cages to bring in other birds like Wreathed hornbills to the school. Students were allowed to observe and study different species of bird under the supervision of their teachers. The breeding sanctuary enabled the students to observe the laying of eggs and the raising of the young Bali Starlings. Interviews disclosed that the students were amazed with the breeding sanctuary and they regarded it as the most unique outdoor learning spaces in the campus. A student stated, "The sanctuary helps to breed Bali Starling. I like to go there and watch the birds. I am glad that our school set up a sanctuary here in the campus".

Apart from the breeding sanctuary, the Green School set up a farm as an interactive learning space. Chickens, ducks and gooses were allowed to roam freely within the campus. A water buffalo, a cow and a family of endangered Balinese black pigs were kept in a stable (Figure 4.7). The farm was treated as a vital part of EE because it integrated learning with the animals. For instance, the cow dung was used in the biogas gas generator while the food waste from the school was fed to the pigs. A student said, "Green School is a big farm to me… My previous school doesn't have chicken and cow. I hope every school has a farm". Additionally, interviews disclosed that students identified the bamboo nursery as an interesting outdoor setting. Meranggi Foundation was an affiliate of Green School initiated to promote plantations of bamboo among the local farmers. This non-profit organization shared their skill and knowledge with locals to help produce high quality bamboo for a growing sustainable construction industry. Working with Meranggi Foundation, the Green School exposed the students to the planting and harvesting of bamboo. A student stated, "We use a lot of bamboo here in Green School. I like the bamboo nursery… because I learn how to plant, take care and finally harvest the bamboo. I think Meranggi Foundation has done a great job".

Figure 4.7: Garden (left) and stable (right) in the campus

<u>sub-theme 3: site specific features</u>

Site specific features in the Green School were fully utilized as pedagogical tools that contributed significantly to the teaching and learning about “place”. The site for the school straddled both sides of the Ajung River on a site that contained farmland, rainforest and mountain sides. As a part of the sustainable campus planning, only minimal alterations to existing grade were made. The master plan understood and responded to the natural topography including its potential and constraints in inserting new buildings within the existing landscape. As a result, the Green School maintained most of its site features that it could be easily reverted back to previously agricultural uses. As noted by a student, “no major change to the site was done…the school planning respects the environment and climate”. The adjacent Ajung River provided a readily available and accessible setting for EE to take place (Figure 4.8). Students were allowed to explore the river or collect specimens under the guidance of their teacher. When asked about the favourite places in Green School, a student responded:

> “Ajung River is unique to Green School. I like the river very much. We are not allowed to go there on our own. But sometimes we go there for Green Studies… I like the sound of the flowing water, plant and fish... The water vortex is also there. Electricity can be generated using the water from the river!”

Figure 4.8: The Ajung River

The Green School campus was situated on the high table land on both sides of the Ajung River. There was a 70 metre vertical drop from the table land on both sides down to the level of the Ajung River. The school was protected from flooding because of this steep vertical elevation between the river and the school buildings. A student stated, “We don’t have flooding here. We are on a higher ground”. The Green School’s campus planning also emphasized on site infrastructure and its integration into the existing context. Thus, bridges, pathways and steps were strategically placed within the steep hillside connecting various parts of the school (Figure 4.9). Buildings were erected according to the existing topography of the land, avoiding major earthwork or flattening of land. Only a number of trees were cut down to give way for building constructions. Whenever possible, trees were transplanted elsewhere. In some cases, trees co-existed with the buildings where trunk and branches were allowed to grow through the roof. A student said, “I see trees growing through the roof here… Tree is part of nature and we should value it”. Field notes and interviews documented that the site features like rainforest, contour, river and tree were incorporated as a significant component of EE. These site specific features promoted a continuous dialogue between the students and their surrounding environment. As a result, nature was successfully weaved back into the students’ daily learning. Nature served as a motivation and inspiration for EE learning. This was well-explained by a teacher:

Interviewer:	…just now I heard one of the students talked about making the roof out of water repelling materials (by studying the water lily leaves in their school pond). As fifth grader, they already have this kind of ability to connect things with nature… Do you teach them about ‘biomimicry’?
Teacher:	… it is amazing to have a fifth grader thinking at that level. And to have that happen in class is not uncommon. There are kids who get so inspired by the nature… Mind is expending and thinking of all the possibility. So instead of closing their minds, and teaching how they should be, it feels really here

> that we are opening their minds to expanding the possibility. That's why I love to be here.

Figure 4.9: The bridge and steps connecting various places

4.2.3 Creativity and Imagination

Interviews and observational data documented that the students regarded their school as a source of 'creativity and imagination'. The school buildings were artistically assembled with natural resources. They served as 3-D textbooks that unfolded students' imagination and provoked creative solutions for environmental problems. This theme could be further divided into three sub-themes: artistic & inventive building, reused of salvaged products and spaces for experimentation.

sub-theme 1: artistic & inventive building

According to the project architect and teachers, the unusual and unique buildings in the campus were designed to engage children's minds. The kindergarten area adopted a sea theme where buildings greeted the students with its imaginative, entertaining and environmentally friendly design. The Pre-K classroom, located next to the Galleon ship, was designed to represent a whale (Figure 4.10). Students entered their classroom through the Whale's tail while the green-inspired learning happened within the Whale's belly. A student noted, "I like the new classroom that looks like a whale. It is a very creative way of making a classroom… It helps to bring out the message of environmental protection, especially sea creatures…". Field notes further disclosed that the buildings in the Green School signified innovation in educational architecture, especially in the form making of buildings. For instance, the Heart of School, located at the crossroads of all walkways through the campus, was an organic shaped building inspired by nature (Figure 4.12). A student explained, "I think it is good where they try to make different things… the Heart of the School is an orange peel". As one of the biggest bamboo structures in the world, the Heart of School was designed to exploit the various physical properties of bamboo as a structural member for organic spaces. The building represented a multi-stemmed forest where the sculptural volumes were connected by a light filled space. Three clusters of vertical bamboo columns were used to define a dynamic light well that also facilitated stack ventilation. Intimate, but open spaces like the library and staff room were located at the upper level platforms. These upper floors helped to create varying height spaces above and below, making the effects of massing, light and shadow more dramatic. A student said, "The Heart of School is the most creative building I have ever seen. I never thought that natural resources like bamboo and *alang-alang* can create such a beautiful building… I hope all schools can have a bamboo building like this. It is wonderful!"

Field notes and interview also disclosed students' amazement towards the Mepantigan Studio. A student stated, "I prefer Mepantigan. It is an iconic building constructed from local materials. It represents sustainability and art". The Mepantigan Studio was a nature-inspired amphitheatre with a central linear skylight (Figure 4.11). Low retaining wall was utilized as stepped seating, offering a broad earthbound base for its large assembly space. Bamboo was used as the structural element to support its broad and generous roof while the decking exposed the underside of the *alang-alang* roof. The students used this dynamic and sculptural building for community gathering and performing arts. A student noted, “Mepantigan is very inspiring. Simple bamboo is transformed into an art piece here. It encourages you to be more innovative and creative”. On the other hand, the Gym, located next to the green field, explored the possibilities of bamboo as structural arch to create a huge column free interior (Figure 4.13). The bamboo arch provided a practical, affordable and innovative way of building a large communal space for leisure activities. A student stated, “The gym is a spacious compound for a variety of activities. It is amazing to see how bamboo can support such a big roof”. In a nut shell, buildings in the Green School were regarded as creative art work that enfolded students with ecological imagination and critical thinking. Buildings in the campus were acknowledged as being functional as well as inspiring. These buildings stood proud as a form of pedagogical tool that motivated students to constantly challenge the conventional standard in hope of generating superior and novel resolutions. It aimed to equipped students with problem-solving capability leading to environmental innovation. It promoted a more ecology-centred way of understanding creativity and it unlocked students’ imagination using physical setting in a school.

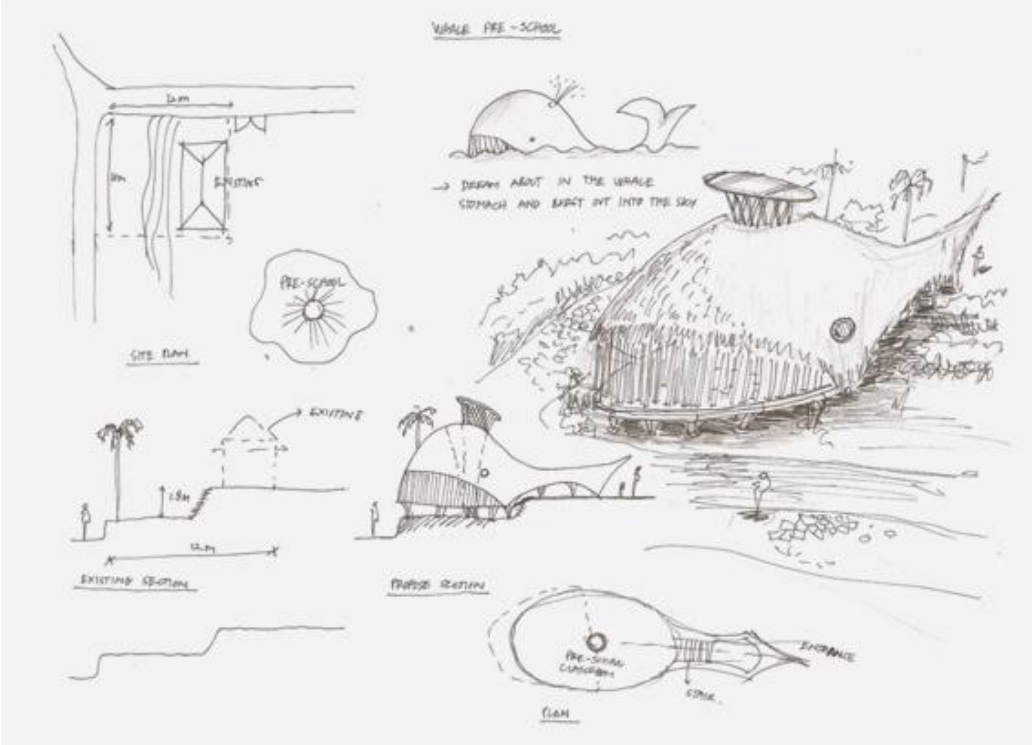


Figure 4.10: Sketches of the Pre-K classroom
(Source: ArchNet, 2012)

Figure 4.11: The Mepantigan Studio

Figure 4.12: The Heart of School

Figure 4.13: The gym

sub-theme 2: reused of salvaged products

Green School encouraged a closed waste cycle. All garbage generated by the campus was sorted and segregated while the organic waste was composted. The built environment was used as a pedagogical tool to provoke thoughts about sustainable waste management. Buildings were utilized as a catalyst to promote further exploration in the aesthetic and functional values of waste. It served as an essential platform to foster links between architecture and resource management. Instead of seeing materials at the end of its useful life as a problem, the Green School looked at these discarded items as an opportunity to promote the minimization of waste, saving of energy and reduction of carbon emissions. Field notes recorded that waste materials were identified and integrated into the design of buildings. For instance, the roof of the new kitchen was made from flattened barrel and recycled metal rafter (Figure 4.14). To continue the creature theme, the kitchen was also designed to look like a dragon. A student said, “The new kitchen is a dragon made from bamboo and recycled materials. I like the roof very much.” The interviewer responded, “Why do you like the roof? What is so special about it?” The dialogue continued as followed:

Student: The roof is made from metal barrels. These barrels come in different colour. They are arranged to form a pattern… It is astonishing to see how waste can be transformed into building elements.

Interviewer: Why do you think Green School uses reclaimed materials instead of new materials and products?

Student: It is the intention of Green School to reuse or recycle whenever possible… Using second-hand materials help to reduce the amount of waste.

Figure 4.14: The new kitchen (left) and white boards (right)

On the other hand, windscreens, side and rear windows were painted white and used as white boards in the classrooms (Figure 4.14). A new usage or application was developed for the windshields without losing its original qualities or characteristics. More importantly, the waste was tapped for its potential second usage and function beyond its original purposes. It ensured that waste was diverted from landfill and at the same time, it helped to implant responsible consumption pattern into the future generations. A student stated, “Waste can be useful. Look at our white board. Windscreens are now used for educational purpose… With creativity, we can solve environmental problem”. Interviews further disclosed that students were amazed with the designer’s “out of the box” approach in reusing waste products. As a result, students demonstrated their ability and interest in finding new uses for discarded items through their artworks. Field notes recorded that students constructed models from household wastes like bottles, aluminium cans and cardboard packaging (Figure 4.15). Furthermore, during the interview, one of the students suggested to reuse an abandoned water tank for recreational and educational purposes (Figure 4.16). The discussion was as follow:

Interviewer:	Tell me about this water tank. We discussed about it yesterday when you were drawing it.
Student:	Well. That… Hmm… This Green School is about making things not buying new things. Ya… I think it will be good if they make a “party” out of the water tank. And cut hole in it so it is like a door. But, ya… So it doesn’t have water in it.
Interviewer:	We talked about this yesterday and you can go in and study inside, right?
Student:	Ya!

Figure 4.15: Examples of students’ art works from household wastes

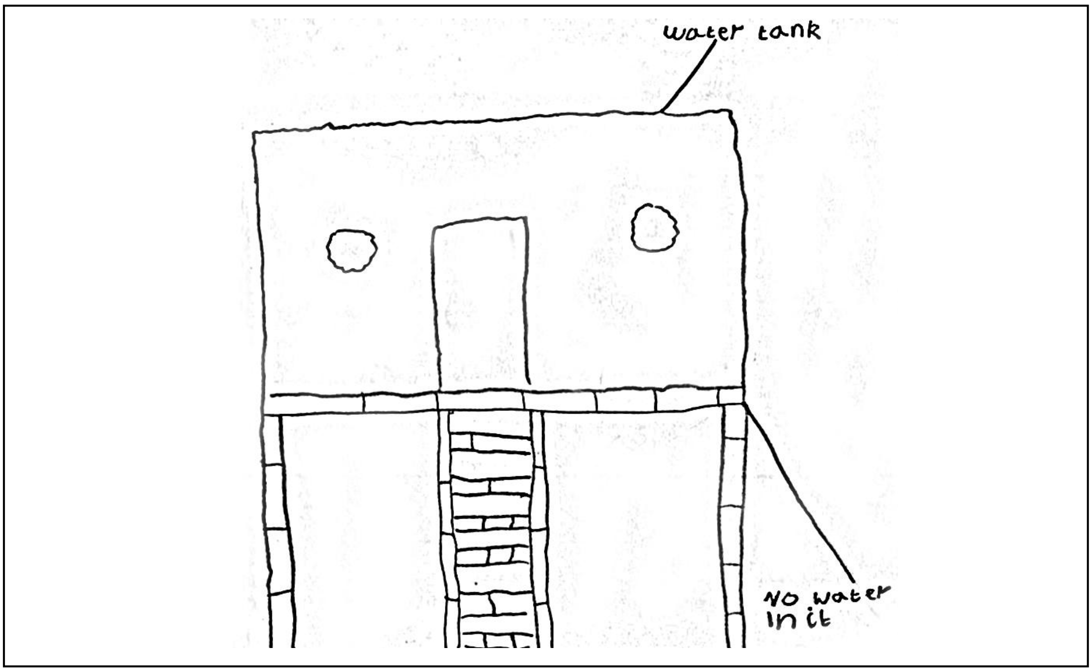


Figure 4.16: Selected student's drawing illustrating a reclaimed water tank

sub-theme 3: spaces for experimentation

The Green School campus was a bold experimentation in sustainable living. This giant laboratory was constructed by a design and build company known as PT Bambu. It was agreed by the school founders that the campus would served as a place of experimentation with bamboo which was a local sustainable material. Tapping the expertise from PT Bambu, a range of inspiring architectural spaces was created within the campus. Buildings in the Green School demonstrated inventive uses of bamboo in numerous scales ranging from huge multi-storey assembly spaces to much smaller classroom. These buildings fully comprehended and appreciated the vernacular architecture of the region. At the same time, innovation and experimentation was applied to go beyond traditional design to create contemporary spaces using conventional materials. Field notes and interviews documented that the students were overwhelmed with the innovations in the built environment which served as living illustration of inventive and sustainable solutions. They acknowledged the importance of experiment in environmental learning. The result was a holistic green community dedicated to inspire students to be more adventurous, more curious and more passionate about the environmental innovations. A student noted:

> "Green School is all about experimentation. Look at the buildings here. They are all products of experimentation with bamboo. They demonstrated opportunity and possibility of using bamboo as a substitute of rain forest to make beautiful structures… Studying here is like being in a huge laboratory. It reminds you to keep your mind opened. Keep trying and experimenting…"

In line with the original spirit of experimentation, the Green School provided specialize areas to support the testing of new ideas during formal lessons. Students were allowed to use the art studio in the Heart of School to perform various experimentations with waste items or natural resources (Figure 4.17). A vital component of the art studio was an ever changing student display area where completed products and projects in progress were exhibited. This display area highlighted the journey of inquiry behind each project and it showcased the authentic work of the school community. The art studio also provided the setting for drawing, painting and sculpturing to support practical work in the art and science curriculum. A student said, "Art studio is a very special learning place. Here, we express our thought through sketch and drawing. Sometimes, we can build model or sculpture to test our ideas". Additionally, a science lab with needed equipment and technology were provided as a place of invention. It was designed for sustainability, ecology and exploration of living science. The science lab was opened into an outdoor garden where students could gather material and specimen for their projects. The lab was not merely about conducting predictable experiment, it was also devoted to discovery. Students were encouraged to do active research and formulate their own hypotheses based on observation. Additionally, the lab could be used for small or large group discussions. It allowed for debate and deliberation in an informal setting where students could share their experience and latest experimental results. A student noted, "Experiments are conducted in the lab where ideas are put to real test. New knowledge and innovation are generated here… Like other buildings, the lab is opened to an outdoor garden".

Figure 4.17: The art studio

4.2.4 Active Setting

Field notes and interview disclosed that students were not merely passive observers. Instead, they were actively interacting with the natural and built environment in their learning process. This suggested the final theme – 'active setting', where it described the use of physical environment as a 3-D textbook to promote the notion of "learning by doing". It could be further divided into three sub-themes: open-ended spaces, operation & maintenance and project-based activity.

sub-theme 1: open-ended spaces

The design of the buildings and landscape in the Green School was open-ended where the students and teachers were allowed to transform them in a variety of ways. In other words, the space was designed to be multipurpose and more importantly it could be adapted to different environmental learning activities. Unlike the conventional schools that were dominated by classroom-based lecture, the Green

School was well equipped with facilities and infrastructures that promoted active learning in and out of the classrooms. The students utilized these open-ended and information rich environment to acquire new understanding either by individual exploration or with the support of others. For instance, field notes indicated that the school grounds were utilized as gardening space for group learning (Figure 4.18). The same settings could also support self-discovery by allowing individual student to explore different species of flora and fauna during their free time. A student noted, “The garden can be used for different activities. Sometimes, we do our Green Studies and science lesson there... I like to walk in the garden after school. A lot of insects can be found… And some of the plants are named so that we know the species”. Circulating through the gardens also promoted interaction among students from all year levels as well as exposing them to ecology, botany and biology. Each garden was treated as a multipurpose facility with its own cultivation cycle. Students were encouraged to be observant gardeners to examine the seedling, pollination and mature plants throughout the site. This student-created garden offered flexibility and adaptability that allowed users to change the space themselves. A student said, “We discuss with our teacher what to plant in the garden. We are allowed to change the landscape design… Making changes to the garden enables us to observe different plant and animal throughout the year”.

The Grade Five Classroom was designed around a triangular plan with minimal structural columns (Figure 4.19). It was planned to maximize the open space, enabling flexible spatial arrangements to suit different learning needs. Three interchangeable yet distinct spaces were located within the triangular plan – formal, informal and communal. The formal learning space was planned with desks facing teacher and blackboard. Field notes documented that the desks were interlocked in different spatial arrangement to facilitate the modification of space. The bamboo desks could be separated for individual learning or adjoined in pairs for group exercises. Thus, the formal space was highly flexible and it could accommodate a number of learning modalities. On the other hand, the central space with circular couches was used for informal meeting such as brainstorming, discussion or presentation. During the hotter days, a canvas cocoon coated with natural latex was used to cover this central learning space (Figure 4.19), creating a huge 'bubble' within the classroom. A fan was used to cool the students inside the 'bubble' through the peak afternoon sun. Classroom was also equipped with a communal learning space for group activities. Desk and work bench could be easily moved to allow for instance change over to match the learning activities. A student said, "Classroom here is multipurpose. We sit in rows of desks there during formal lessons… We may use the 'bubble' area for discussion. A fan will blow and it is very cooling to be in the 'bubble' even during the hot afternoon... We sit on the floor there for storytelling or group activities. It is fun…".

Figure 4.18: Garden for individual (left) as well as group (right) learning

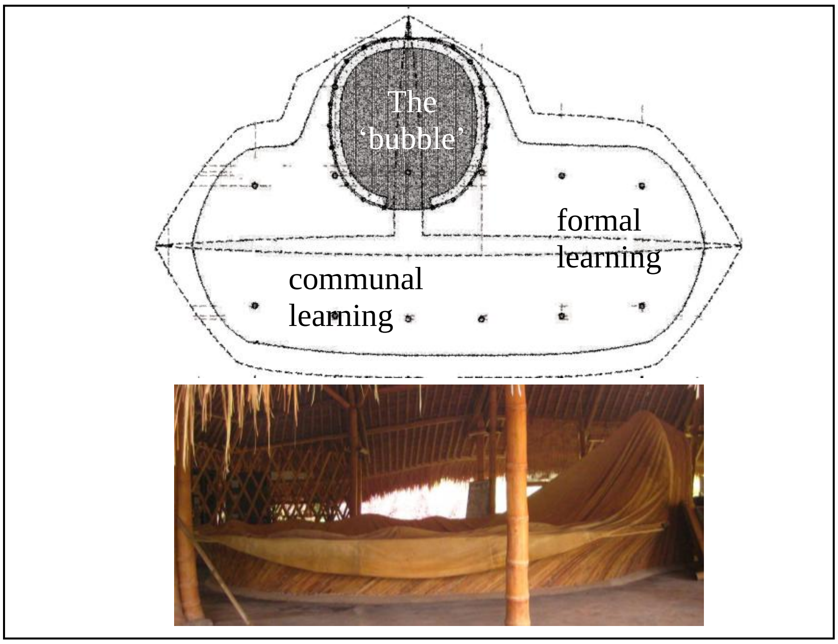


Figure 4.19: Plan for Grade Five Classroom (above) and the 'bubble' area (below)

sub-theme 2: operation & maintenance

Apart from academic achievement, the Green School gave equal attention to life skill development. It was the intention of the school founders to equip students with the necessary knowledge and ability to deal with the demands and challenges of everyday life. Thus, the campus was designed as a living context for essential life skills training. Participation in the operation and maintenance of the school ground and facilities was a vital strategy to promote life skills alongside with environmental values (Figure 4.20). This included taking care of the farming plots, watering plants and undertaking building repairs. Although bamboo was a sustainable resource, it was susceptible to humidity, insect and mould. Thus, the bamboo buildings in the campus required maintenance and continuous monitoring and inspections. Engineers conducted visual examinations of the bamboo structures to review key joints and structural strength. The students and the Green School bamboo construction team would help to monitor the building performance and made necessary modifications to address any defect or problem. The students were also expected to carry out repairs of the non-structural components under the guidance of the local craftsmen. For instance, they could help to rectify the *alang-alang* roof if it leaked or refurbish the bamboo furniture, cabinet and storage unit in the classroom. A student said, "I learn how to fix things… And what maintenance is required for a bamboo building. Bamboo is strong but needs to be inspected periodically".

Figure 4.20: Repair and maintenance works observed by students

Green School placed special emphasis on food and sustainability. Although the school was not self-sufficient in terms of food at the current moment, the campus was able to produce organic vegetables for the students. The farming plots in the campus consisted of a stable, rice fields, fruit trees and vegetable fields. Students were in charge of feeding the resident cow, buffalo and Balinese pigs. These animals, in turn, provided a steady supply of compos for gardening as well as biogas for cooking. A student noted, "The animals here are part of Green School. They are kept in a shelter there… The students are taking care of them". At the same time, the students were expected to understand the life cycle of rice by growing their own food through organic farming (Figure 4.21). They learnt how to be good farmers and more importantly they could taste the food they grew themselves. The most significant part of this experience was having the students to understand what it took to bring food to the table so that they could appreciate the essentials of Balinese rice-planting ceremony. Students got their hands dirty, participated in the weeding of soil, planting of seeds and harvesting of rice from the nice and neat row of paddies. It encouraged them to develop new knowledge, skills and environmental awareness through hands-on activity. This was well illustrated by the following conversation:

Interviewer: Yesterday when I followed your Green Studies class, I noticed that you all really get your hands dirty and do things by yourself… Not everyone has the opportunity to grow their own vegetables and fruit… Share with me how you feel about this.

Student: … You go through all these troubles… at the beginning of the year, you can't… Because there is left over from last year… There are weeds all over the place and the beds are collapsed. The first thing you have to do is to make it "proper"… and "growable" so that you can grow things on it. You have to clean everything; you have to make the soil aerated. And then you put all the seeds in. And you have to water every single day. And then at the very end, everybody can go in there after a quite long time. And everybody knows how much works that they all put in. And then you get to eat it. And you feel really proud of yourself because you actually did it all by yourself…

Interviewer: From your description and my observation yesterday, I think you have the skill of gardening now. Do you agree?

Student: Ya!

Figure 4.21: Organic farming

sub-theme 3: project-based activity

The Green School promoted project-based activities that enabled the users to alter physical settings within the campus. The school ground was treated as a platform for students to practice construction, preservation and conservation. For instance, the students were planning to design and build a tetra packs recycling station on campus to expedite the recycling of this material and raise awareness about sustainable waste management. Field notes and interviews disclosed that participation empowered the students in the making and management of the learning environment as well as giving them a chance to feel trusted by the adults. The resultant spaces generated identification, meaning and significance to the school community because of its user group involvement. Moreover, through this proactive architectural process, students learned how to think and solve real-life problems. A student noted, “Green School is different. We take part in various projects… We gain a lot of new knowledge through the act of building and making”. On the other hand, the seventh and eighth graders participated in a student lockers project where they were exposed to the many ways in which bamboo was used in design and construction. The students were required to work with the craftsmen to construct new lockers for the school using bamboo as the primary material. They learned how to measure, cut and lay bamboo planks as well as securing bamboo dowel by crafting and sawing the bamboo. In carrying this project, various skills and creative problem solving were applied. The students were enlightened about the different possibility of using bamboo. They gained understanding of how this sustainable resource might be used to inspire and change the life of people. Participation in this project-based activity had provided them with new viewpoints and perspectives that could support their green-orientated lessons in classrooms. A student noted, “Learning by doing. That is what we do here. Constructing simple structure from bamboo makes you appreciate the hard work and thinking behind it”.

Additionally, the fifth-graders were responsible for the demolition, design and rebuild of a chicken coop for the school (Figure 4.22). In the beginning of the project, the author and a landscape designer were invited to brief the students on the design and construction processes. The students were then divided into groups based on their role in the project. The ‘architecture’ team was in charge of the overall planning and design. They used sketches and cardboard model as a medium of communication with their teachers and local carpenters. The ‘project management’ team was responsible to check the schedule, cost and quality while the ‘building’ team carried out site clearing and setting out for the upcoming chicken coop. Subsequently, all the fifth-graders took part in the construction where they worked with the carpenters to complete the project. Field notes documented that the students drew upon different skills and knowledge from math, science and art during the design and construction processes. A student noted, “I am very excited about the chicken coop project… We will measure and calculate the site area. We will also do small model to check the safety and stability of structure”.

Figure 4.22: Measuring and clearing site for the chicken coop project

4.3 DISCUSSION

Table 4.2 recounts the themes and sub-themes emerged from the current case study. These data provided important information to answer the research question which required the definition of the attributes of a 3-D textbook. Particularly, the emerged ‘themes’ can be utilized as the ‘design features’ of the 3-D textbook for further exploration in Phase 2. Therefore, the following sections examine and discuss the emerged themes in relation to the existing theories and researches.

4.3.1 Transparency

The theme of ‘transparency’ resonates with Taylor’s and Enggass’s (2009) suggestion to translate apparent and sustainable elements into learning opportunity. Architectural elements such as building materials, finishes and walls can be active learning tools if they are visible to the students. For instance, a simple concept of skylights in the Green School is used to teach about the properties of light, reflection, absorption, temperature and energy efficiency. Thus, various learning opportunities can emerge from carefully designed places and objects. Common architectural elements, if accessible, can be tapped for their maximum potential as learning manifestations. The current case study also concurs with Mitchell’s (2005) findings that highly visible design solutions such as salvaged materials, composting toilets and photovoltaic are more often associated with a pro-environmental message because they stand out from conventional building practices. Therefore, by integrating vital concepts such as energy, water and material efficiency, a school becomes a tool to demonstrate a wide range of technical and community issues.

Table 4.2: Summary of the themes and sub-themes

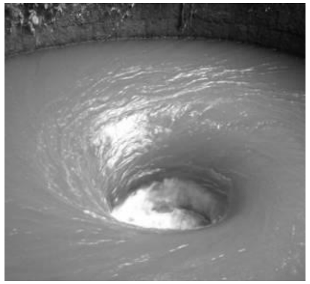
<table>
<tr><th>Theme</th><th>Purpose</th><th>Sub-Theme</th><th>Short Description</th><th colspan="2">Examples in the Green School, Bali</th></tr>
<tr><td rowspan="3">Transparency</td><td rowspan="3">To model high performance and sustainability to the students.
To unmask the processes in the built and natural environment so that these systems are more visible and accessible to the students.
To provide the necessary scaffolding for students to acquire mastery over the abstract EE concept.</td><td>Exposed Materials</td><td>Building materials, finishes and furnishing that reflect sustainability and EE.</td><td></td><td>The buildings in the Green School mirrored sustainable living by using and revealing bamboo as a rapidly renewable resource.</td></tr>
<tr><td>Exposed Technologies & Services</td><td>Integrating green technologies and building services (e.g. photovoltaic, rainwater harvesting, composting toilet, etc) into EE.</td><td></td><td>Students studied about the water vortex power plant because it is part of the school’s efforts to generate clean and renewable energy.</td></tr>
<tr><td>Exposed Ecological Processes</td><td>Revealing the processes and systems in nature (e.g. native vegetation restoration, waste water filtration in wetland, flow of storm water, etc) as an opportunity for EE.</td><td></td><td>The Green School utilized a pond in the campus as an ecological site for students to explore aquatic ecosystems.</td></tr>
</table>

Table 4.2, continued

Feature	Purpose	Sub-Feature	Short Description	Examples in the Green School, Bali	
In One with Nature	• To integrate the surrounding environment as part of the educational spaces • To reconnect students back to the ecosystem and natural cycles • To make children aware of the local climatic conditions (e.g. the order of sun, wind, rain, etc)	Indoor-Outdoor Relationship	Promote the indoor-outdoor connectivity by providing large openings, windows or accesses to the adjacent greeneries		The open classroom in Green School reunited the outdoor and indoor spaces. It had the advantage of capturing the prevailing breezes and view of the greenery.
		Outdoor Learning Spaces	Open or outdoor areas (e.g. garden, trees, courtyard, etc) with access to flora and fauna		Various lessons and activities during Green Studies were conducted outdoor in the garden, farming plot or bamboo nursery.
		Site Specific Features	Including specific site features (e.g. contour, rainforest, river, etc) as an opportunity to learn about "place"		The river adjacent to the campus was incorporated as a significant component of EE in Green School. Students were allowed to explore the river valley under the supervision of their teachers.

Table 4.2, continued

Feature	Purpose	Sub-Feature	Short Description	Examples in the Green School, Bali	
Creativity & Imagination	• To enfolds students with ecological imagination and critical thinking • To equip students with problem-solving capability leading to environmental innovation • To encourage the generation of superior and novel resolutions by conducting experimentations and testing of new ideas	Artistic and Inventive Buildings	Buildings that demonstrate inventions (e.g. form making, colour, texture, pattern etc) and served as a source of inspiration for the students.		The school buildings were artistically assembled with natural resources. The buildings' forms were inspired by the nature. For example, the kindergarten looked like a whale and the Heart Of the School was an orange peel.
		Reuse of Salvaged Products	Reuse or repurpose salvaged items (e.g. second-hand door / window, reclaimed bricks, bottles, aluminium cans, etc) creatively in the built environment and landscape.		The roof of the new kitchen was made from flattened metal barrel.
		Spaces for Experimentation	Specialize areas (e.g. studio, workshop, etc) with or without needed equipment to support the testing of new ideas during formal lessons (e.g. Science, Ecology, Art, etc)		An art studio was allocated for students to perform various experimentations with waste or natural items.

Table 4.2, continued

Feature	Purpose	Sub-Feature	Short Description	Examples in the Green School, Bali	
Active Setting	• To encourage active interaction with the natural and built environment throughout the learning process. • To promote the notion of “learning by doing”. • To utilize the school ground as a living laboratory for students to practice construction, preservation or conservation.	Open-Ended Spaces	Multipurpose areas that allow students and teachers to transform them in a variety of ways to support different activities within the same space.		The school grounds are utilized as farming space for group learning. The same settings can also support self-discovery by allowing individual student to explore different species of fruits and vegetables during their free time.
		Operation and Maintenance	School ground or facility that invites students’ participation in its operation and maintenance (e.g. edible schoolyard, energy monitoring system, refurbishment of building, etc)		Students are entrusted with the responsibility to take care of the flora and fauna in the campus as well as perform minor maintenance tasks under the supervision of the technicians.
		Project Based Activity	Project-based activities (e.g. tree house, rabbit / fish farm, etc) that enable the teachers and students to alter the physical settings within the campus.		The fifth-graders in the Green School were responsible for the demolition, design and rebuild of a chicken coop for the school.

Baird (2001) documents the significant of revealing thermal environmental controls systems in architectural design. His writings are consistent with the theme of ‘transparency’ that explores visual exploitation of environmental services. Particularly, environmental control systems should be regarded as an architectural opportunity rather than restriction. It reinforces a profound change in the correlation between architectural and services design that is occurring in environmentally progressive building as noted by Badarnah (2009) and Orr (1997). Environmental control systems can be exposed and expressed as architectural design elements on the exterior or interior of buildings. For instance, the water vortex power plant and biogas reactor have become symbolic of energy efficient in the Green School where they play an important role in the campus planning and design.

The current research concurs with Orr’s (1997) writing on ‘Architecture as Pedagogy’. It reveals that students receive numerous messages about sustainability from different dimensions of their experiences in a campus. Therefore, physical environment is conceptualized as an ‘informal’ curriculum that influences student learning and behaviour. Visible and sustainable practices, such as photovoltaic panels and energy efficient lighting, can help students to deconstruct the hidden campus curriculum, leading to enhanced sustainability literacy. Exposed and accessible systems also enabled sustainability issues to be communicated through the campus environment as suggested by Shapiro (2012). It facilitates evaluative dialogue around campus sustainability and self reflection, which can be transformative and translate into pro-environmental behaviour change.

The theme of ‘transparency’ also resonates with the eco-revelatory design (ERD) as discussed by various scholars (Bargmann & Levy, 1998; Brown, 1998; Gortz-Reaves, 2010) in landscape architecture. The current research supports the design approach that exposes the significant ecological aspects of a site and helps students build meaning and connection between the landscape and their own lives as suggested by Medeiros (2011). Therefore, built and natural environments in the Green School are designed to illuminate the unseen cycles through technology or system that makes these connections visible. Apparent green solution helps the students to see and become more aware of the abreactions human superimpose on the land and it makes complex system in the designed environment visible and understandable. Each building and site can be turned into an educational prospect for the exploration of ecology, power, food, water, resources and ecosystem.

4.3.2 In One with Nature

The theme of 'in one with nature' resonates with Nair's et al. (2009) suggestion to integrate outdoors as a natural extension of indoor learning. Every opportunity should be explored to create string connections between the indoor spaces and outdoor areas as suggested by Howie (1974). In the Green School, open classrooms with no walls are used to seamlessly connect indoor and outdoor settings. It provides an opportunity to expand a student's horizons by creating visible lines of sight that extend as far as possible outside the room. At the simplest level, classroom learning can be taken to an outdoor setting where the students can participate in various activities that they might have done indoors. Outdoor settings also permit other types of learning to occur that could not take place indoors. It is an excellent opportunity to connect students with nature. It is an ideal setting for group activities such as gardening, nature walk and composting.

The theme of 'in one with nature' also promotes the integration of indoor and outdoor environment to as suggested by Ryn and Cowan (1996). For instance, having the school buildings in the Green School to work in partnership with the nature, architecture becomes an extension of the nature into the man-made realm. As a result, students are not detached from the natural environment. Instead, they are connected back to the natural cycles so that they are sensitive to the patterns of the wind and rain, the rhythm of light and shadow, the change of climate, the sources of food and the life-cycles of materials. This reinforced Ryn's and Cowan's (1996) statement of "design transforms awareness" (p. 186), where they proposed to use architecture to transform human awareness of processes, patterns and relationships within the nature.

The theme of 'in one with nature' concurs with the concept of learning landscape as proposed by Taylor and Enggass (2009). Learning landscapes reflect the importance of nature as well as local culture and values. They are pedagogical tools that go beyond the undisputed benefits of relaxation, physical exercise and sports to act as organic, 3-D textbook. They are resources for readily accessible, real-life study and an inspiration for curriculum development. For instance, gardens in the Green School are a living laboratory that puts the natural world at students' fingertips. The garden system offers an essential context in which to study ecosystem, cycles, resource and waste, soils and minerals, succession, and sustainability.

The theme of "in one with nature" promotes the use of site features (e.g. contours, wetland, etc) within the campus as an opportunity for EE. This reinforces Nair's et al. (2009) suggestion that natural elements can help to build environmental consciousness and teach important lessons of sustainability, ecology and living science. The Ajung River in the Green School, for example, is an identifying, local signature used to support and advance ecological studies. The river is carefully matched to the level and type of learning and thus it can act as a pedagogical tool that helps to advance EE. It is also an ideal setting for active engagement in biology, botany and environmental science. By integrating design within the opportunities and limits of place, as in the case of the Ajung River, the Green School has responded to the site and ecological realities.

4.3.3 Creativity and Imagination

The theme of 'creativity and imagination' is no stranger in the field of EE. Orr (2000) claimed that creativity plays a key role in the transformation route of producing sustainability thinkers. This current study seems to concur with Orr (2000). For instance, buildings in the Green School are regarded as creative art work that enfolds students with ecological imagination and critical thinking. These buildings stand proud as a form of architectural swift that proclaims eco-friendly design in opposition to the prevailing factory-liked model. It makes clear to the students that they should not accept any given information or facts blindly. Instead, students are encouraged to constantly challenge the conventional standard in hope of generating superior and novel resolutions.

The theme of 'creativity and imagination' concurs with Nair's et al. (2009) suggestion to have specific areas for experimentations. Science labs and art rooms should be used for formal learning as well as to test ideas for practical applications. Additionally, studios, workshops and laboratories enable students to put theory into practice as suggested by OWP/P Architects Inc, et al. (2010). For instance, the students in the Green School can propose a project, develop an experiment and carry out the work, all in a completely flexible space in a workshop or studio setting.

The theme of ‘creativity and imagination’ also echoes Yeang’s (2006) writings on green aesthetic in ecological design. Apart from meeting the systemic aspects of ecological design, a green building must also be aesthetically pleasing, economically competitive and excel in user performance. In the Green School, the technology and innovation have been juggled together to develop a new ecology-based aesthetic for architecture and built environment. Particularly, creativity and imagination is used to balance the biotic and abiotic components in a building and this has significantly affected its appearance and aesthetics. Creativity and imagination should also be used to balance the function and appearance in any design decision. Therefore, the task of the designers is to make the Green School as ecologically responsive and as aesthetically fulfilling as possible. The resultant learning spaces in the campus reflect innovative solution by capturing a true sense of connectedness to ecological processes.

Reuse of waste products in architectural process also resonates with the theme of ‘creativity and imagination’. Interesting architectural solutions like reusing and repurposing reclaimed components in the built environment invariably sets the stage for environmental innovation in the Green School. It stirs students’ imagination and encourages them to find alternative and sustainable resolutions. Reused buildings or structures are also more emphatically green and therefore are more effective in communicating a pro-environmental message. This is supported by Mitchell (2005) who noted that green buildings that reuse exiting structures or materials teach the importance of history and heritage, while sending a strong message of resource conservation. Incorporating elements of the past is not only respectful, but adds a feeling of exploratory to the building as noted by Day & Midbjer. Thus, reused spaces or items often demonstrate that the world is full of optimistic possibilities beyond imagination.

4.3.4 Active Setting

The theme of ‘active setting’ concurs with Fraser’s and Gestwicki’s (2002) writings in their exploration of Reggio Emilia approach - Environment as the Third Teacher (p. 99 to p. 128). The concept of the environment acting as a third teacher furnishes the classroom with the characteristics of a living being. Consequently, it must be open to change and responsive to the students and teachers. In the current study, the classroom and school ground in the Green School are open-ended so that it can be adapted for different environmental activities. The campus as a whole is an inspiring environment that offers students many options. As a result, it not only provokes them to take part in a variety of activities but it also promotes them to investigate an extensive range of materials. EE is no longer segregated in certain areas of the room but is available for use wherever it is needed, indoors or outdoors. This is one of the reasons the Green School adopts the idea of the school grounds as a multipurpose space that can be transform in a variety of ways to complement indoor learning. The outdoor settings, such as farming plot and garden, can be used for group learning as well as individual exploration.

The theme of ‘active setting’ promotes the modification of spaces using the ideas of ‘flexibility’ and ‘variety’ as suggested by Nair, et al. (2009). For instance, flexible spaces in the Green School contain moveable partitions, open plan and flexible furniture layout that allow the students to change the space themselves. The Green School has moved away from a model of single-purpose space to multifunctional area by adopting flexible spaces to accommodate as many of the EE activities into any given space as possible. In addition, 'variety' allows for instance change and for learning activities to be perfectly matched to environments that best suits them. It allows users to change the quality of their space simply by moving, for instance, from an open classroom to the adjacent garden in the Green School. Therefore, space is readily available for working with a number of different sized groups of students and teachers in different modalities with a common feature of active learning, rather than teacher control. This is supported by Birney and Reed (2009), Moore and Lackney (1993).

The theme of 'active setting' emphasizes on the participation of students in the daily routine of their school. Connecting students to the operation and maintenance of the school can assist them in developing new skill or environmental awareness. Participation in maintenance and on-going care of school grounds can also encourage sedentary students to get outside and get moving. Particularly, up-keeping provides learning experiences in stewardship and pride of space. The hope is that students who understand, use and feel connected to their surroundings will grow into adults who appreciate and protect its healthy, functional and aesthetic properties. Including students in the operations of the school also makes the resources, cycles, expenditure, inequities, sustainability and finances of the school more tangible and accessible as suggested by Tilbury and Wortman (2005).

The theme of 'active setting' also resonates with Walden's (2009) writings on participation and user design. An active setting requires the participation of the users in its architectural processes. There are many activities and aspects of schools that can become the subject of participatory projects. For instance, in the Green School, remodelling or renovation in the campus have been made into a form of special project weeks, by project groups, or in common work by teachers, students and parents. Inside, such projects may involve decorative details for the hall, furnishing of classrooms, extension of indoor learning spaces, and the interior fit-out of workshop or studio. Outside, projects may involve the courtyard, farming plots or fish pond. These projects allow intensive immersion in a specific subject. Through participation in the design and building process, students may take lead in the conversion of their school to sustainable practices. It enables the students to express their ideas in sustainability, as well as demonstrating these to others.

4.4 SUMMARY

Phase 1 aims to uncover the design features for a 3-D textbook by conducting a qualitative case analysis which describes and interprets the architectural intervention from the students' perspective. At this stage, the research uncovers four design features (i.e. 'transparency', 'in one with nature', 'creativity & imagination' and 'active setting') for further exploration in Phase 2. Although the findings of Phase 1 cannot be generalized too broadly, nevertheless, this case study is an initial attempt to better comprehend the qualitative dimension of the child-environment relationship and how the physical environment can be a source of environmental learning. Phase 1 also expands the author's understanding on the use of architecture as a scaffold for EE. Particularly, the emerged themes provide an important guide to define the design features for the 3-D textbook. This section formally closes Phase 1. As noted in Chapter 3, the quantitative researches in Phase 2 would help to gather numerical information and statistical support to strengthen the findings of Phase 1 and expand its influence.

CHAPTER 5

PHASE 2 – QUASI EXPERIMENT

5.1 INTRODUCTION

The current research has sought to determine the design features of a 3-D textbook and ascertain if this architectural intervention is successful in improving EE outcomes. This chapter describes the analysis undertaken with the Phase 2 quantitative and qualitative data. It provides results relating to the testing of normality and reliability of the data, homogeneity of variance and homogeneity of regression slopes. A series of analyses of covariance (ANCOVA) has been carried out to test the hypotheses. Qualitative data was also analyzed in an attempt to construct a deeper understanding on the participants' perceptions towards different setting attributes. These insights were used in conjunction with the quantitative results, to expand the influence of Phase 1 findings. Additionally, this chapter compares the quantitative results and qualitative findings with the literature and past researches to explore possible interpretation and explanation. The significant results from the ANCOVA and the literature are juxtaposed for similarities and differences to assist the construction of an explanation. Additionally, the themes identified from the qualitative data in Phase 2 are debated by relating the emerged setting attributes to the literature and findings from Phase 1.

5.2 REFINED SCOPE OF INVESTIGATION

In conjunction with a sequential exploratory design, the scope of investigation should be refined upon the completion of Phase 1. Following this, the findings of Phase 1 need to be linked to Phase 2 for further testing and generalization.

5.2.1 Overview

From literature review and findings of Phase 1, the author noted that various environmental performances (e.g. litter reduction, energy conservation, water conservation and purchasing products with recycled content) could be measured. However, measurements of all outcomes pose numerous problems in terms of feasibility and practicality. An investigation of this nature would need more time than is possible to allocate in a doctoral project. The current research is not in a position to manage the enormity of such a complex investigation. The durational confines prevent a multi-phase study, and the funding is not sufficient to support this strand of investigation. In addition, Phase 2 is a quasi experiment, including measurement of knowledge, attitude and behaviour prior to and after the intervention (i.e. the 3-D textbook) and comparison with a control group to account for external variables influencing the performance over the time period. Consequently, the measurement of environmental performance requires accurate definition of the performance to be measured so that reliable measurement tools can be identified.

Furthermore, Schultz et al. (1995) noted that investigators of pro-EB should not assume that people who show a tendency for performing one pro-EB are likely to show a similar tendency for another. They argued that someone who conserves electricity might not, for example, save water or even be an environmentally conscious shopper. Their statement is supported by several studies, which found that various pro-EB are not closely related (e.g. Tracy & Oskamp, 1983-1984). For instance, Siegfried et al. (1982) used attitudinal and demographic variables to predict each of four pro-EB (i.e. lowering thermostats, using less hot water, purchasing environmentally safe products, and avoiding the use of unnecessary lights). Their analysis failed to reveal a consistent pattern of predictors for the four behaviours. Siegfried et al. concluded “generalizations from one specific pro-EB to other forms of behaviour may be inappropriate” (p. 288). Similar conclusions were reached by Oskamp et al. (1991). Thus, the measurement of pro-environmental performance in Phase 2 would require accurate definition of the performance to be measured. Further, this research recognizes the importance of improved EK, EA and EB as a result of interaction with the 3-D textbook and feels that retaining this area of investigation will allow a more reliable study to be undertaken at Phase 2. Thus, the author decided to narrow down the scope of investigation to focus on a specific environmental performance so that meaningful conclusion can be drawn in Phase 2. This is in line with the pragmatic approach, where the author attempts to perform an investigation that can be reasonably engaged.

Therefore, attention turns to the question of which environmental performance should be measured for the study. In order to give a direction to this exploration, the author reviewed and analyzed the literature in the field of environment-behaviour to examine the impacts of the designed environment on educational outcomes (Ahrentzen & Evans, 1984; Cohen & Trostle, 1990; Cotterell, 1984; Klatte, et al., 2010; Kumar, et al., 2008; MacPherson, 1984; Read, et al., 1999). Some first indicators were found in the journal of *Buildings and Environment*. The use of a building or a demonstration facility as an educational tool and catalyst for behaviour change has only been evaluated once in Utah House (Dietz, et al., 2009). Dietz, et al.

noted that some of the behavioural change required a long time to evaluate its outcome and thus is not suitable for a quasi experiment. As a result, they recommended future researchers to concentrate on waste management like 3Rs practices, which can be performed at any time. Their recommendation echoes with Phase 1 findings where the Green School uses buildings as a 3-D textbook to convey the message of recycling. With the dearth of investigation on this subject, measuring the impact of 3-D textbook on recycling performance would help to advance the body of knowledge. The focus for Phase 2 thus lied towards the effectiveness of a 3-D textbook to improve pro-recycling knowledge, attitudes and behaviour.

Consequently, measurement of other environmental performance is considered to be a recommendation for future research and is not attempted as part of this study. The argument to delay the exploration of 3-D textbook on other environmental performance is supported by the exploratory nature of the research. In Phase 1, the theory behind the study shapes through an inductive methodology, where care is taken not to leave out any potential information and also acknowledge previous experience and bias but not be persuaded by these. The open approach to information in the process of exploratory research offers the advantage of providing an opportunity to investigate the subject from many different directions. Implementing such an investigation fully and thoroughly may take time. Gilbert (2010), for example, maintains an idea through his research yet selecting important findings for follow-up in the second phase of his study. This was partially informed by the high level of uncertainty at the start of his project, which measured the outcomes of graduate development program.

In addition, the exclusion of other environmental performances for the research project is also supported by the pragmatic approach taken for the work, which urges that research should be guided by practical circumstances. Bromberg noted that controlled experiments demand high costs and time (Brandt, et al., 2010). In spite of the value of this type of in-depth research, conducting such work is frequently not possible within the given timelines and budgets for projects. Therefore, researchers are encouraged to be pragmatic by focusing on approaches that can be reasonably achieved in their project.

5.2.2 Recycling and the 3-D Textbook

The following section explores the impact of different educational setting on recycling performances (i.e. knowledge, attitudes, and behaviour) by reviewing the current literature on recycling. It reveals the potential linkage between recycling and the 3-D textbook and thus helps to narrow down the scope of investigation to a manageable form for Phase 2.

Public awareness of recycling in Malaysia is still low when compared to other countries such as Singapore. Singapore lies ahead in recycling at 40 per cent as compared to Malaysia, which is targeting 22 percent by 2020. According to Kathirvale et al. (2004), the average amount of municipal solid waste (MSW) generated in Malaysia was 0.5-0.8 kg/person/day and could rich as high as 1.7 kg/ person/day in major cities. By the year 2020, the quantity of MSW generated would have increased to an estimated 31,000 tons resulting in heavier responsibilities for local governments to achieve a sustainable rate of recycling, because landfills would have become increasingly scarce (Mahmud & Osman, 2010). Furthermore, Cherif (1995) explains that recycling can reach a level of collective consciousness only if the education begins at the fundamental level, teaching the school children about the importance of resource conservation.

In Malaysia, EE plays a vital role in promoting recycling awareness among the students. Recycling was introduced within the Malaysia school system through the infusion and integration approach, in relevant subjects such as Science, Civic and Citizenship. However, most of the recycling elements that are included in the formal subjects are cognitive and knowledge elements. Recycling activity or campaign has been implemented, but only on an ad-hoc basis. A descriptive study by Lim (2005) in two Selangor schools revealed that environmental awareness of Malaysian students was low. In the same study, it was found that waste management and recycling in the schools were not satisfactory. Another study by Daniel and Shafiee (2006) reveals that while Malaysians in general have knowledge about the environment and realize the environment needs to be taken care of, most of them are not orientated to translate their knowledge into behaviour.

Stevenson (2007) has argued that the largest barrier to effective recycling stems from the lack of any connection between the structure and purpose of traditional schooling methods versus the purpose of EE. As he describes, schools were originally created as a way to convey basic knowledge and skills to students. They were not meant to groom students with an understanding of recycling and other environmental issues. Due to this barrier, recycling and EE in general is at odds with traditional schooling. This fact might explain why recycling education has not been as effective as it could be. Additionally, Williams (2011) documents that while schools may educate about environmental sustainability, the immense production of trash in many schools conflicts with the ideals of sustainability. Other scholars noted that although many schools address the theme of recycling in their curricula and extracurricular activities, the recycling concepts being taught sometimes conflict with unsustainable behaviour that the schools model to their students (Cherif, 1995;

Schultz, et al., 1995). For instance, recycling promotes conservation of resources. However, the school buildings are constructed from virgin materials instead of salvaged or second-hand components. This inconsistency between teachings and practice has confused students and decreased the likelihood of emulation and educational effectiveness.

Orr (1992) argued, "The crisis cannot be solved by the same kind of education that helped create the problems" (p. 84). This has prompted the scholars to look into other intervention to promote recycling awareness. One of the alternative strategies is to provide students with a 3-D textbook by greening the facilities within the campus. Characterized by its combination of architecture and education, scholars believe that the 3-D textbook can endow students with the knowledge and values to make a positive impact on the environment (Taylor & Enggass, 2009). However, as discussed in Chapter 1, there is much to be done to transform theory to practice. The use of a 3-D textbook as an educational tool to improve pro-recycling knowledge, attitudes and behaviour has not been evaluated in the literature. Thus, the objectives of Phase 2 were to perform a comprehensive analysis to determine if a 3-D textbook is an effective educational tool and also to assess in greater detail the experience of the participants as a result of their interaction with the 3-D textbook.

While there is ample literary evidence that supports the potential effectiveness of different interventions in influencing knowledge and attitudes to shift environmental behaviour, the number of studies specifically regarding recycling is more limited. This is perhaps due to the fact that recycling is just one environmental issue out of the plethora that are there today. Although the studies specifically about recycling are not as numerous as those involving general EE, it has been shown that different educational settings have the potential to significantly increase knowledge, promote positive attitudes and increase recycling behaviours in students. For instance, Smith et. al (1997) found that the program in which students actively took a fieldtrip to a landfill resulted in a higher attitudinal and behavioural change than the program in which they remained in the classroom. Smith argued that classroom education changes behaviour by first changing knowledge, while fieldtrips and more active forms of education first change attitudes. This study demonstrates that different settings could alter knowledge and pro-recycling attitudes and, thereby, are potentially effective at impacting behaviours.

Another study by Mitchell (2005) indicated that buildings with reused buildings and reclaimed components (e.g. second hand door, salvaged bricks, etc) are strongly linked with pro-EB through the wide-scale promotion of the 3Rs. She stated that, "along with pro-environmental message, retaining a historic building communicated a connection to the past, increased longevity and healthy interiors" (p. 188). Additionally, salvaged materials are identified as elements of a successful visual strategy. Mitchell (2005) noted that it is easy to identify salvaged materials because they look older than virgin construction materials. This strategy can be an obvious cue that prompts an occupant to pause and reflect on its age and the association between the older materials and 3Rs practice. Furthermore, Louw and Forlizzi (2004) explored the design of a recycling station that encourages recycling behaviour and supports learning about recycling in the café of Pittsburgh Children's Museum. Their design solution evolved through a series of four user-centred prototyping and evaluation cycles that built up the interaction, information and physical design of a recycling station to include sensor-based interactive technologies. It was found that their design contributed to a positive learning experience that increases the rates of recycling. In addition, it improves the child participation in the recycling activity and families had more conversations about recycling. By augmenting an everyday object with an interactive design solution, they demonstrated the power of design in promoting awareness, discussion and learning about recycling.

5.2.3 Refined Theoretical Framework

Based on the review of literature in Section 5.2.2 and the findings in Phase 1, it is believed that introducing the design features as the moderator is expected to strengthen all the positive hypothetical relationships associated with the constructs depicted in the Figure 5.1. Therefore, the three hypotheses are refined to be as follow for further testing and validation in a quasi experiment:

H1: Students who interact with the 3-D textbook would demonstrate an improvement in recycling knowledge as compared to their peers who have not interacted, after controlling for the effect of pretest scores.

H2: Students who interact with the 3-D textbook would demonstrate more pro-recycling attitudes as compared to their peers who have not interacted, after controlling for the effect of pretest scores.

H3: Students who interact with the 3-D textbook would engage in more recycling behaviour as compared to their peers who have not interacted, after controlling for the effect of pretest scores.

The Research Question 2 (RQ2) is also refined to complement the data collected from the quasi experiment:

How do participants of a quasi experiment perceive the impacts of the 3-D Textbook on their pro-recycling knowledge, attitudes and behaviour?

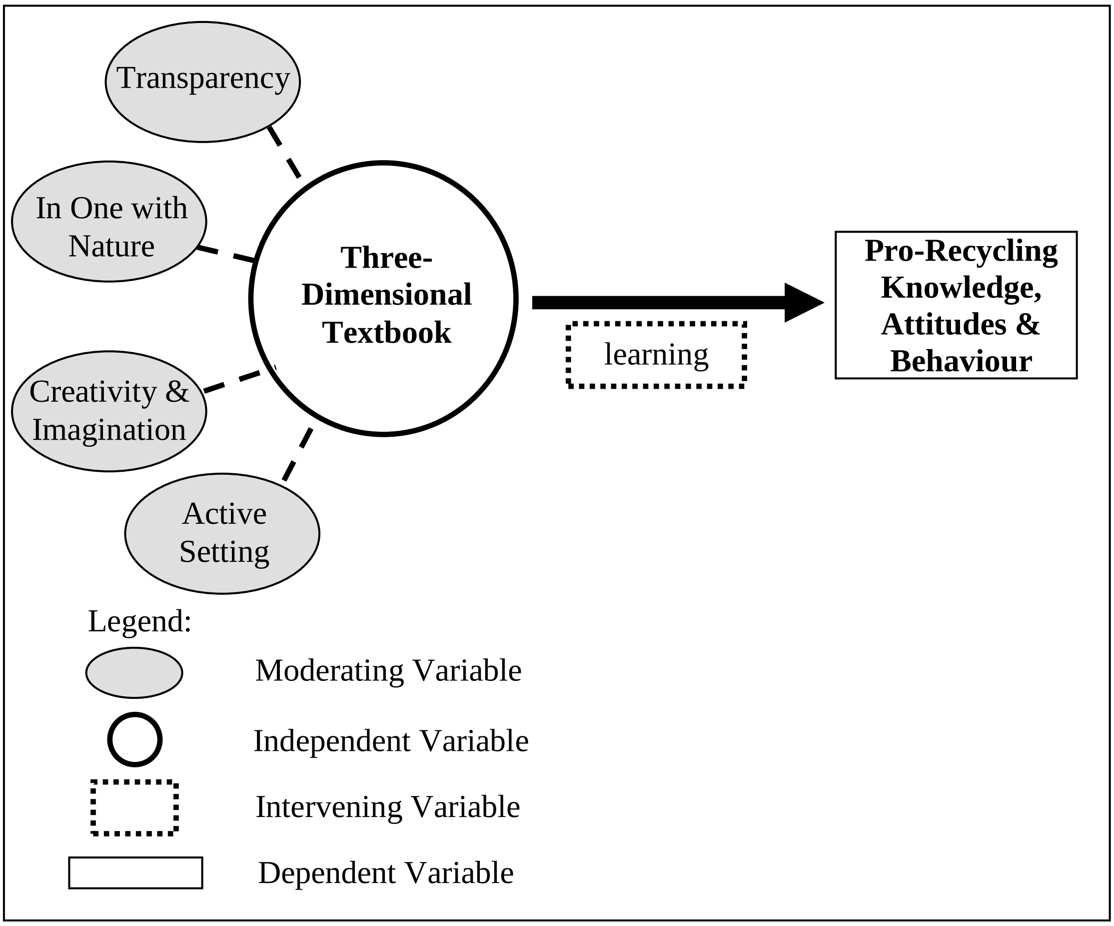


Figure 5.1: Refined theoretical framework

5.3 DEVELOPMENT OF A FULL-SCALED PHYSICAL MODEL

Physical models and testing have been the pivotal activities in creating design outcomes and testing performance capacities. In this current study, modelling is grounded in hypotheses about design performance, enabling the author to test the relationship between design intent and design outcome performance. In particularly, the modelling is guided by the aim of Phase 2 to establish the prevalence of the findings of Phase 1 by testing the effectiveness of the 3-D textbook on selected students. The reminder of this section detailed the process of translating the design features from a rural setting (i.e. case study in Green School, Bali) to an urban context (i.e. quasi experiment in Section 6 Primary School, Shah Alam).

5.3.1 Procedure

The author contacted five primary schools in the State of Selangor to identify potential site for the quasi experiment. These short listed schools were selected through purposeful sampling by reviewing recommendations by interested colleagues (i.e. Mr Sho and Mrs Ati Rosemary) and Ministry of Education. After a series of site visits and discussions, the Section 6 Primary School in Shah Alam had been identified as the ideal site due to its commitment to support the research work. The school also matched the notion of a "Factory Model" design as described by Leland and Kasten (2002). The author took a more participatory role in the development of the physical model. He conducted site visits to the participating school to better understand how findings from Phase 1 could be realized in the actual site (Figure 5.2). In addition, he worked with local waste operators to identify urban discards that could be salvaged for the physical model (Figure 5.3). The author also organized site visits to landfills and recycling centres to better comprehend the process of collection, separation and processing of waste. This allowed the author to generate ideas and inspirations by observing and learning from the real-life situation.

Figure 5.2: Site for the physical model as approved by the participating school

Figure 5.3: Urban discards salvaged from a recycling centre
in Bukit Beruntung, Rawang

The author liaised with three mentors consisting of two senior lecturers (Dr Naziaty Mohd Yaacob and Ati Rosemary Mohd Ariffin) from Faculty of Built Environment and an associate professor (Dr. Esther Gnanamalar Sarojini A/P A Daniel) from Faculty of Education to carry out the design of the physical model. He spent a significant amount of time with these mentors, during which efforts were made to incorporate Phase 1 findings into the model. Starting with sketches and quick cardboard or polystyrene models, the author made 3-D digital models of these objects, where some form of analytical analysis and testing can take place. Subsequently, additional mock-ups were constructed ranging from simple and cheap materials to complex working models of the specific reclaimed components (Figure 5.4). A lot of time was spent on building mock-ups as the author found that this was the best way to engage the interdisciplinary partners in the process.

Figure 5.4: Construction of mock-ups in the laboratory of
Faculty of Built Environment

Brandt et al. (2010) noted that a good model for any experiment depended on how well it represented the reality. Therefore, a good model should reflect the purpose of the experiment as well as produce objective and credible results. In the current study, it was crucial to ensure that the findings from Phase 1 were well-translated into the physical model so that the results of the subsequent quasi experiment were valid. The author had adopted the following strategies to avoid any bias in the design decision and ensure that the physical model was a good representation of the 3-D textbook:

1) Review by a Panel of Experts on an Ad-Hoc Basis

The meaning and applicability of the model, as well as the findings from Phase 1 used to shape its design, were discussed with a panel of experts which was invited to serve as an external auditor to review the design on an ad-hoc basis, as well as to give their professional input on the design intent, constructability, feasibility and practicality aspects. These experts were selected based on a purposeful sampling, and consisted of:

a) two architects who had prior experience in designing with waste;

b) a waste artist who repurposed urban discards and found items into innovative products;

c) an environmental scientist from University of Malaya who specialized in waste management;

d) a builder who had more than 10 years of experience in constructing prototypes or mock-ups for experimental purpose.

2) International Conferences

The author presented the design of the physical model to a number of interdisciplinary scientists at international conferences to get their point of view (Kong, et al., 2011a; Kong, et al., 2011b; Kong, et al., 2011c). The discussions focused on the design of the physical model in relation to the findings from Phase 1. The scientists contributed to the outcomes by sharing their valuable knowledge and suggestion to repurpose salvaged materials into building components.

3) Discussion with the Participating School

The author conducted three discussions with the teachers in Section 6 Primary School to strengthen his initial design brief. The author utilized the Green School, Bali as a cue for more meaningful discussion with the participating school. In response, the teachers gave constructive input on the design and operation of the physical model in relation to the EE teaching.

4) Presentation to the Malaysia Eco-School Committee

Findings from Phase 1, together with the design of the physical model, were presented to the Eco-School Committee in Malaysia. These discussions provided deep insights into the obstacles faced in constructing and operating a 3-D textbook in a public school. This information served as an important basis in developing a more feasible approach to incorporate the physical model into the local school context.

5.3.2 Outcome

Working with the interdisciplinary partners, the author developed an initial design scheme (Table 5.1) based on the qualitative case study in the Green School, Bali. The panel of experts and Malaysia Eco-School Committee agreed to the proposed solutions and contented that the physical model would be a representation of the 3-D textbook. The scientists at international conferences (Kong, et al., 2011a; Kong, et al., 2011b; Kong, et al., 2011c) and the participating school were equally supportive of the design with only very minor comments. The primary concern was evolved around the safety issue because the model had to be constructed by the participants of the quasi experiment in Phase 2. Although this makes the quasi experiment problematic in the light of the shoestring budget and tight schedule, Phase 1 does reveal an unanticipated finding about the considerable potential for using DBO explicitly within a 3-D textbook with a view to maximize potential for learning. The author acknowledged that a secure construction site for the students was very important and the resulting building should be safe to be occupied. As such, he strived to establish a balance between guidance and freedom. The participants were given the opportunity to make the final decision about the form, façade configuration and colour scheme. This allowed them to bring their own taste to the formation of the design. However, the participants ought to work under the supervision of architects or technicians on the connection details, construction techniques and supporting structure. As noted by Walden (2009b), "participation by children and young people does not mean that they will plan alone; it always means that they will work on the problems and develop proposals together with adults" (p. 95).

The author completed the preliminary drawings (Figure 5.5). These drawings would be used as a blueprint and a medium of communication with the participants of the subsequent quasi experiment. The initial design scheme would be further during the DBO Workshop (see Section 5.3.3). Students would be given opportunity to contribute their views and opinions to formulate a final design. The materials used for the physical model was salvaged from nearby demolition projects, commercial centres and landfills. With the help of the waste operators, the following materials were salvaged:

- 30 nos of rejected aluminium frames acquired through a wholesale company
- 100m of PVC pipes salvaged from nearby demolition projects
- 200 nos of plastic bags and banners in various sizes salvaged from landfills
- 40 nos of PVC storage boxes salvaged from landfills
- 10 nos of plastic roller salvaged from a recycling centre
- 30 nos of cardboard tube / paper roller salvaged from a recycling centre
- 250 aluminium / metal tins donated by the participating school
- 300 glass / plastic bottles donated by the participating school

The program of the project was very simple. A total of 150 square feet of space was required with enough room to house three recycling bins and other composting facilities. The idea was to create a series of supporting frames with infill panels, which would simplify the on-site building process and provide the scope for maximum use of materials with very minimum waste. The frames, constructed from reclaimed PVC pipes, were to be of two sizes: 50mm diameter and 120mm diameter (Figure 5.6). The infill panels were built out of rejected aluminium frames, which could be interlocked in any configuration, such as building blocks (Figure 5.7). The basic idea was to create a collage of elements, which could be easily interchanged and built by the students. By composting the salvaged and donated materials, a simplified architecture was developed, directly tied to available materials and limited conditions of technology.

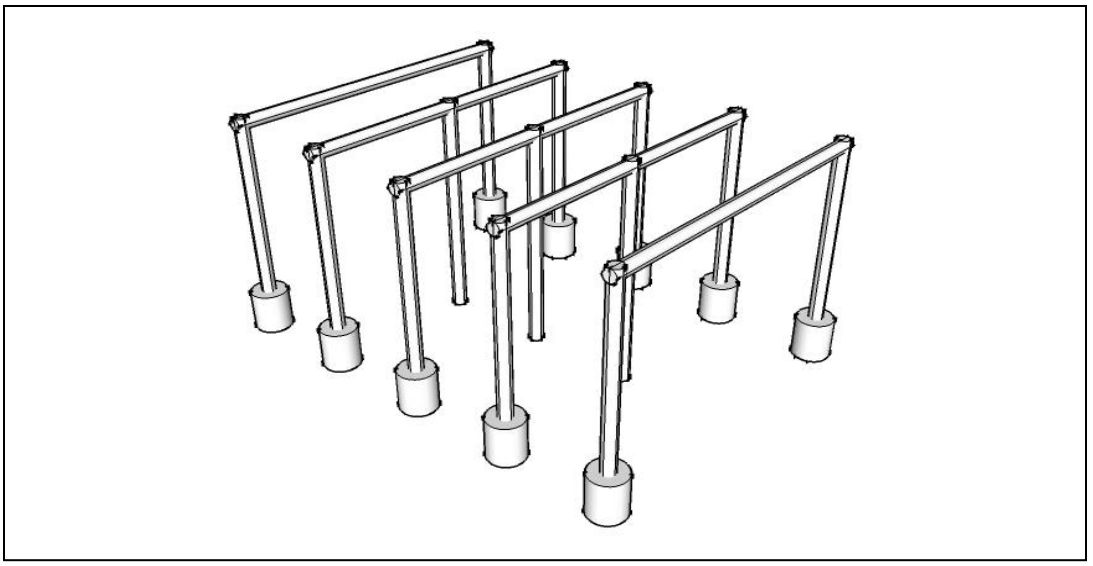


Figure 5.6: Supporting frames from reclaimed PVC pipes

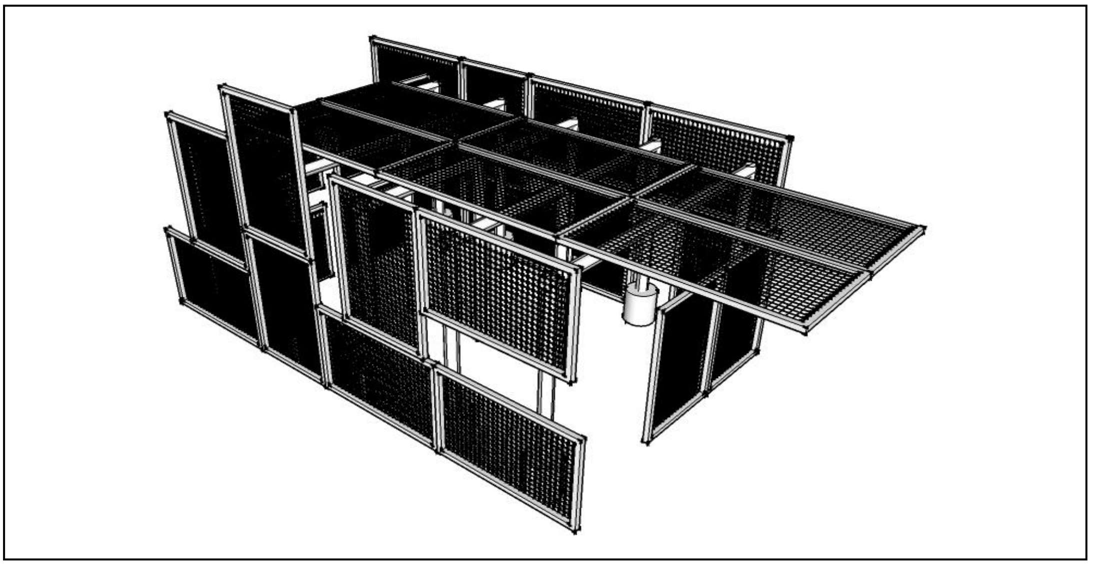


Figure 5.7: Infill panels from rejected aluminium frames

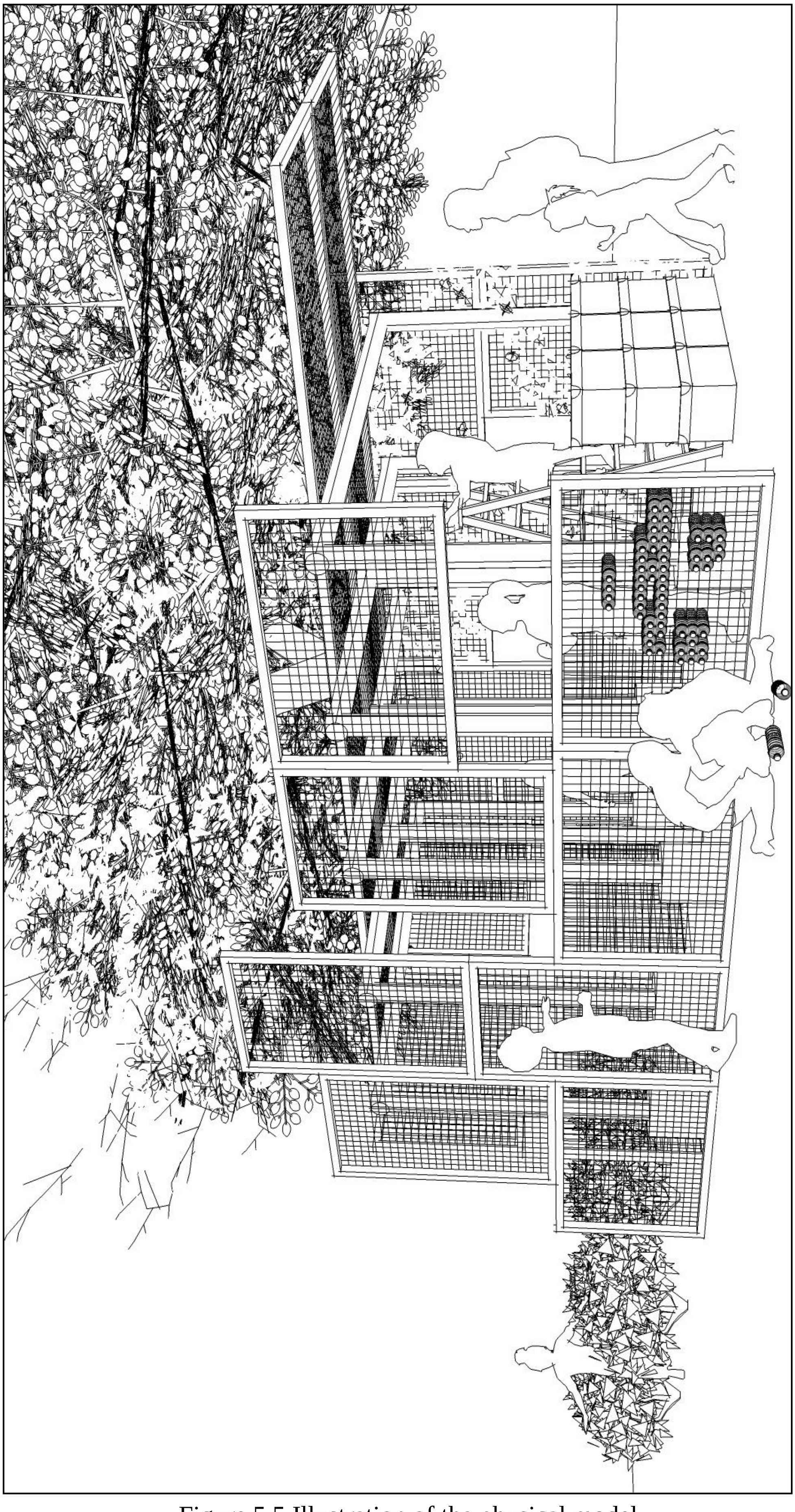


Figure 5.5 Illustration of the physical model

Table 5.1: Feature, sub-feature and description of the initial design scheme

Feature	Sub-Feature	Short Description
Transparency	Exposed Materials	Recyclables and reclaimed components were used to construct the physical model. These salvaged materials were displayed throughout the façade, structure and roof.
	Exposed Technologies & Services	The roof revealed the rainwater collection and recycling processes to the participants.
	Exposed Ecological Processes	The low walls made composting more visible and accessible to the participants by enabling them to continuously observe and monitor the decomposition of organic wastes.
In One with Nature	Indoor-Outdoor Relationship	The physical model was semi-opened, allowing for greater ventilation and daylight penetration into the interior. These environmental conditions support indoor composting using the organic matters collected outdoor.
	Outdoor Learning Spaces	Organic farming plot was allocated next to the physical model as an outdoor learning space.
	Site Specific Features	The physical model was strategically located under a matured tree where abundant of dried leaves were available for composting.
Creativity & Imagination	Artistic and Inventive Buildings	The wall was like a collage, composed of numerous tins and bottles. Additionally, creepers could be grown on the east-west elevation as natural sun screen.
	Reuse of Salvaged Products	The structure was made from reclaimed PVC pipes while the infill panels were assembled from rejected aluminium frames.
	Spaces for Experimentation	The physical model served as an art studio for students to perform various experimentations with waste products (e.g. paper roll, bottles, etc).
Active Setting	Open-Ended Spaces	The physical model was a multipurpose space that can be easily retrofitted for collecting, sorting, cleaning and reprocessing of waste materials.
	Operation and Maintenance	Participants were in charge of the daily operation of the physical model as well as perform maintenance tasks under the supervision of the author.
	Project-Based Activity	Participants took part in a DOB workshop. Furthermore, the façade, colour scheme and aesthetic appearance can be continuously altered through project-based activities (e.g. art or science projects).

Findings from Phase 1 highlighted the importance of making materials, services and ecological processes ‘transparent’ to the students. Thus, the discarded item has been displayed and celebrated as an environmentally friendly material by the physical model. Reclaimed components, such as rejected aluminium frames and PVC pipes, were tapped for its potential secondary use. Recyclables like tins and bottles were displayed throughout the façades. Moreover, plastic bottles were installed at the roof as a rainwater collection device, whereby it helped to make the rainwater harvesting system more visible and accessible to the students. The collected rainwater could be used for irrigation and cleaning purposes. On the other hand, PVC storage boxes were stacked on top of each other to form a low composting wall. This helped the students to observe the decomposition of organic waste.

Findings from Phase 1 also disclosed the significant of being ‘in one with nature’. Thus, the physical model was designed to be semi-opened, allowing for greater ventilation and daylight penetration into the interior. This would facilitate the indoor composting using the organic matters collected outdoor. The physical model also allowed light to enter through soda bottles, which are built into the walls. Additionally, an organic farming plot was allocated next to the physical model for students to grow vegetables and fruits. The organic fertilizer generated by the composting wall could be used in the farming plot. The physical model also responded to its site by integrating itself with the existing ecosystem. It was strategically located under a matured tree where abundant of dried leaves and garden wastes were available for composting. The physical model served as an ideal setting for decomposition of organic waste and thus helped to return nutrients to the soil.

Phase 1 findings revealed that 'creativity and imagination' was an important criterion for a 3-D textbook. Thus, the walls of the physical model were used as a collage, consisting of numerous tins and bottles. Additionally, creepers would be grown on the east-west elevation as natural sun-screen. Salvaged products would also be reused creatively to inspire students toward sustainable waste management. For instance, students could clean, cut and reassemble the reclaimed PVC pipes to form the skeleton of the physical model, and rejected aluminium frames would be used as the infill panels. Furthermore, the physical model served as an art studio for students to perform various experimentations with waste products. It supported and promoted the exploration of recycled arts and crafts.

Phase 1 findings highlighted that the 3-D textbook should have an 'active setting' instead of a passive environment. Therefore, the physical model was designed to serve multiple purposes. The recycling bins could be rearranged easily to provide flexibility for collecting, sorting, cleaning and reprocessing of waste materials. The students would be in charge of the daily operation and maintenance. They were expected to perform repairs under the supervision of the technicians. A DBO workshop would be organized so that the students could be fully involved with the architectural processes. Furthermore, the façade, colour scheme and aesthetic appearance of the physical model could be continuously altered through project-based activities.

5.3.3 The DBO Workshop

The DBO Workshop was opened for registration on 6th October 2011. 42 interested standard five students signed up for the workshop with their parents' consent. The DBO Workshop would enable them to design, build and operate a full-scaled model which acted as a representation of the 3-D textbook (Table 5.2). All aspects of the workshop was planned and arranged by the author with the help from an architect, two facilitators and an experienced builder.

The design and build activities took place during the school holidays where the participants spent six consecutive days (ten hours per day) in their school to complete the tasks given. For the purposes of the workshop, the participants were organized into three groups, each under the supervision of an architect or facilitator. In the beginning of the workshop, the author presented Phase 1 findings together with the initial design scheme to the participants. They were then requested to discuss and write their comments about the physical model using sketches and diagrams. Special emphasis was placed upon the understanding of the properties and limitations inherent to the reclaimed materials (e.g. their amount, their dimension, their appearance, etc.) and how the design could help to achieve the objectives of the quasi experiment.

The participants were exposed to architectural design by drawing their concept and idea in plan view, elevation and perspectives. Initial individual solutions were then evaluated by the other group members where the differences were discussed, negotiated and revised. Subsequently, collaboration was formed between the groups to combine different design aspects into one hybrid solution. The participants developed the final product by building a cardboard model through the synthesis of the groups' findings (Figure 5.8). It was found that the participants' comment towards the initial design scheme developed by the author was very minor. The main revision was on the façade configuration, where the participants preferred to use their own composition instead of the pattern proposed by the author. The workshop was subsequently evolved into full-scaled construction using equipments borrowed from the Faculty of Built Environment, University of Malaya (Figure 5.9).

The participants involved as active and valued contributors throughout the construction process. They were allowed to develop simple detailing under the guidance of the author or architect. Using bolt and nut, for example, provided both speed and creative possibility during the construction process. It also allowed the participants to do more with their inadequate knowledge of construction and limited abilities. The final product was a cumulative, imaginative structure which grew from a set of parameters of time, resources and ability, as well as the participants' own dynamic personalities (Figure 5.10). It denoted a simplified architecture that responded to the available materials, limited budget and children capability (Figure 5.11). The main structure was built out of reclaimed PVC pipes salvaged from landfills and nearby demolition projects (Figure 5.12). The roof and facades were composted out of rejected aluminium frames acquired through a wholesale company (Figure 5.13). Additionally, creepers were grown on the east elevation as natural sun screen while the west facade was used to store plastic bottles (Figure 5.14). Moreover, the roof construction was inspired by a popular traditional craft in Malaysia – weaving. Plastic bags and banners were cut into strips and then woven by the participants according to their earlier design (Figure 5.15).

Upon the completion of the design and build activities, the DBO Workshop evolved into the operational stage for a period of two months. All the 42 participants took part in this stage which enabled them to operate and maintain the physical model as a new recycling centre in their school. They were involved in the daily activities such as watering plants with collected rainwater, sorting of recyclables and cleaning of salvaged materials (Figure 5.16). These hands-on activities were able to equip the participants with the required skill and knowledge in recycling. Emphasize was placed on the understanding of cyclic process instead of linear consumption. For instance, the participants collected food waste (e.g. stems, peels and leaves) for composting. The compost was then used as fertilizer in the organic farming plot to grow fruits and vegetables. The participants were also allowed to use the physical model for special projects after school. For instance, the participants constructed bar chimes from salvaged paper rolls and aluminium cans. The bar chimes were hung on the roof frames, and displayed as a musical instrument made from recyclables.

Table 5.2: The DBO Workshop

Stage	Process	Short Description	Facilitated by	Duration
1	Design	• Reviewing initial design scheme • Studying the properties of different waste materials and their potential for recycling • Exploring design options for the physical model • Discussing and presenting idea sketches to facilitators and group members • Making cardboard model to study structure, form, facades and construction	The author, an architect and two facilitators	Two days
2	Build	• Implementing ideas at the actual site • Hands-on construction activities • Making foundation, structure and infill-panels from reclaimed materials	The author, an architect, two facilitators and an experienced builder	Four days
3	Operate	• Before school: 1. watering plants with collected rainwater 2. sending waste materials collected from home to the physical model 3. sorting and cleaning recyclables • During recess: 1. collecting waste materials within the campus 2. collecting organic waste (e.g. food waste, dried leaves, grass cuttings) for composting • After school: 1. sorting and cleaning of recyclables 2. repair work (if applicable) 3. special projects (i.e. making recycling bins, composting walls, bar chime and organic farming)	The author	Daily, for a period of two months

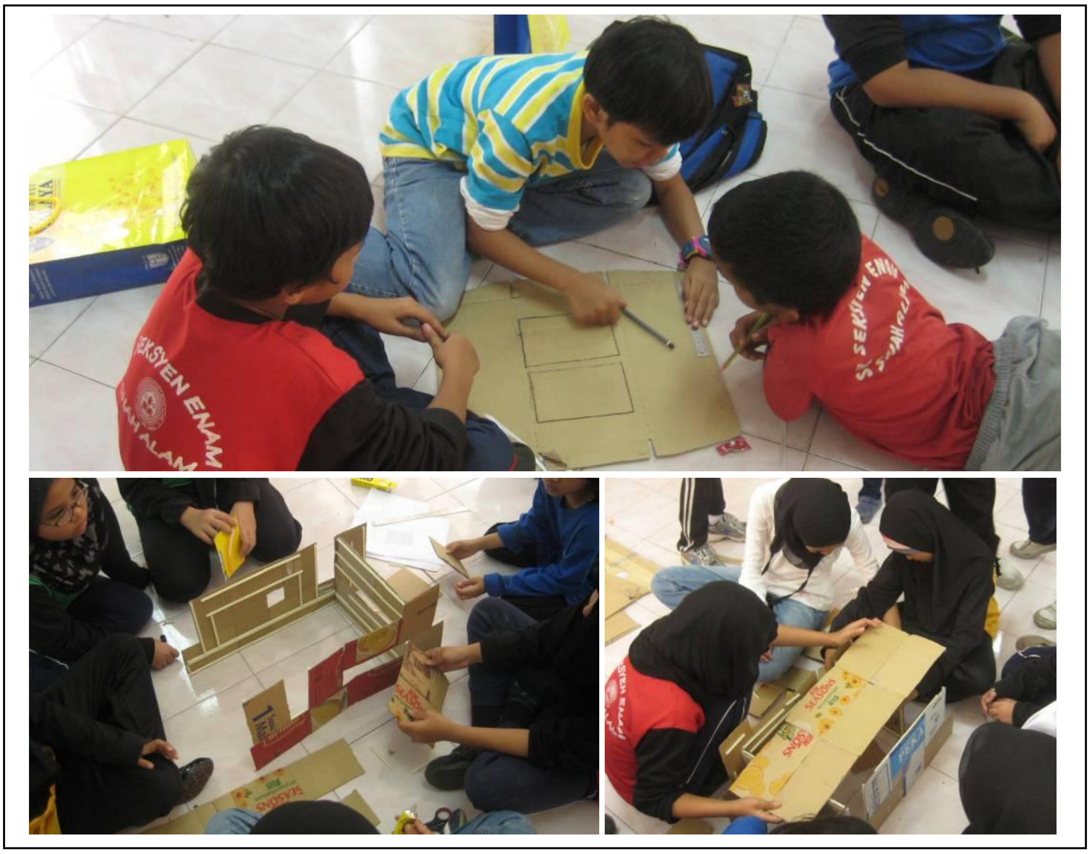


Figure 5.8: Building a cardboard model to understand form and space

Figure 5.9: Cut off saw and power drill were used,
rather than the more meticulous hand-carpentry methods

Figure 5.10: The physical model was a collage of recyclables which could be easily interchanged, built and maintained by the participants

Figure 5.11: Photographic records of the construction progress on-site

Figure 5.12: The PVC frames were cleaned, refurbished, joined and tested in a badminton court prior to the installation on-site

Figure 5.13: The participants were allowed to configure the aluminium frames in a variety of pattern with their own creativity

Figure 5.14: Plastic bottles were used as 'planter boxes' on the east elevation while the west facade served as an 'art board' to store plastic bottles

Figure 5.15: Weaving took place on-site

Figure 5.16: Operation and maintenance of the physical model

5.4 RESULTS

5.4.1 Quantitative Data Assessment

The quantitative data ought to be assessed for its normality and reliability prior to the inferential analysis. Also, scholars noted that it was essential to check the assumptions of ANCOVA (i.e. homogeneity of variance and homogeneity of regression slopes) in experimental research so that meaningful conclusion could be drawn (Culen & Volk, 2000; Leeming, et al., 1997; Noiseux & Hostetler, 2008).

5.4.1.1 Normality test

The author adopted the following tests to check the assumption of normality. The first test involved visual inspection and thus it was a subjective test. The subsequent two tests were statistical.

1. visual inspection of histograms
2. Kolmogorov-Smirnov test
3. Shapiro-Wilk test

Comparing a histogram of the data to a normal probability curve was an informal approach for normality testing (Figure 5.17). The empirical distribution of the data ought to be bell-shaped and be similar to the normal distribution. The inspection of the histograms revealed satisfactory where most of the frequency counts bunched in the middle and with the counts dying off out in the tails. However, this was a subjective method to test for normality and open to abuse (Field, 2009). With small sample sizes (N=42), discerning the shape of the histogram was a challenging task. Moreover, the shape of the histogram could change considerably by just altering the interval width of the histogram bars. Thus, objective tests were needed to decide whether or not a distribution was normal.

Kolmogorov-Smirnov and Shapiro-Wilk tests compared the scores in the sample to a normality distributed set of scores with the same mean and standard deviation

(Field, 2009). Thus these tests could be utilized to impartially evaluate whether the data was normally distributed, even with small sample sizes. The distribution of the sample was considered to be not significantly different from a normal distribution (i.e. it is normal), if the test was non-significant (p>.05). However, if the test was significant (p<.05), then the distribution was significantly different from a normal distribution (i.e. it is non-normal). The results of these tests (Table 5.4, Table 5.5 and Table 5.6) revealed non-significant values (*Sig.* more than .05) for all scores and hence reflected normal data.

Three of the tests above revealed that the distributions were fairly normal. Given that normality was much harder to achieve with a small sample, this was considered a satisfactory result. Thus, a one-way analysis of covariance (ANCOVA) could be conducted based on the assumption of normally distributed data.

5.4.1.2 Reliability

Cronbach's alpha was the reliability test used to establish the reliability of the collected data. An alpha result of 0.7 or higher was indicative of good reliability (Field, 2009). Analysis of the pretest and posttest with alpha values were presented in Table 5.3 below, thus indicating good reliability for all quantitative data.

Table 5.3: Reliability coefficients for all measures

Scale	Group	Alpha Coefficients	
		Pre-test	Post-test
Knowledge	Comparison	.737	.795
	Participant	.725	.754
Attitude	Comparison	.876	.881
	Participant	.804	.847
Behaviour	Comparison	.935	.930
	Participant	.901	.892

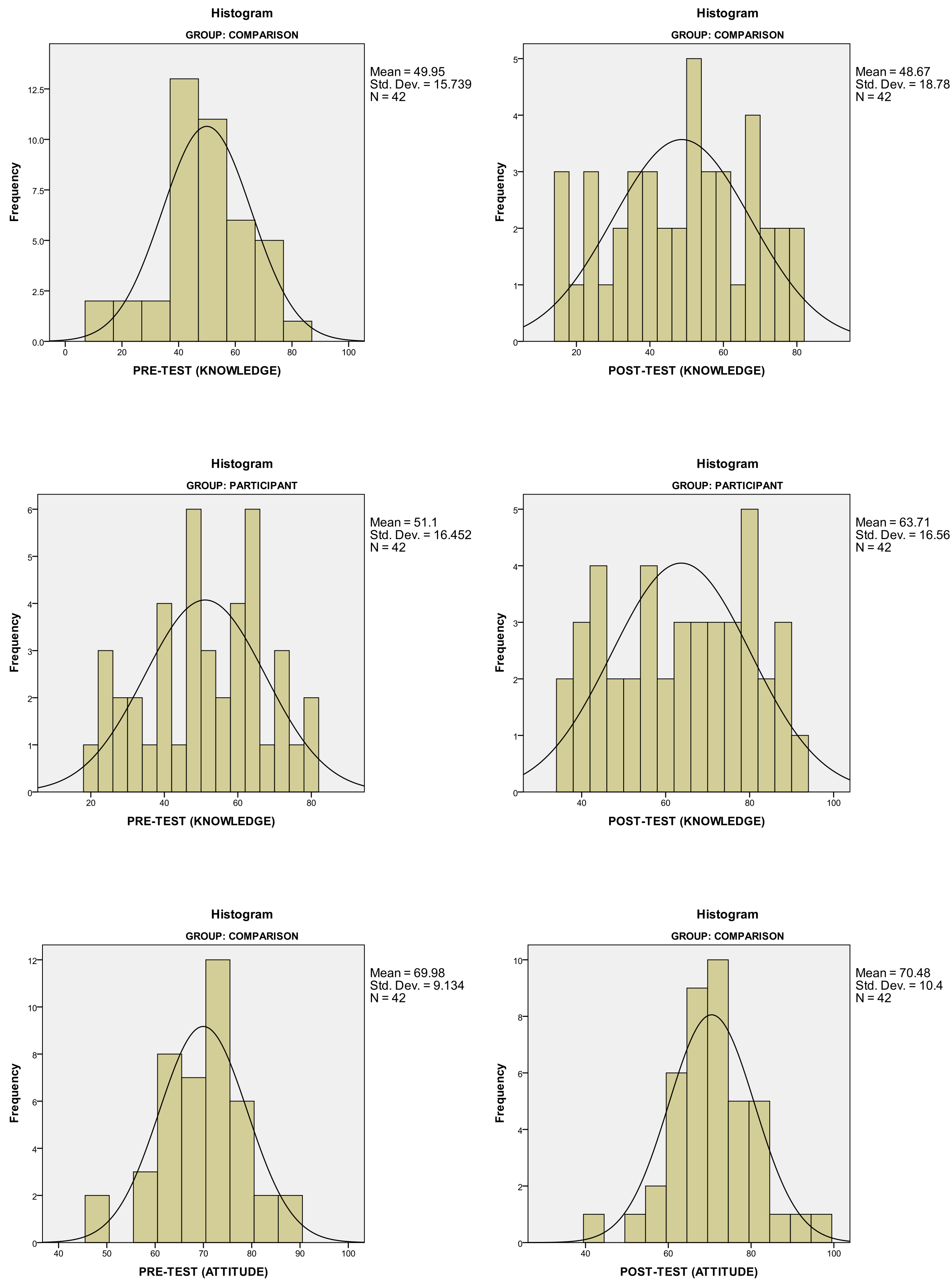


Figure 5.17: Histograms of the pretest and posttest data

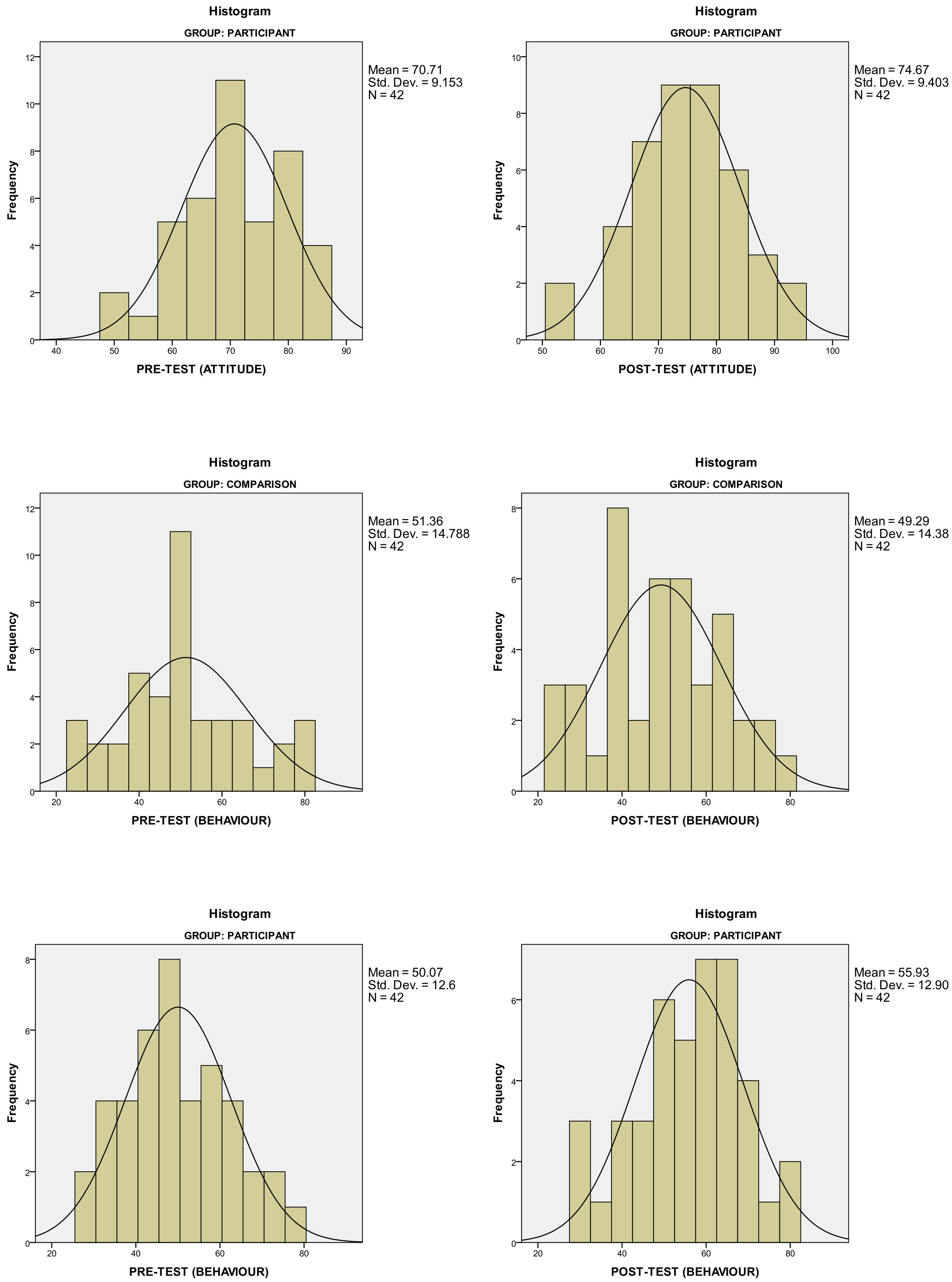


Figure 5.17, continued

Table 5.4: Tests of normality (knowledge)

	Group	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Post-Test	Comparison	.094	42	.200*	.961	42	.160
	Participant	.104	42	.200*	.948	42	.056
Pre-Test	Comparison	.121	42	.132	.967	42	.262
	Participant	.093	42	.200*	.965	42	.227

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Table 5.5: Tests of normality (attitudes)

	Group	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Post-Test	Comparison	.095	42	.200*	.985	42	.855
	Participant	.063	42	.200*	.991	42	.984
Pre-Test	Comparison	.100	42	.200*	.981	42	.719
	Participant	.085	42	.200*	.966	42	.247

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Table 5.6: Tests of normality (behaviour)

	Group	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Post-Test	Comparison	.075	42	.200*	.975	42	.488
	Participant	.094	42	.200*	.976	42	.521
Pre-Test	Comparison	.126	42	.094	.966	42	.250
	Participant	.079	42	.200*	.978	42	.567

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

5.4.1.3 Homogeneity of variance

Before any inferential statistical analysis could be carried out, the data must be tested for homogeneity of variance (Field, 2009). That is, the assumption that the groups came from populations with equal variances (Coakes & Ong, 2011). This test was pertinent when using ANCOVA which assumed homogeneity of variance. The appropriate test for homogeneity of variance was Levene's test (Coakes & Ong, 2011). It had an advantage over other tests because it did not require the data to be normal in order for the result to be reliable. Although normality testing in Section 5.4.1.1 concluded that the quantitative data was generally normal, particularly taking into account the small sample size, Levene's test was deemed to be more appropriate here because other tests required larger sample size with absolutely normal data.

Levene's test assessed the hypothesis that the variances in the groups were equal (i.e. the difference between the variance was zero). Therefore, if Levene's test was significant at $p<.05$ then the null hypothesis was incorrect and that the variances had been violated. If, however, Levene's test was non-significant (i.e. $p>.05$) then it could be assumed the difference between the variances was zero – the variances were roughly equal and the assumption was tenable. When the pretest and posttest scores were tested, the significance values were $p=.74$ for knowledge, $p=.11$ for attitudes and $p=.79$ for behaviour, indicating that the assumption for homogeneity of variance had been met (Table 5.7, Table 5.8 and Table 5.9). It was noted that ANCOVA was fairly robust in terms of violation of the assumption of homogeneity of variance when the sample of sizes for both participant and comparison groups were equal (Field, 2009; Haberman & Bush, 1998; Lipsey, 1990; Lipsey, 1998).

Table 5.7: Levene's test of equality of error variances[a] (Knowledge)

F	df1	df2	Sig.
.112	1	82	.739

Dependent Variable:POST-TEST (KNOWLEDGE)

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + PRETEST + GROUP

Table 5.8: Levene's test of equality of error variances[a] (Attitudes)

F	df1	df2	Sig.
2.592	1	82	.111

Dependent Variable:POST-TEST (ATTITUDE)

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + PRETEST + GROUP

Table 5.9: Levene's test of equality of error variances[a] (Behaviour)

F	df1	df2	Sig.
.070	1	82	.791

Dependent Variable:POST-TEST (BEHAVIOUR)

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + PRETEST + GROUP

5.4.1.4 Homogeneity of regression slopes

Before conducting ANCOVA tests, the homogeneity-of-regression slopes assumption should first be tested (Culen & Volk, 2000; Noiseux & Hostetler, 2008). The test evaluated the overall relationship between the independent variable and covariate in the prediction of the dependent variable. A significant interaction between the independent variable and the covariate suggested that the differences on the dependent variable among groups vary as a function of the covariate. If the interaction was significant – the results from an ANCOVA were not meaningful and ANCOVA should not be conducted.

When the quantitative data of the current study were tested, the results suggested that the interaction was not significant (p>.05), for knowledge [F(1, 80)=1.982, p=.163], attitudes [F(1, 80)=1.387, p=.242] and behaviour [F(1, 80)=.034, p=.854]. The interaction source was labelled as GROUP*PRETEST in Table 5.10, Table 5.11 and Table 5.12. The results indicated that the assumption for homogeneity of regression slopes had been met.

Table 5.10: Tests of between-subjects effects (Knowledge)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10801.874[a]	3	3600.625	14.652	.000
Intercept	6854.853	1	6854.853	27.895	.000
GROUP	1676.198	1	1676.198	6.821	.011
PRETEST	5695.597	1	5695.597	23.177	.000
GROUP * PRETEST	486.937	1	486.937	1.982	.163
Error	19659.078	80	245.738		
Total	295680.000	84			
Corrected Total	30460.952	83			

Dependent Variable:POST-TEST (KNOWLEDGE)

a. R Squared = .355 (Adjusted R Squared = .330)

Table 5.11: Tests of between-subjects effects (Attitudes)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3629.199[a]	3	1209.733	26.299	.000
Intercept	606.624	1	606.624	13.188	.000
GROUP	36.388	1	36.388	.791	.376
PRETEST	3008.195	1	3008.195	65.397	.000
GROUP * PRETEST	63.793	1	63.793	1.387	.242
Error	3679.944	80	45.999		
Total	451448.000	84			
Corrected Total	7309.143	83			

Dependent Variable:POST-TEST (ATTITUDES)

a. R Squared = .497 (Adjusted R Squared = .478)

Table 5.12: Tests of between-subjects effects (Behaviour)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5841.458[a]	3	1947.153	14.995	.000
Intercept	3213.232	1	3213.232	24.744	.000
GROUP	113.956	1	113.956	.878	.352
PRETEST	4740.440	1	4740.440	36.505	.000
GROUP * PRETEST	4.431	1	4.431	.034	.854
Error	10388.578	80	129.857		
Total	248701.000	84			
Corrected Total	16230.036	83			

Dependent Variable:POST-TEST (BEHAVIOUR)

a. R Squared = .360 (Adjusted R Squared = .336)

5.4.2 Quantitative Findings

A one-way analysis of covariance (ANCOVA) was conducted to test the hypotheses. The groups (i.e. participant and comparison) were used as the independent variables while the dependent variables were the posttest scores for knowledge, attitudes and behaviour. Additionally, the pretest scores were included in the regression model as covariates to control for the influence they had on the dependent variables. The descriptive statistics for all relevant variables was presented in Table 5.13.

Table 5.13: Participant and comparison descriptive statistics

Measure	Group	N	Pre-Test		Post-Test	
			M	*SD*	*M*	*SD*
Knowledge	Comparison	42	49.95	15.739	48.67	18.781
	Participant	42	51.10	16.452	63.71	16.561
Attitudes	Comparison	42	69.98	9.134	70.48	10.400
	Participant	42	70.71	9.153	74.67	9.403
Behaviour	Comparison	42	51.36	14.788	49.29	14.380
	Participant	42	50.07	12.600	55.93	12.902

5.4.2.1 Hypothesis 1

The covariate (i.e. pretest scores), was significantly related to the posttest scores, $F(1,81)=22.35$, $p<.05$, r=.60. There was also significant effect of treatment on posttest scores after controlling for the effect of pretest scores, $F(1,81)=17.64$, $p<.05$, r=.55. Thus, results from ANCOVA supported the hypothesis that the participant group would experience significant growth in knowledge in relationship to the comparison group. These results indicated that when controlling for pretest score, there was a significant positive effect of the 3-D textbook on students' recycling knowledge.

The line graph in Figure 5.18 gave a visual picture of what was going on with the study. The pre-post means of the participant group were joined with a thicker line while the pre-post means of the comparison group were joined with a thinner one. These values corresponded to those found in Table 5.14. The key to understanding this outcome was that the comparison group did not change much between the pretest and the posttest. However, the participant group demonstrated improved knowledge in recycling from pre to post. In summary, the first hypothesis was supported. Thus, it was accurate to say that students who interacted with the 3-D textbook demonstrated an improvement in recycling knowledge as compared to their peers who had not interacted, after controlling for the effect of pretest scores.

5.4.2.2 Hypothesis 2

The covariate (i.e. pretest scores), was significantly related to the posttest scores, $F(1,81)=70.21$, $p<.05$, $r=.74$. There were also significant effect of treatment on posttest scores after controlling for the effect of pretest scores, $F(1,81)=5.52$, $p<.05$, $r=.51$. Thus, results from ANCOVA supported the hypothesis that the participant group would experience significant growth in pro-recycling attitudes in relationship to the comparison group. These results indicated that when controlling for pretest score, there was a significant positive effect of the 3-D textbook on students' pro-recycling attitudes.

The line graph in Figure 5.19 gave a better picture of the study. The pre-post means of the participant group were joined with a thicker line while the pre-post means of the comparison group were joined with a thinner one. These values corresponded to those found in Table 5.15. Here, both the participant and comparison groups had similar means during the pretest. However, the participant group demonstrated an improvement from pre to post, while the comparison group remained unchanged. This outcome pattern may be used as a supporting evidence for the ANCOVA analysis above. In summary, the second hypothesis was supported. Thus, it was accurate to say that students who interacted with the 3-D textbook demonstrated more pro-recycling attitudes as compared to their peers who have not interacted, after controlling for the effect of pretest scores.

5.4.2.3 Hypothesis 3

The covariate (i.e. pretest scores), was significantly related to the posttest scores, $F(1,81)=38.27$, $p<.05$, r=.70. There were also significant effect of treatment on posttest scores after controlling for the effect of pretest scores, $F(1,81)=8.86$, $p<.05$, r=.53. Thus, results from ANCOVA supported the hypothesis that the participant group would experience significant growth in recycling behaviour in relationship to the comparison group. These results indicated that when controlling for pretest score, there was a significant positive effect of the 3-D textbook on students' recycling behaviour.

The line graph in Figure 5.20 illustrated what was going on with the study. The pre-post means of the participant group were joined with a thicker line while the pre-post means of the comparison group were joined with a thinner one. These values corresponded to those found in Table 5.16. A "cross-over" pattern was noticed. The comparison group didn't appear to change much from pre to post. However the participant group did, starting out lower than the comparison group and ending up above them. This echoed the ANCOVA analysis above and served as the clearest pattern of evidence for the effectiveness of the treatment. In summary, the third hypothesis was supported. Thus, it was accurate to say that students who interacted with the 3-D textbook engaged in more recycling behaviour as compared to their peers who had not interacted, after controlling for the effect of pretest scores.

Table 5.14: Table Tests of Between-Subjects Effects (Hypothesis 1)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10314.938[a]	2	5157.469	20.736	.000
Intercept	6977.321	1	6977.321	28.053	.000
PRETEST	5559.890	1	5559.890	22.354	.000
GROUP	4387.136	1	4387.136	17.639	.000
Error	20146.015	81	248.716		
Total	295680.000	84			
Corrected Total	30460.952	83			

Dependent Variable:POST-TEST (KNOWLEDGE)

a. R Squared = .339 (Adjusted R Squared = .322)

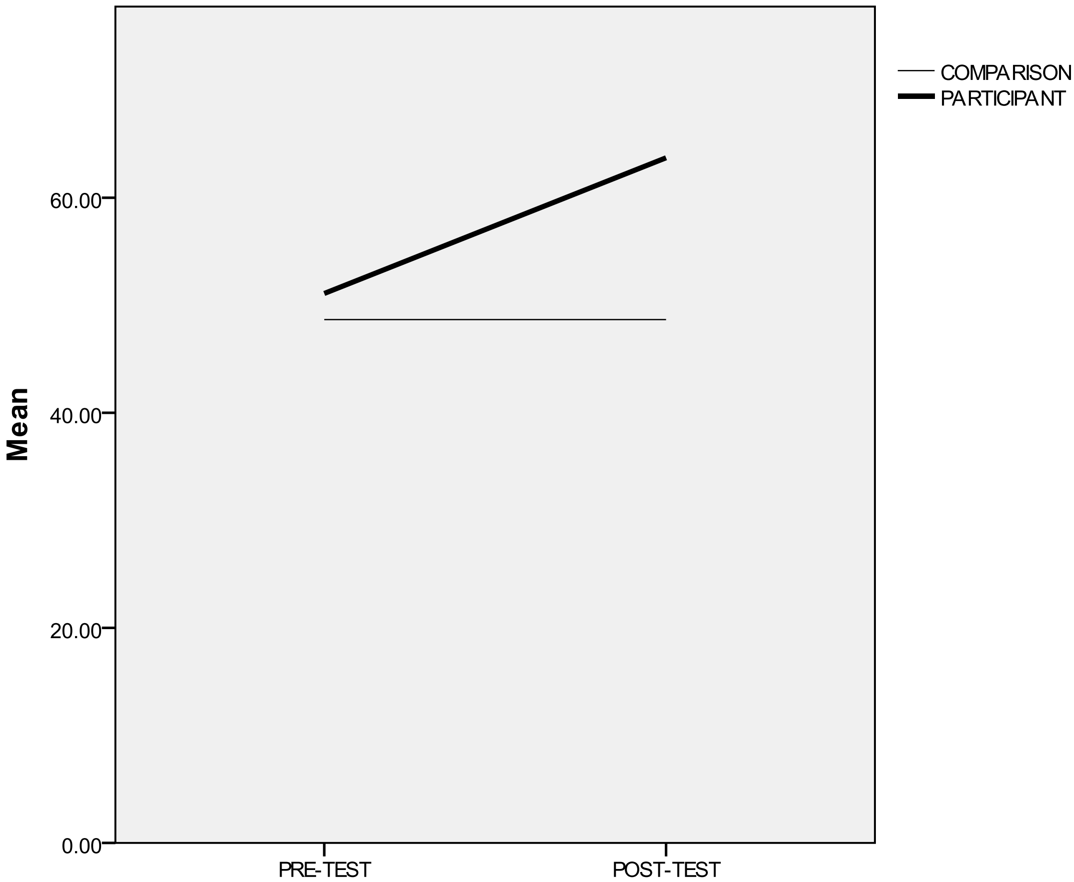


Figure 5.18: Line graph representing mean scores for knowledge according to tests (as indicated along the *x*-axis) and separated into groups (as described in the legend)

Table 5.15: Table Tests of Between-Subjects Effects (Hypothesis 2)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3565.406[a]	2	1782.703	38.571	.000
Intercept	559.417	1	559.417	12.104	.001
PRETEST	3245.216	1	3245.216	70.214	.000
GROUP	255.107	1	255.107	5.520	.021
Error	3743.737	81	46.219		
Total	451448.000	84			
Corrected Total	7309.143	83			

Dependent Variable:POST-TEST (ATTITUDES)

a. R Squared = .488 (Adjusted R Squared = .475)

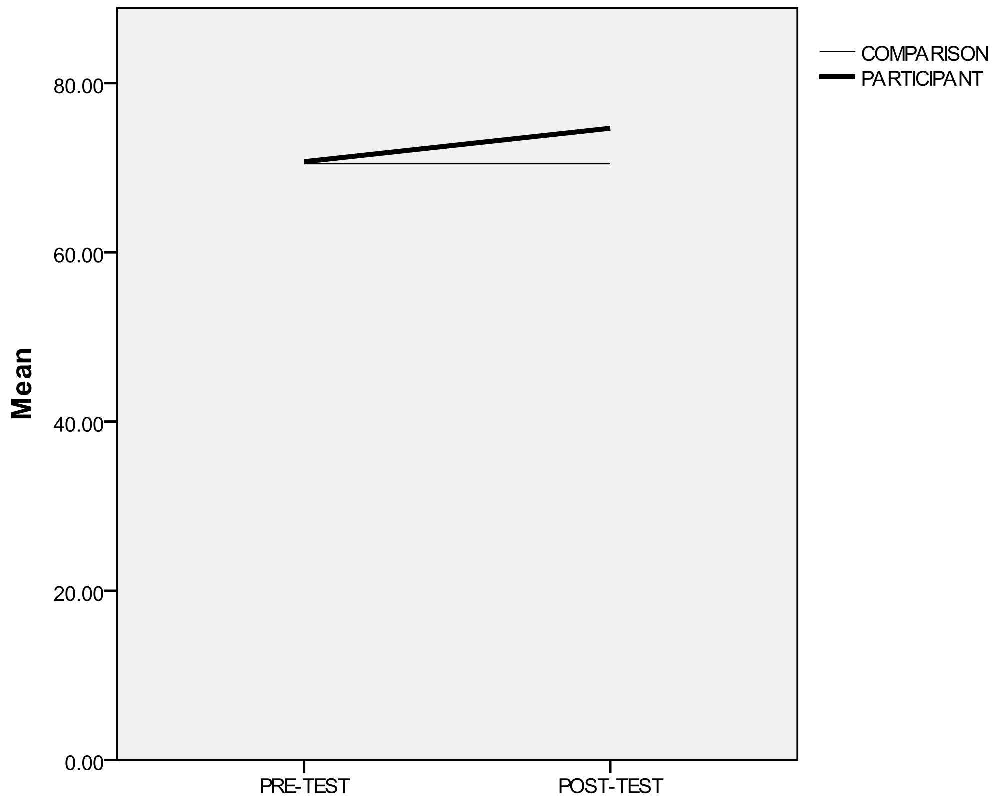


Figure 5.19: Line graph representing mean scores for attitudes according to tests (as indicated along the *x*-axis) and separated into groups (as described in the legend)

Table 5.16: Table Tests of Between-Subjects Effects (Hypothesis 3)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5837.027[a]	2	2918.514	22.746	.000
Intercept	3244.517	1	3244.517	25.287	.000
PRETEST	4910.349	1	4910.349	38.270	.000
GROUP	1137.211	1	1137.211	8.863	.004
Error	10393.008	81	128.309		
Total	248701.000	84			
Corrected Total	16230.036	83			

Dependent Variable:POST-TEST (BEHAVIOUR)

a. R Squared = .360 (Adjusted R Squared = .344)

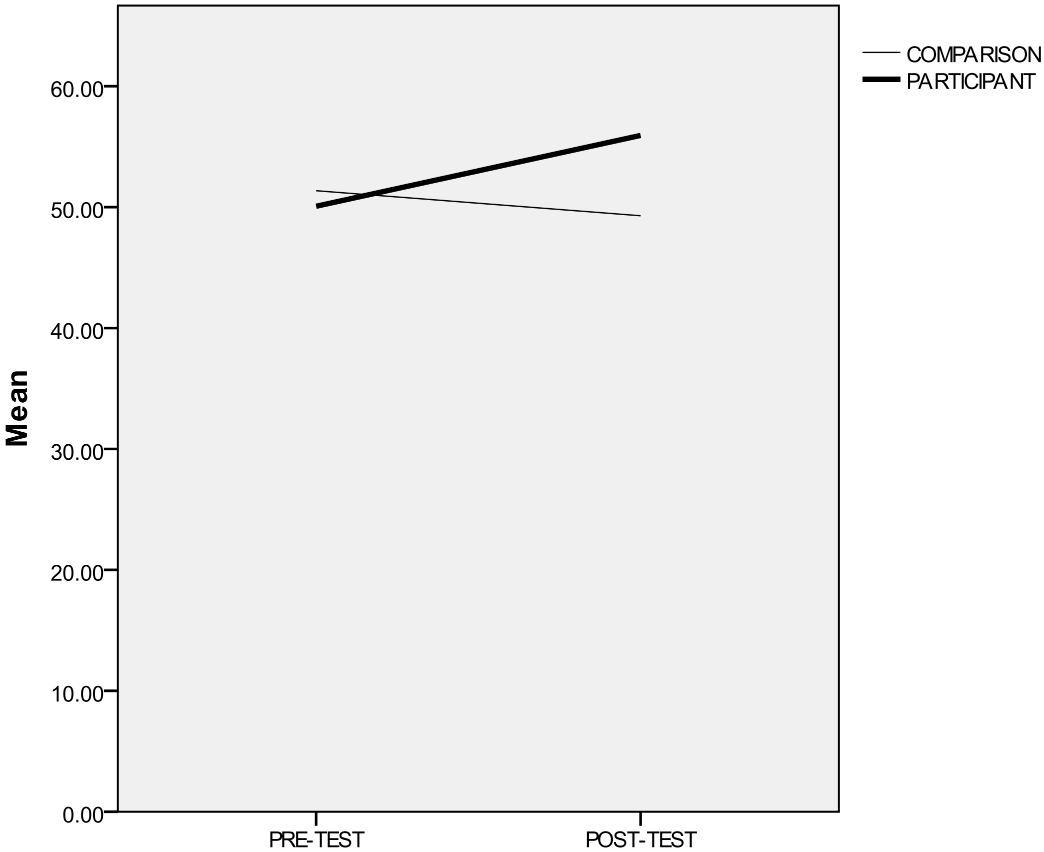


Figure 5.20: Line graph representing mean scores for behaviour according to tests (as indicated along the *x*-axis) and separated into groups (as described in the legend)

5.4.3 Qualitative Findings

The participants' interviews, journal entries and field notes were generally consistent with the quantitative results. The author found that, where statistically significant differences between the participant and comparison groups were found, qualitative data usually provided a plausible explanation, suggesting further support for the validity of the quantitative results. It should be noted that since the physical model was operated as a new recycling centre in the school, the terms "physical model" and "recycling centre" had been used interchangeably throughout the journal entries and interviews.

5.4.3.1 Knowledge

The participants felt that they were more likely to understand recycling concepts if they were actively involved in the process. They regarded the physical model as a pedagogical tool that supported the act of hands-on learning. For example, a participant noted: "I learn more about items that are recyclable in my school because I am in charge of the collection and separation of waste in the recycling centre… Learning happens when I am doing and practicing it". His statement was concurred by other participants where most of them believed that they had developed a relatively solid foundation about recyclables versus non-recyclables through the daily operation of the physical model. Field note documented that: "The error in recycling has been substantially reduced. The participants have developed the required knowledge in collecting and separating organic and inorganic waste as well as recyclables and non-recyclables. They are more confident and independent in the daily operation and maintenance of the physical model now".

Development of more specific knowledge about the recycling process was also noted. For instance, a participant stated that, "…recycling is not about throwing things away. Instead, it is an eco-friendly waste management which involves collection, separation and processing of waste into something useful”. Furthermore, participants described the physical model as an interactive exhibit that increased knowledge about waste sorting. A participant said, “I used to be very confused about waste sorting in my school. However, in the physical model, it is very easy and engaging. I put the bottles into the wall, aluminium cans into the bar chimes and paper into the portable bins”. When asked how to handle organic waste during the interviews, the most common answer was “composting”. The following drawing (Figure 5.21) and comment were shared by a participant:

> “Composting is recycling of organic waste in nature… I made my first compost in the recycling centre using dried leaves and vegetables from the canteen. It is amazing to see these organic resources transformed into fertilize. And it helps to make my bitter gourd grow faster… I know how to mix the ‘green’ and ‘brown’ materials as well as using the earthworm to speed up the composting process.”

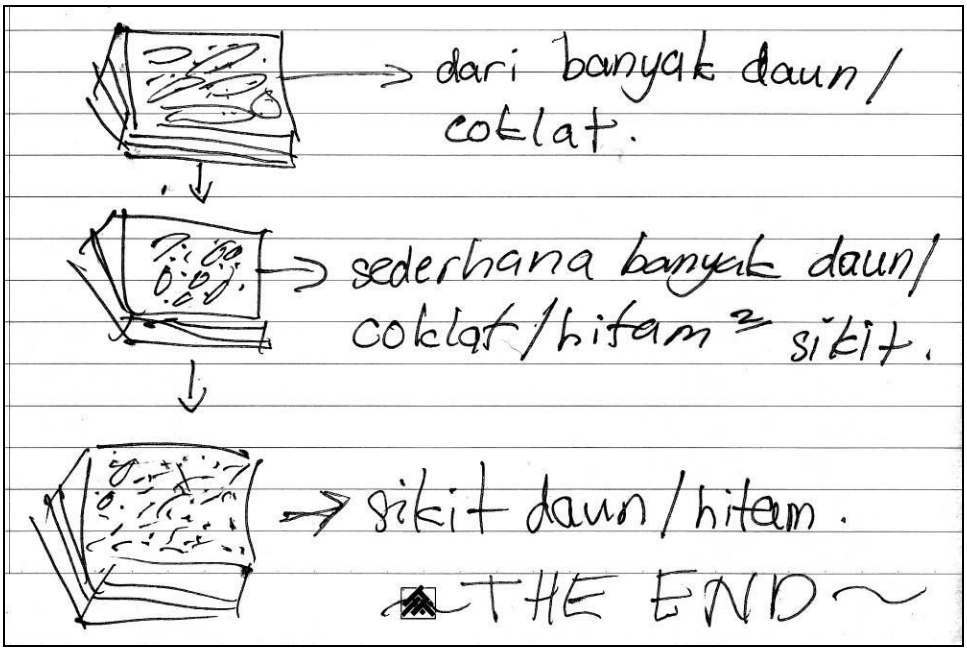


Figure 5.21: Composting process

5.4.3.2 Attitudes

The participants expressed positive attitudes toward recycling, along with a sense of uneasiness about the impact of non-recyclable or non-biodegradable products on the environment. As a participant noted, “I don’t like toys from plastic and rubber because they are harmful to the environment... These toys are non-recyclable and non-biodegradable”. Landfills were perceived to have a negative impact on the environment, thus many participants were concerned about the effect of urban discards on earth. Particularly, they were worried of the pollution, depleting of resources and accumulation of garbage as a result of the increased number of landfills. For instance, a participant said, “I am worry about the amount of rubbish generated, thus, everyone must recycle. If not, there will be more and more rubbish in landfills”.

Overall, participants held strong beliefs toward conservation and recycling. They were concerned about the sustainability issues and the health of planet earth. The following drawing (Figure 5.22) and comment was shared by a participant: “We must save the Earth together. Recycle the rainwater and other wastes”. When asked what was the best way to help the Earth, most participants chose to recycle. They regarded recycling as an alternative to discarding. For example, a participant stated, “Recycling is very important because it helps to conserve resources... It is really scary to see how rubbish can damage the environment. People should stop creating rubbish by recycling”. Additionally, participants expressed that recycling was fun and that they felt good when they recycled as evidenced by statements like “I am glad to recycle in my school and at home” or “I am very excited today because I help to collect and separate recyclables from the canteen”. Most participants felt that they were responsible to solve the environmental problem. A participant said:

> "Children should in charge of the recycling in schools instead of the teacher or cleaner. We are capable of contributing to the conservation of environment… We have designed, built and operated this physical model. I hope other schools can have a similar model like this. It is a very powerful tool for education… More importantly, it changes our perception and attitudes towards recycling. I think now I care more about the environment…"

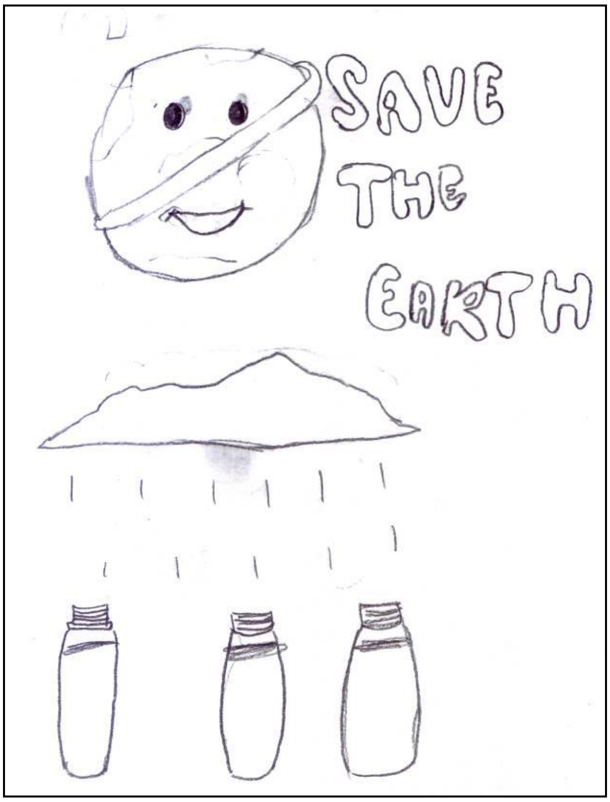


Figure 5.22: Saving the Earth by recycling of rainwater

5.4.3.3 Behaviour

When asked what was gained from the design, build and operate of the physical model, most participants focused on the development of recycling as a habitual behaviour. For example, one participant stated:

> "I use recyclables to design and build this physical model. I also collect, separate and repurpose waste in this model during the operational stage. It is a wonderful experience… It changes the way I look at recycling and it definitely motivates me to recycle more. I do not recycle last time, but I am recycling bottles and newspaper on a daily basis now… I also help my mother to separate her kitchen waste for composting."

It was not compulsory for the participants to recycle, however, at the end of the DBO workshop, many participants felt obliged to do so. A participant said: "I recycle every day now. I collect plastic bottles from the canteen, field and hall". Another participant shared his drawing (Figure 5.23) and comment: "I recycle bottles, aluminium cans and paper in my school. I want to minimize the waste". Interviews and journal entries further revealed that the participants felt that they were performing tasks over and above routine lessons in the DBO workshop. For some participants, learning through the textbook did not really have a significant influence on their behaviour. They believed that a more direct experience was required in order to impact their conduct. They were also aware of the differences between the indirect experience offered by their classroom and the direct experience they gained through the interaction with the physical model. As one participant mentioned:

> "Classroom lesson concentrates on facts and numbers. It is more abstract in nature and most of time I just listen and do nothing... However, the recycling centre promotes learning by doing. I think these hands-on activities help me to develop a recycling habit. More important, the recycling centre helps me to acquire the skills of collecting, separating and processing waste. I don't think I can get these skills through my textbook."

Apart from recycling in school, participants also reported that they were committed to recycle at home. A participant explained how the physical model promoted this voluntary behaviour change: "Apart from recycling in school, I also recycle in my house. I like the physical model very much. It inspires me to set up a small recycling corner in my house". Furthermore, the physical model appeared to have acted as a medium to transform pre-existing knowledge into action. This development was obvious from the statement of a participant who expressed a heightened interest in recycling following his interaction with the model, "I learn about recycling in my classroom, but I have limited opportunity to practice what I have learnt. Now things have changed! The recycling centre provides an excellent platform for me to apply what I know".

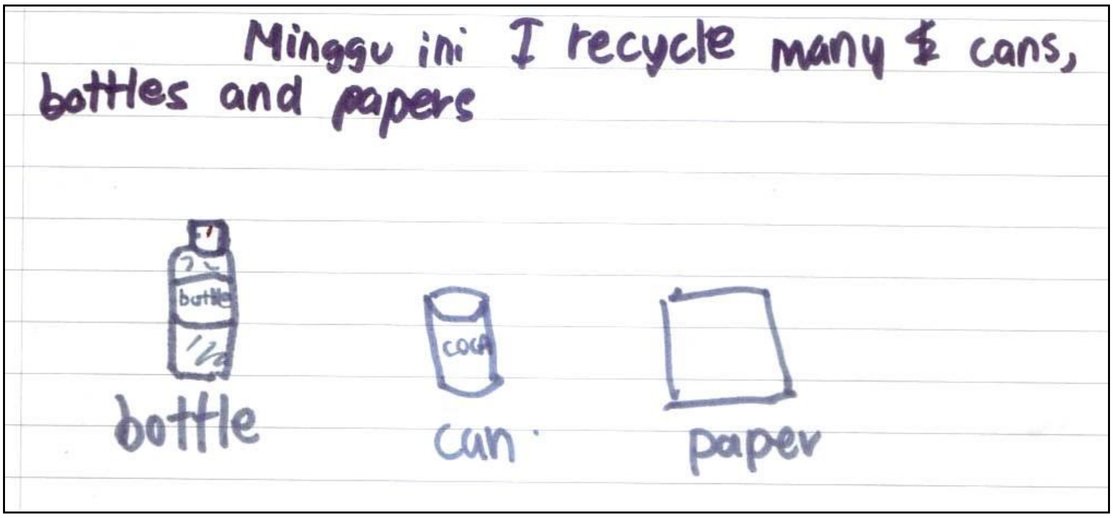


Figure 5.23: Recycling in school

5.4.3.4 Setting Attributes

The participants believed that the physical model was a strong infrastructure that promoted recycling in not only their school, but at home and in their community as well. Many of the participants identified the following setting attributes which gave a positive impact on their knowledge, attitudes and behaviour:

1. Informative environment with apparent clues

The participants described the physical model as "informative" because the building materials and systems were not hidden from view. Particularly, the physical model provided an abundant of organic and inorganic waste for further exploration by the participants. These recyclables, being displayed throughout the façades, structure and roof, inspired and motivated the participants toward recycling. Additionally, it was a part and parcel of the intention to unmask the rainwater harvesting system so that the water cycle was more visible to the participants. The exposed system enlightened the participants the opportunity to recycle rainwater for non-domestic use (i.e. irrigation and cleaning). Thus, it recognized that many resources can be saved and recycled. On the other hand, the stacked composting bins, which formed a low wall at the back of the physical model, enabled the participants to observe and monitor the decomposition of organic wastes. It helped to make the decomposition process more accessible to the participants so that they could understand how this ecological process closed the loop in nature. The following drawings (Figure 5.24) and conversation exemplified this perspective:

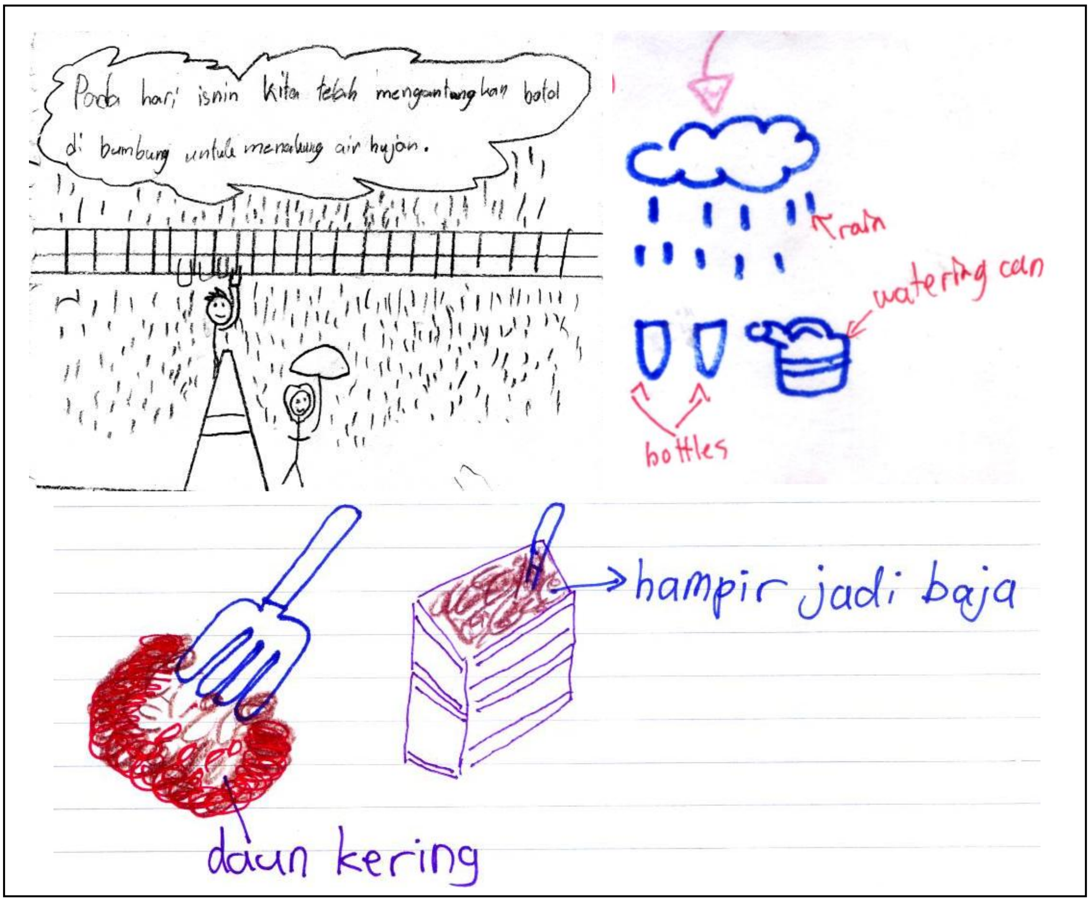


Figure 5.24: Selected participants’ drawings illustrating the rainwater harvesting system and stacked composting bins

Interviewer:	Can you please describe the physical model to me?
Participant:	The physical model is operated as a recycling centre. It is a very special building because it is constructed from recyclables… I am always amazed to see the different building components from reclaimed materials. It conveys a strong environmental message to the students.
Interviewer:	Can you give an example of how you learn from the physical model?
Participant:	Oh, yes… The most obvious example is the stacked composting bins. These bins make composting more visible and accessible to us. It shows how organic wastes are recyclable through decomposition… I can observe the decomposition of dried leaves and fruit peels. I will check the progress every morning.
Interviewer:	Great! Can you elaborate on another example?
Participant:	Let me think... I am also impressed with the roof which capable of capturing and recycling rainwater. The entire rainwater harvesting process is very apparent. I can see everything that happens. The plastic bottles are transparent. So, I can see water slowly filled up the bottles when it rains… The bottles are installed at the roof structure to collect rainwater… We are in charge to take the bottles down every morning to water the plants.

2. Eco-friendly building that worked with the surroundings

Journal entries and interviews documented that the participants recognized the physical model as an eco-friendly building that integrated the surroundings as part of the educational spaces. The physical model was strategically located under a matured tree where abundant of dried leaves could be found. Instead of seeing the dried leaves as a garden waste, the physical model provided the facility to compost these organic matters into fertilizers. The participants were amazed how dried leaves from a tree could be composted and returned to the soil to support plant growth. Moreover, the physical model was semi-opened, allowing for greater ventilation and daylight penetration into the interior. These environmental conditions supported indoor composting using the organic matters collected outdoor. A participant stated: “The recycling centre is not totally enclosed like the classroom. It is semi-opened and naturally ventilated. It provided the optimal temperature, moisture and air for composting". Furthermore, a 65sqft organic farming plot was allocated next to the physical model as an outdoor learning space. Participants learned about organic farming as an alternative to using chemical fertilizer and pesticide. Participants were exposed to the nutrient cycle where most of them understood that food waste from the canteen can be composted and recycled as manure. This was illustrated by the photo (Figure 5.25) and dialogue below:

Figure 5.25: Collection of dried leaves for composting and organic farming

Interviewer:	Can you elaborate on the organic farming plot?
Participant:	Hmm… The organic farming plot is part of the recycling centre. We plant vegetables and fruits there.
Interviewer:	Why do you say that the farming plot is part of the recycle centre?
Participant:	Well… As you can see, the farming plot relies on the supply of fertilizer from the stacked compost bins in the recycling centre… And the compost bins rely on the supply of dried leaves, twigs and grass clippings which we collected outdoor.
Interviewer:	Interesting. So, how would you elaborate the indoor-outdoor relationship then?
Participant:	The indoor supported the outdoor and vice versa. This is because the recycling centre is the 'greenest' building in the school. Green building works with the surrounding… It helps to enhance the flora and fauna.

3. **Innovative design and solution**

Interviews and journal entries documented that the participants regarded the physical model as an exemplar building for innovative design and solution. It served as a living illustration that prompted the participant to re-evaluate waste as a more productive resource. The physical model was designed and constructed from recyclables. The structure was made from reclaimed PVC pipes while the infill panels were assembled from rejected aluminium frames. Interviews disclosed that the physical model was capable of captivating interest and awareness in the subject of recycling and sustainable waste management. Thus, most of the participants recognized that recycling was a better alternative to throwing away. Additionally, the physical model served as an art studio for the participants to perform various experimentations with waste products (e.g. paper roll, bottles, aluminium tins, etc.). Field notes documented that “The bottles wall is the central of attraction. Participants bring bottles from their home and school to fill up the wall in an attempt to compose different pattern as a collage”. In addition, the participants were eager to conduct a series of tests to determine the properties of different waste materials. Field notes and interviews noted that participants intended to divert waste from landfill through recycling and repurposing waste for alternative uses. The following drawings (Figure 5.26) and dialogue exemplified this perspective:

Figure 5.26: Selected drawing and photo illustrating the PVC pipe structure, aluminium frame infill panel and bottles wall

Interviewer: What do you like about the physical model?

Participant: Surely it's creative approach in design, construction and operation. It is uncommon to see this type of building here in Malaysia… The normal school buildings are dull and uninteresting. However, this physical model is very innovative and inventive. It is so inspiring to have a recycling centre constructed from recyclables here.

Interviewer: Tell me more about the recyclables in the physical model.

Participant: The recyclables are waste materials or discarded items. However, with creativity, we have repurposed these materials for other uses. For instance, the structure of the physical model is constructed out of reclaimed PVC pipes… There are a lot of possibilities to convert waste to resource. And creativity is the key leading to this transformation… The physical model is also an ideal setting for conducting experimentation with recyclables. It served as the testing ground for waste characterization… and the use of the findings to fully explore the potential embedded in these materials… For instance, we explored the properties and strength of the paper roll in the physical model and then decided to cut holes, add string and waterproof tapes to the paper roll to convert it into the frame of a recycling bin…

4. Interactive spaces for hands-on activity

Unlike the traditional EE lesson which was often examination-driven, the physical model acted as a catalyst for hands-on activities (Figure 5.27). Participants noted that they gained the basic definition and concept of recycling through classroom lessons, but they hoped for opportunities to learn more about these issues out of the classroom. Thus, they were very excited about the physical model which was interactive and engaging. Participants were in charge of the daily operation as well as performed various maintenance tasks under the supervision of the author. Their active participation enlightened them about the amount and type of recyclables in their school. Additionally, the physical model was a multipurpose space that could be easily retrofitted for collecting, sorting, cleaning and reprocessing of waste materials. It enabled the participants to develop a complete picture of the various stages and processes in recycling. Furthermore, the façade, colour scheme and aesthetic appearance of the physical model could be continuously altered through project-based activities (i.e. art or science projects). Thus, the physical model served as a catalyst to attract interest, attention and support for school-based recycling activity. The participants acknowledged that the physical model transformed recycling into a fun, lively and engaging activity. As evidence by the following conversation:

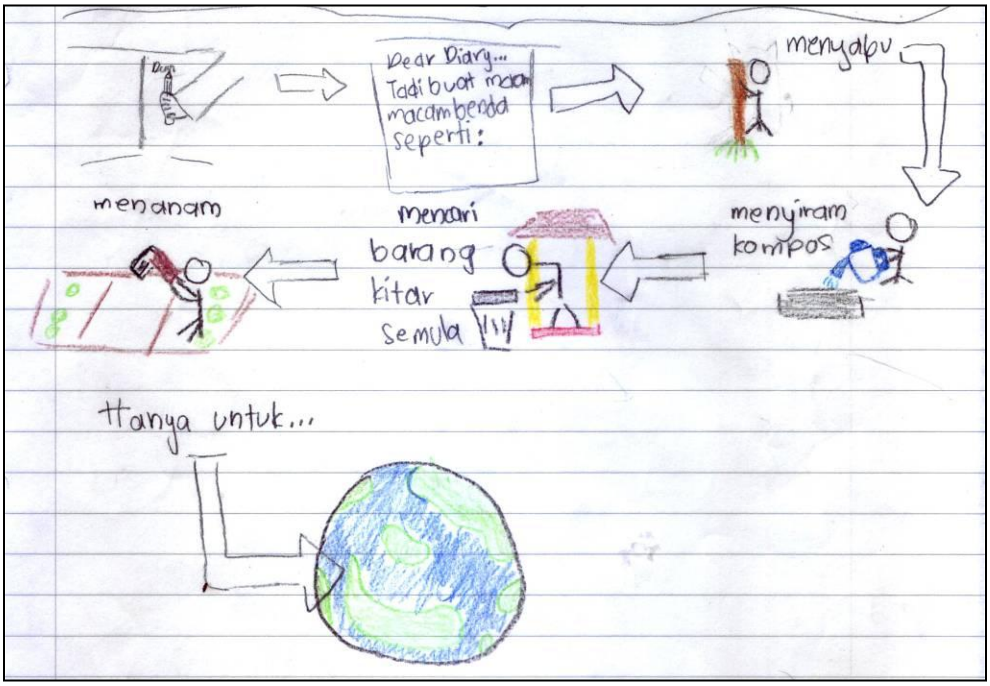


Figure 5.27: Selected participant’s drawing illustrating hands-on activities

Interviewer: How would you describe recycling?

Participant: I used to think that recycling is throwing things into bins only… But the physical model changes my perception. Recycling involves a lot of activities.

Interviewer: Can you please elaborate the activities?

Participant: Oh, can! It involves collection, storage and separation of waste. All these can be done in the multipurpose space within the physical model… The bottles wall is for bottle while the portable bin is for the paper. Sometimes, I am also involved with the maintenance. I need to cut the banner into plastic strips to repair the damaged roof.

Interviewer: How would you describe the physical model then?

Participant: I like the physical model very much. No other school has the same… It is the heart of recycling activities.

5.5 DISCUSSION

Both the quantitative and qualitative data offer a better comprehension of the relationship between the 3-D textbook and EE outcomes. These findings also expand and offer insights concerning previous empirical (e.g. Culen & Volk, 2000; Dietz, et al., 2009) and theoretical work (e.g. Orr, 1993; Taylor & Enggass, 2009) in this area of study. The remaining sections contain sequential quantitative and qualitative discussions followed by a synthesis of the study's findings.

5.5.1 Quantitative Discussion

Phase 2 is intended to test the effectiveness of the 3-D textbook to enhance the EE outcomes. Following the nonequivalent pre-post test design for a quasi experiment, the author sought to develop an understanding on the impact of the 3-D textbook on pro-recycling knowledge, attitudes and behaviour. A physical model is used as a full-scaled representation of the 3-D textbook. Findings from the quasi experiment offer statistical support for the study's hypotheses. The results are discussed below.

5.5.1.1 Knowledge

ANCOVA analysis discloses that when controlling for pretest score, there is a significant positive effect ($p<.05$) of the 3-D textbook on participant's pro-recycling knowledge. It is interesting to note that the 3-D textbook is able to promote a more cognitive development among the participants. Although it is proven that traditional EE programs in classroom play a significant role in students' knowledge, the success of the non-traditional setting in promoting cognitive development is scarce. The findings from the current research supported scholars' (Taylor, 1993; Taylor & Enggass, 2009; Taylor & Vlastos, 1983) argument that a non-traditional setting like the 3-D textbook can be used for knowledge transmission in school. A profound and reasonable explanation of the above findings is that the participants' do possess an understanding of the recycling issue, but at certain points it is still imperfect or diffuse, therefore possibility influencing the pre-score in a negative way. Scholars (Jensen, 2002; Kuhlemeier, et al., 1999; Rickinson, 2001) noted that the books can be valuable for providing fundamental facts and information, but they are insufficient in asking students to think critically about recycling. However, the use of a 3-D textbook enables the participants to convert factual knowledge into application, making them more conscious of their own thoughts. It also encourages them to check their own ideas with teacher or other students, to reflect upon and, if required, to consider an alteration of these ideas as suggested by Schultz, et al. (1995). It promotes a better comprehension of recycling issues, critical thinking about local trash problems and appropriate settings to carry out sustainable waste management. Thus, the 3-D textbook appears to have acted as a catalyst, broadening and deepening the concepts already present in the participants' existing knowledge.

The positive impact of the 3-D textbook on the pro-recycling knowledge is also supported by Taylor's and Enggass's (2009) writings. Students who participated in the architectural procedures are able to develop a fundamental knowledge of environmental concepts and processes. This could occur because DBO enables the students to see and critically analyze the physical world as suggested by Shapiro (2012). It also allows them to read the environment with deeper understanding. For instance, through the design and build processes, the 3-D textbook enlightened the participants about the origin of the reclaimed materials and how to prevent these resources from ended up in landfill. It promotes cycle thinking instead of liner as well as highlighting the properties of waste (e.g. size, shape, colour, degradability, etc) to the participants. Also, through the daily operation, the 3-D textbook enlightened the participants about which materials are recyclable, or where recyclables are collected.

The positive impact of the 3-D textbook on participants' knowledge scores also responds to the growing recognition of the importance of hands-on learning as proposed by Aho, et al. (1993) and Rickinson (2001). The 3-D textbook is an environmentally friendly and innovative testament to recycling that highly impacts the motivation to learn as well as the understanding of knowledge. This is supported by Lim and Mun-Desalle (2010) who noted that hands-on activity enables the participants to extend their intellectual capacity as well as provide knowledge to their peers. For example, sorting of waste enables the participants of the current research to construct a clear distinction between 'recyclables' and 'non-recyclables'. It also highlights the challenges in recycling laminated packaging materials and the unfeasibility of waste separation after dumping. The concept of 'learning by doing' is exciting because it moves the sole onus and ownership of the transfer of knowledge away from the hands of schools and the teacher as suggested by Griffin (1998). Students become both learners and teachers. Instead of just receiving information from a teacher or text book, students have a chance to own knowledge, make discoveries, and share them with their families and friends.

This current study also responds to the increased interest on how to engage students in recycling through their interaction with the physical environment (Cherif, 1995; Higgs & McMillan, 2006). A 3-D textbook offers students real-world scientific experiences that encourage and support them in learning about the process of recycling and how to become environmentally responsible citizens. This is consistent with the cognitive aims such as comprehension, analytical and problem-orientated thinking as suggested by Millar & Millar (1996). In this current study, the 3-D textbook appears to be fruitful in engaging the participants in activities positioned in real-world contexts to improve their local significance. This architectural intervention has succeeded in improving the participants' understanding of the mechanisms and processes in recycling. The basis for these arguments is that most participants when asked about their experience of interacting with the 3-D textbook, they were able to articulate accounts of actual recycling which touch on reality instead of abstract ideas. It appears that the 3-D textbook is capable of making the participants' learning real and relevant to their lives. It promoted the generation of new knowledge through the daily experiences. This concurs with Kortland's (1997) and Rickinson's (2001) suggestion to use students' daily life understanding of the waste issue for cognitive development as well as helping them to link the recycling processes and cycles in a meaningful way. Therefore, the 3-D textbook enables the students to extract and integrate information from the physical settings spontaneously and has a significant impact on the students' knowledge scores.

5.5.1.2 Attitudes

ANCOVA analysis discloses that when controlling for pretest score, there is a significant positive effect ($p<.05$) of the 3-D textbook on participant's pro-recycling attitudes. In this study, attitudes is operationalized as feelings about recycling similar to Tonglet, et al. (2004). The current research concurs with previous researches (Carlson & Baumgartner, 1974; Duerden & Witt, 2010; Ernst & Theimer, 2011; Price & Hein, 1991) which suggest that participation in architectural or ecological activities is a promising technique for improving students' environmental attitudes.

The participants were actively involved in the DBO of the 3-D textbook. Meaning is generated from their participation where ideas and concepts of the 3-D textbook as a learning environment are reinforced. Students who take part in the design of spaces build up a sense of meaningful involvement and responsibility in environmental issues. The current research concurs with previous studies (Fien, 1997; Gough, 2005; James & Bixler, 2008) that students who can obtain a sense of connectedness, active involvement and personal investment in their learning are able to better comprehend and retain information, and therefore promote the development of positive attitudes.

Additionally, the 3-D textbook in this research enables the participants to personalize the environment, to portray territoriality and to be included in their own learning. The participants were able to share with their peers significant characteristics of recycling as well as externalizing its expressions. The act of designing and constructing a space with reclaimed materials helps to mirror the underlying value of sustainability and at the same time produces a stronger sense of self-identity in the individual student as suggested by some scholars (Kadji-Beltran, et al., 2012; Rauch, 2000; Tilbury, 1995). The 3-D textbook allows participants to portray their values and personalities through means of the physical settings. Involvement of participants in the learning and architectural processes of the 3-D textbook in the current research mean that there are active strategies to promote the development of pro-recycling attitudes as suggested by Eagles and Demare (1999). This also concurs with earlier studies (Cronin-Jones, 2000; Eagly & Chaiken, 1993; Ferreira, 2011; Palmer, 1993; Shepard & Speelman, 1986) which documented that the physical environments that students occupy and the extent to which they feel involved in shaping them or caring for them are a significant domain for pro-EA.

The positive impact of the 3-D textbook on participants' attitudinal scores also suggests a strong link between physical environment and pro-EA as suggested by Dietz, et al. (2009), Fredrickson and Anderson (1999). The current research provides additional empirical evidences that interaction with physical environment (i.e. 3-D Textbook) mediated the attitudes and norms of students. A reasonable explanation for above-mentioned is that the 3-D textbook provided an appropriate opportunity and setting for child-environment interaction where it helps to establish emotional bonds and positive attitudes toward the physical settings and recycling issues as noted by Perkins (2010). Direct experiences enable the students to observe and contribute towards ecologically conscious attitudes and decisions. Therefore, the current research responds to the growing recognition of the importance of physical settings in fostering positive EA as noted by some scholars (Kaiser & Gutscher, 2003; Lisowski & Disinger, 1991; Zelezny, 1999).

In the current research, the 3-D textbook appears to be a 'thought provoking' signage (Romani, et al., 2012) for long-term attitude change. It concurs with Mitchell's (2005) proposition that buildings from salvaged materials are strongly associated with the 3Rs and thus pro-environmental messages. The findings revealed that built environment can be utilized as a strong and clear visual signage to remind one to recycle as well as promoting accessible and durable attitudes change. It supports the notion of "emotion driven design" as advocated by various design practitioners such as Norman (2004), van Gorp and Adams (2012). For instance, the physical appearance of the 3-D textbook reinforces the values and ideas of sustainable waste management. Therefore, the participants regarded the 3-D textbook as a persuasive sign to promote and teach new reasons for recycling in and beyond the campus. In short, the 3-D textbook in this study is regarded as a "trigger" which caused the participants to link the physical settings with a pro-environmental construct. This architectural intervention yields relatively high cognitions, sustained recycling, positive attitudes and reasonably detailed description for how architecture becomes a symbol or a persuasion for recycling.

5.5.1.3 Behaviour

ANCOVA analysis discloses that when controlling for pretest score, there is a significant positive effect ($p<.05$) of the 3-D textbook on participants' recycling behaviour. This corresponds with certain other pieces of work in the field of environment-behaviour (Anthony, 1987; Duerden & Witt, 2010; Kumar, et al., 2008). Geller et al. (1982) classifies behavioural intervention strategies into two groups: antecedent and consequence interventions. The 3-D textbook in this research can be considered as an antecedent strategy because it provides prompting and helps to remove barrier in recycling prior to performance of the behaviour. The 3-D textbook, constructed from reclaimed materials, acts as the simplest, least expensive and least intrusive strategies to convey the message of sustainable waste management to the students. Also, the 3-D textbook provided a convenient drop-off for recyclables within the school. It is an open-ended space that can suit various recycling work so that the participants' intentions of recycling can be developed. Additionally, the 3-D textbook helps to make the sorting of waste more interesting with minimum effort involved. Werner and Makela (1998) note that when a task is not intrinsically enjoyable or rewarding, students will not do it except they have some motivation to persist. Sansone and Morgan (1992) further explain that intervention for recycling can focus on formerly unseen aspects of the task, add variety to how the task is performed, or even change the definition or meaning of the task. For instance, with respect to the 3-D textbook in this research, it is capable of making recycling more interesting by changing the participants' focal point from how time-consuming it is to how quickly the collage wall or composting wall fill; or change their definition by highlighting that they are working with a recyclable resource rather than garbage. Undoubtedly, making recycling more appealing and convenient can strengthen the students' recycling intentions and increase the frequency of recycling. This is supported by Reid, et al. (1976). The strength and key contribution of the 3-D textbook is to make the recycling more interesting and more relevant to the students' life.

The 3-D textbook can be also be classified as a consequence strategy because it attempts to modify recycling behaviour by presenting a consequence (i.e. feedback) contingent upon the behaviour. For instance, the 3-D textbook has collage walls which indicate the number of bottles collected, enabling the participants to observe the effects of their behaviour. Additionally, some of the participants measured the changes of weight or volume of trash and recyclable materials by hand and then recorded the information in their journal entries. This concurs with Seligman's et al. (1981) writings that noticeable feedback or changes help to increase recycling behaviour. The 3-D textbook also responds to the increasing recognition that physical environment can function as integral components of the EE by serving as laboratories for teaching and learning of environmental sustainability lessons as suggested by Ford (2007), Fusco (2001), Orr (1997) and Rauch (2000). It provides students with clear, direct and actionable feedback on the environmental impact of activities and technologies as a mechanism for engaging, educating, motivating and empowering the students to make desirable changes in environmental behaviour. For instance, in the current research, the exposed bottles installed at the roof enable the students to observe, study and most importantly carry out rainwater collection and recycling. Also, the composting wall provides visible feedbacks to the participants by displaying different rate of decomposition with different organic mixtures. Therefore, the 3-D textbook first attract interest and after that create an experiential learning environment in which the observer can easily sees and then understands the environmental impacts of design decisions and personal behaviour on the processes and cycles of matter through the physical environment as noted by Knapp (2005). The premise is that the new knowledge and understanding will then motivate the observer to adopt pro-EB (Oskamp, et al., 1991). In short, the current study suggests that the 3-D textbook have a profound and transformative affect on the participants' thinking and action. The participants feel empowered by the experience with the 3-D textbook and they are committed to act as a participant rather than a spectator in recycling.

Critics of EE have argued that few interventions actually encourage responsible environmental behaviour because they do not actively involve students in environmental issues (Volk, et al., 1984). Others have argued that interventions, in general, are ineffective in their ability to change behaviour (Cone & Hayes, 1980). The current study, however, countered this argument. The results indicate that 3-D textbook is an architectural intervention that renders a positive impact on the participants' recycling behaviour through their active involvement in the process. Particularly, the 3-D textbook promotes hands-on activities (e.g. separating of recyclables, experimenting with biodegradable materials, creating an art project out of discarded items, etc) for its success in a school setting. This concurs with Higgs's and McMillan's (2006) documentation that school facilities and operations can promote pro-EB by modelling sustainable practices, creating a context for hands-on learning and increasing students stewardship of their environment. Additionally, the 3-D textbook helps the students to transform the ideas of recycling from abstract concepts to personal and tangible applications. It appears that this architectural intervention allows physical environment to foster learning about recycling and the adoption of recycling behaviour without the need to proselytize, thus avoiding the problems associated with overt advocacy as noted by some scholars (Berryman & Breighner, 1994; Cangemi & Kahn, 1979; Frayer & Klausmeier, 1972).

The current study also concurs with Dietz's (2009) suggestion that a building can be used as a catalyst for behavioural change. The 3-D textbook set a consistent behavioural standard and created a holistic approach to recycling behaviour. Previous studies (Schunk, 1987; Schunk, et al., 1987; Wagstaff & Wilson, 1988) reveal that if students learn through direct and frequent observation that the people and institutions they respect engage in sustainable practices, rather than merely being told of their importance, they are more probably to adopt such behaviours. The current research concurs with the above-mentioned. The participants in the quasi experiment who have involved and seen recycling practices being carried out firsthand at the 3-D textbook are better prepared to adopt the habit of recycling.

5.5.2 Qualitative Discussion

The 3-D textbook may be favourable for knowledge, attitudes and behaviour development, but this appears to be contingent upon how it is designed, constructed and operated. The qualitative findings from this study provide some insights regarding the attributes of the 3-D textbook, in other words, what makes a meaningful learning setting from the students' point of view. In Phase 2, participants' perceptions of what setting attributes that influenced their knowledge, attitudes and behaviour suggests that the defining characteristics of the 3-D textbook are: 1) informative environment with apparent clues; 2) eco-friendly building that worked with the surrounding; 3) innovative design & solution; 4) flexible spaces for hands-on activities.

The theme of 'informative environment with apparent clues' is consistent with the research literature, which suggests to "make the invisible visible" (Mitchell, 2005, p. 28) as a method to teach students about recycling issues. For instance, Day and Midbjer (2007) noted that recycling is an essential process in nature, however, conventional architecture has made this into a hidden process. Thus, they suggest to have "A 'compost window' – with insulating shutters to maintain middle-heap temperature – can show worms and other creatures at work" (p. 214). The current research echoes their suggestion because the recycling of rainwater, composting and campus waste stream have been woven into the physical environment, making the 3-D textbook an informative space for learning. By making these recycling processes visible and accessible to the students, the 3-D textbook can help to link narrow, blinkered, linear systems into closed-cycle communities of production. Additionally, a cue or prompt in the 3-D textbook can be an effective tool that incites students to learn not only about recycling, but also leads them to an understanding of the underlying ideas, patterns and principles of sustainable waste management as suggested by Arnheim (1997), Grandin (2006), Shams and Seitz (2008). Thus, in this study, exposed materials, technology, building services and ecological processes promote awareness of and dialogue concerning the value of recycling. It makes recycling processes visible and active at all levels of scale from the classroom to the campus to the entire neighbourhood. This is supported by Barr (2011).

Participants' description of an 'eco-friendly building that worked with the surrounding' is consistent with the ecological design principles, which encourage students to learn from green buildings that work with nature as defined by Van der Ryn and Cowan (1996). The 3-D textbook promotes the integration of indoor and outdoor settings, bringing the students back to the wider living community, enlightening them to the sources of energy, the cycles of water and the pattern of rain. This concurs with some scholars (Kolb, 1984; Silberman, 2007) who suggested that outdoor setting can help to develop visual and emotional literacy and give recycling and composting an 'experiential' basis. Furthermore, the 3-D textbook uses ecological design to transform awareness in waste management. It is the central to the design of this architectural intervention to embody and mirror the concept of recycling that creates it. The waste generated from other projects is reclaimed and incorporated as useful inputs to the 3-D textbook, articulating an implicit hope that students might do the same. Weaving recycling back into the learning environment also helps to break down dichotomies between architecture and education as proposed by Stevenson (2007). It reminds the students of the recycling and composting processes present within the campus, making the cycle streams more immediate and close-at-hand.

The current study highlighted the importance of 'innovative design & solution' in the context of waste management. Innovation is the key criteria to transform waste into resources in line with the central idea underlying the concept of recycling. Instead of seeing materials at the end of its useful life as a problem, the designers ought to look at these discarded items as an opportunity. The 3-D textbook echoes scholars' (Addis, 2006; Collivignarelli & Sorlini, 2001; Thompson & Sorvig, 2008) recommendation to create inspiring learning spaces by incorporating waste into architecture, in hope of implanting responsible consumption pattern into the future generations. Reclaimed materials or buildings are effective teaching tool that stir students' imagination and promotes alternative and sustainable resolutions within the campus. In the present study, the appearance and aesthetic of the 3-D textbook is bounded by the conditions and limitations inherent to the abandoned sources (e.g. their amount, their dimension, their appearance, etc.). The participants worked within a defined palette of urban discards that promoted experimentation and innovation. The testing and invention captivate their interest as well as promote an inspirational learning experience. Materials exploration also allows them to develop an understanding on the unique qualities of recycling and to develop a respect for the use of reclaimed materials in built environment.

The theme of 'flexible spaces for hands-on activities' is consistent with the research literature (Cadwell, 2003; Van Wagenberg, et al., 1981), which suggests to have open-ended and stimulating environment so that it can be adapted for different environmental activities. Schultz et al. (1995) noted that "recycling is not simply the act of placing a can or bottle in a recycling crate" (p. 119). Thus, scholars (Cherif, 1995; Mahmud & Osman, 2010; Smith, et al., 1997) publish bold call for reform of learning environment to support the collection, sorting, cleaning and reprocessing of recyclables within the campus. The current study seems to concur with the above-mentioned. The 3-D textbook provides a multipurpose space for hands-on learning where the participants can carry out various recycling work, all in a completely flexible space. It allows for changes over the course of each day or for many weeks depending on the kinds of learning activities under way. Additionally, the 3-D textbook assists the participants in developing new skill or environmental awareness by involving them in the operation and maintenance procedures as suggested by

Higgs and McMillan (2006). Involving the students in the operation and maintenance makes the waste and consumption of the school more accessible and tangible. Apart from the daily routine, the 3-D textbook also enables the students to take part in longer work projects such as small scale building construction, decoration or refurbishment. It resonates with Walden's (2009b) writings on participation and user design. Particularly, the architectural process of the 3-D textbook has been made into a form of special project, empowering the students in the making and management of the spaces they occupy. Through this proactive process of design and construction, students learn the value of recycling and waste reduction. It invariably attracts more interest and support for recycling activity within the campus.

5.5.3 Synthesis of the Findings

A synthesis of the study's quantitative and qualitative findings suggests a few important insights. First, the 3-D textbook led to growth in pro-recycling knowledge, attitude and behaviour. The quantitative and qualitative findings bear out the viability of this argument. It proposes that a linkage existed between the architectural intervention and EE outcomes. Second, the 3-D textbook provides possibilities for the application of previously obtained information which transforms knowledge into something more influential than simple figures and facts as suggested by Schelly, et al., (2012). Participants gained recycling knowledge during the traditional EE lessons in their classrooms, but had few opportunities to actually apply their newfound knowledge due to the indirect nature of the experience as noted by Fazio and Zanna (1981). In contrary, the 3-D textbook offered intense and numerous chances for participants to practice what they had studied. This explanation is supported by the qualitative data. For instance, most of the participants were conscious of the benefits of recycling and the impacts of not recycling, however, they had limited opportunity to expand and apply their understanding in real life settings. This deficit represents a substantial obstacle to their recycling behaviour and putting theory to practice was a main concern of these participants. It can be inferred from the quantitative and qualitative findings that the participants' knowledge about recycling remains dormant until the 3-D textbook transforms it into something influential enough to change their attitudes and behaviour. This is similar to Valle, et al. (2005).

Third, the quantitative findings suggest that both the participant and comparison groups gained higher scores in attitudes as compared to knowledge and behaviour scales. Interestingly, though knowledge and behaviour are low, pro-recycling attitudes were strong. Conventionally, knowledge, attitudes and behaviour are regarded as 3-step chronological model, however, the current study found that strong pro-recycling attitudes are already in place despite comparatively weak knowledge about recycling among the primary school students. Similar findings were found in Prestina's and Pearce's (2010) study. This is in line with the hypothesis that children tend to be environmentally conscious, globally minded and future-orientated, expressing concern for the longevity and health of the environment as echoed by Cohen and Trostle (1990). However, as a result of the interaction with the 3-D textbook, these positive attitudes towards the environment become more intense where most participants believed that their generation ought to care for the earth now so that when they inherited it later, the planet would be in a good condition. Particularly, the participants felt more positively toward recycling and believed that they cared more about this behaviour than did the adults.

Fourth, while many EE interventions focus on attitudes change, the current study found that participants regarded recycling as a good behaviour with positive impacts. Instead of trying to 'advertise' recycling to these participants, the 3-D textbook builds upon their positive attitude toward this behaviour by offering the infrastructure to support the behaviour. It enlightens them about the importance and meaning of recycling. Therefore, some participants described the 3-D textbook as a tool to assist them to convey their beliefs to adults and peers and would probably be an useful approach to promote recycling beyond the schools. These findings highlight the additional advantage of the 3-D textbook and that further study is required to completely comprehend the uniqueness and effects of this architectural intervention beyond the campus.

Fifth, participants believed that the 3-D textbook is an important infrastructure supporting recycling and facilitating this behaviour. It corroborates those of earlier studies (Oskamp, et al., 1991; Schultz, et al., 1995), which found that without suitable infrastructure, recycling behaviour cannot happen. Thus, the participants revealed their desire to have every school outfitted with at least a 3-D textbook, with many stating that the 3-D textbook would encourage consistent recycling behaviour. Beyond providing the required infrastructure, the participants also described the role of this architectural intervention to promote recycling that can be relevant, interesting and engaging within the campus. As noted by many participants, their involvement, the opportunity to be in control and their perceptions that their actions mattered in the world were rewarding in and of themselves. This concurs with Kollmuss's and Agyeman's (2002) statement that it is not sufficient to provide the infrastructure without addressing the users and the operational issues. Prestina and Pearce (2010) further explains that EE interventions that focused on promoting recycling as 'cool' would likely foster positive attitudes and behaviour and this is apparent in this research.

Finally, the 3-D textbook appears slightly more complicated in terms of its association with learning outcomes. The 3-D textbook may be favourable for knowledge, attitudes and behaviour development, but this appears to be contingent upon how it is designed, constructed and operated. Students' perceptions of what setting attributes that influenced their knowledge, attitudes and behaviour suggests that the defining characteristics of the 3-D textbook are: 1) informative environment with apparent clues; 2) eco-friendly building that worked with the surrounding; 3) innovative design & solution; 4) flexible spaces for hands-on activities. These findings are consistent with the themes in Phase 1, which define the design features for a 3-D textbook as 'transparent', 'in one with nature', 'creativity & imagination' and 'active settings' (Table 5.17). Thus, the qualitative data help to validate Phase 1 findings while the quantitative data provides evidence which links Phase 1 findings with improved environmental performances.

Table 5.17: Themes in Phase 1 and Phase 2

	Phase 1	Phase 2
Theme 1	Transparent	Informative environment with apparent clues
Theme 2	In one with nature	Eco-friendly building that worked with the surroundings
Theme 3	Creativity & Imagination	Innovative design & solution
Theme 4	Active settings	Flexible spaces for hands-on activity

The themes of 'informative environment with apparent clues' and 'transparency' emphasize on the notion of making the invisible visible. Phase 1 and Phase 2 findings disclose that exposed material is the key criteria in expressing environmental messages leading to pro-EB change. For instance, the Green School uses bamboo to reflect their commitment towards sustainability while the physical model in Phase 2 utilizes reclaimed materials to promote resources conservation. In both cases, the buildings contributed positively to students' learning, serving as living examples of sustainable life choices and systems. It reinforces earlier claim (Van der Ryn & Cowan, 1996) that architectural elements such as building materials, finishes and walls can be active learning tools if they are visible and accessible to the students. More importantly, it concurs with other scholars (Mitchell, 2005; Nair, et al., 2009) that green buildings can act as "triggers" by capturing a student's attention and causing them to link the strategy with a pro-environmental construct. Phase 1 and Phase 2 findings also promote the expression of building services and ecological system rather than suppressing these processes. In the Green School, green technologies such as the biogas reactor and water vortex power plant are integrated as part of the learning environment. Similarly, the rainwater harvesting system has been exposed and expressed as an architectural design element on the exterior and interior of the physical model in Phase 2. These exposed and accessible systems can help students to deconstruct the hidden curriculum, leading to enhanced environmental performances. This is supported by Eagly and Chaiken (1993), Kaiser, et al. (2007) and Ryan (1991).

The theme of 'eco-friendly building that worked with the surroundings' echoes with 'in one of nature' because it promotes the transformation of nature into pedagogical tool with particular emphasis on the local environment. It integrates outdoors as a natural extension of indoor learning, where every opportunity is explored to create string connections between the indoor spaces and outdoor areas. The findings support previous researches (Bargmann & Levy, 1998; Brown, 1998) related to the notion of learning landscapes. The 3-D textbook reflects the importance of nature and goes beyond the undisputed benefits of relaxation, physical exercise and sports to act as an organic and informative teaching tool similar to Williams and Brown (2011). For instance, Phase 1 and Phase 2 findings acknowledged that outdoor environments enable other kinds of learning to occur that could not take place indoors. Additionally, natural element can be a unique identity for a school. Site specific elements can help to build environmental consciousness and teach important lessons of sustainability, ecology and living science. For example, the Green School make use of the river and contour to teach important lessons about 'place' while the physical model in Phase 2 exposed students to on-site composting through the decomposition of organic waste generated by the local settings. This is in line with other studies (e.g. Cronin-Jones, 2000; Eagles & Demare, 1999; Farmer, et al., 2007; Jensen, 2002; Kruse & Card, 2004; Leeming, et al., 1993) which suggest that constant interaction with outdoor settings such as garden, schoolyard and Natural Park can lead to improved EK, EA, and EB.

The theme of 'innovative design & solution' concurs with 'creativity & imagination' because it acknowledges that inventive architecture plays a key role in the transformative route of producing sustainability thinkers. It echoes with other scholars (Jones, 2002; McClintock & McClintock, 1968) that any design's aesthetic should reflect innovative solution by capturing a true sense of connectedness to sustainability. Yeang (2006) noted that a green building must be aesthetically pleasing as well as enhancing pro-environmental performance among the users. Thus, in the current research, architecture and EE were juggled together to develop a new ecology-based aesthetic for the built environments. For instance, the bamboo buildings in the Green School were regarded as creative art work that enfolded students with ecological imagination. They stood proud as a form of architectural swift that proclaimed eco-friendly design in opposition to the prevailing factory-liked school. Similarly, the physical model in Phase 2 repurposed or reused reclaimed materials in its façade to set the stage for environmental innovation. It stirred students' imagination and encourages them to find alternative resolutions in opposition to discarding away. Additionally, Phase 1 and Phase 2 findings emphasized on studios, workshops and laboratories because these spaces provided a wide range of experiences, encouraging resourcefulness and imaginative thinking to link consequences to actions. These spaces can be used for formal learning as well as experimentation. Students can propose a project and test their ideas for practical applications. More importantly, experimentations enable the students to generate novel resolutions leading to both affective and cognitive development similar to the works of McKellar (1957), Thornton and Brunton (2007).

The theme of 'flexible spaces for hands-on activity' reflects the underlying concept of 'active settings'. It acknowledges that school ought to be flexible in the use of space and materials. This is in line with the notion of a multipurpose environment that offers students many choices, provokes them to engage in many activities and allow them to act on and transform the learning settings in many ways. The school grounds in the Green School were designed to be open-ended so that it can be adapted for different environmental activities. The outdoor settings, such as farming plot and garden, can be used for group learning as well as individual exploration. Similarly, the physical model in Phase 2 provided a multipurpose space for the collection, cleaning, sorting and processing of recyclables. Phase 1 and Phase 2 findings also emphasize the importance of connecting students to the operation and maintenance of the school. Up-keeping provides learning experiences in stewardship and pride of space. It also assists students in developing new skill or environmental awareness. Students' involvement as caretakers of their schools acts as catalyst for the discussions about sustainability and gives them opportunities to attempt new, sustainable behaviour. This is supported by other scholars (Rauch, 2000; Sterling & E. F. Schumacher Society, 2001; Wagstaff & Wilson, 1988) who noted that green maintenance and operation enables schools to foster learning about EE and the adoption of pro-EB without the need to preach or proselytize. Apart from the daily routine, students in Phase 1 and Phase 2 also take part in longer projects such as building construction and organic gardening. Through participation in the design and building process, they may express their ideas in sustainability, as well as demonstrating these to others.

5.6 SUMMARY

This chapter has presented the discussion on the results from quantitative and qualitative analysis of the data collected in Phase 2. The results from ANCOVA support the hypotheses that the participant group would experience a significant growth in knowledge, attitudes and behaviour in relationship to the comparison group. Each significant result was discussed and explained by comparing the findings with the literature and past researches. In summary, the qualitative data help to validate Phase 1 findings while the quantitative data provides evidence which links Phase 1 findings with improved environmental performances (i.e. knowledge, attitudes and behaviour). All the research questions and hypotheses have now been addressed.

CHAPTER 6

CONCLUSION

6.1 INTRODUCTION

The prime purpose of this research was to explore the design of the 3-D textbook and came with specific dialectic analysis about its applicability to promote pro-environmental knowledge (EK), environmental attitudes (EA) and environmental behaviour (EB) to primary school students. Five research questions and hypotheses aligned themselves with different phases of the research. Phase 1 asked:

RQ1: What are the design features of a 3-D textbook?

While Phase 2 asked:

H1: Students would demonstrate an improvement in environmental knowledge (EK) when they interact with the 3-D textbook than when they receive no treatment.

H2: Students would demonstrate more pro-environmental attitudes (EA) when they interact with the 3-D textbook than when they receive no treatment.

H3: Students would engage in more pro-environmental behaviour (EB) when they interact with the 3-D textbook than when they receive no treatment.

RQ2: How do students perceive the impacts of the 3-D textbook on their environmental knowledge, attitudes and behaviour?

This chapter brings the thesis to a conclusion by addressing the research hypotheses and answers the research questions. Significant and important findings of the research are summarized. The theoretical and practical implications of the findings as well as recommendations for future research are presented.

6.2 RESPONSE TO RESEARCH QUESTIONS AND HYPHOTHESES

The results for this current research can be divided into those which answer the research questions posed at the beginning of the thesis, and those which proved to be statistically significant and therefore worthy of further discussion. Both categories of findings are presented here, organized into five sections according to the research questions and hypotheses.

RQ1: What are the design features of a 3-D textbook?

The Green School in Bali, Indonesia symbolized a first of its kind learning facility that presented a valuable case study in 3-D textbook. Chapter 4 provided a detailed account of students' reactions and perception toward this innovative learning environment. The findings from this qualitative case study included the identification of four design features of the 3-D textbook that linked architecture with EE. These design features comprised of 'transparency', 'in one with nature', 'creativity & imagination' and 'active setting' are briefly discussed below.

The first theme is termed as 'transparency' because the exposed building materials, technologies, services and systems in the Green School serve as 3-D textbooks to model high performance and sustainability to the students. The biggest advantage of having the green features in the campus is the intrinsic pedagogical value, reinforced by data analyzed from the students interviewed. The design intention to reveal the processes and mechanism operable in the built and the natural environment makes these systems visible and accessible to the students. The idea of revealing the underlying systems in the buildings also provides the necessary understanding for the students to acquire mastery over the abstract EE concept. It helps to move the act of teaching and learning away from the abstract representation.

The theme 'in one with nature' reinforces the design concept that the Green School should be integrated with the surrounding environment as part of the educational spaces, re-emphasizing that nature should play a critical role as a 3-D textbook to support and inspire students' learning. The school grounds and gardens in the Green School are fully utilized as outdoor learning spaces that contribute significantly to the teaching and learning about the 'place'. Additionally, field notes derived from observation shows that the site features such as land contour, rainforest and rivers are incorporated as a significant component of EE. The students also enjoy spending time in the outdoor spaces and prefer the open classroom with no walls.

In addition, the students regard the school as a source of 'creativity and imagination'. The school buildings are artistically assembled with natural resources, thus serving as 3-D textbooks that extend the students' imagination and trigger creative solutions for environmental problems. The buildings in the Green School represent innovation in educational architecture, especially in the form making of buildings. Moreover, the findings suggest that reclaimed materials have been creatively reused in the Green School. Interviews further disclose that students are amazed with the designer's 'thinking out of the box' approach in reusing waste products. As a result, the students demonstrate their ability and interest in finding new uses for discarded items as evident in their artworks.

The final theme of 'active setting' describes the use of physical settings as 3-D textbooks to promote the notion of 'learning by doing'. The qualitative data shows that the students are given the responsibility in the operation and maintenance of the school's ground and facilities. Thus, the students are not merely passive observers to their surroundings, but are actively interacting with the natural and built environment in their learning processes. The findings also reveal that the students make the most of the fluid and information-rich environment to acquire new understanding either by individual exploration or with the support of others. Additionally, the campus is used as a living laboratory for students to practice construction, preservation or conservation. The students and teachers are given the freedom and opportunity to alter the physical settings using the project-based activities.

H1: Students would demonstrate an improvement in environmental knowledge (EK) when they interact with the 3-D textbook than when they receive no treatment.

Following completion of Phase 1, and the decision to focus on one of the desirable outcomes for further research, the hypothesis was refined 'Students who interact with the 3-D textbook would demonstrate an improvement in recycling knowledge as compared to their peers who have not interacted, after controlling for the effect of pretest scores'. The evidence arising from this research does support this hypothesis. ANCOVA analysis discloses that when controlling for pretest score, there is a significant positive effect ($p<.05$) of the 3-D textbook on participant's recycling knowledge. A reasonable explanation of the above findings is that the participants do possess an understanding of the recycling issue, but in some certain aspects, it is still facing limitations, therefore possibility influencing the pre-score in a negative way. Classroom lessons and books fall short in asking students to think critically about recycling. However, the use of a 3-D textbook enables the participants to convert factual knowledge into application, leading to better understanding of recycling problems and opportunities to practice citizenship skills related to local trash problem. The 3-D textbook appears to have acted as a catalyst, extending and intensifying the notions which are pre-exist in the present knowledge of the participants.

Additionally, the DBO processes enable the participants to see and critically analyze the physical world. It allows them to read the environment with deeper understanding. For instance, through the design and build processes, the 3-D textbook enlightened the participants about the origin of the reclaimed materials and how to prevent these resources from ended up in landfill. It promotes cycle thinking instead of liner as well as highlighting the properties of waste (e.g. size, shape, colour, degradability, etc) to the participants. The 3-D textbook also appears to be fruitful in improving the participants' understanding of the mechanisms and processes in recycling. The basis for these arguments is that most participants when asked about their experience of interacting with the 3-D textbook, they were able to articulate accounts of actual recycling which touch on reality instead of abstract ideas. It appears that the 3-D textbook is capable of making the participants' learning real and relevant to their lives. It promotes the generation of new knowledge through the daily experiences.

H2: Students would demonstrate more pro-environmental attitudes (EA) when they interact with the 3-D textbook than when they receive no treatment.

Following completion of Phase 1, and the decision to focus on one of the desirable outcomes for further research, the hypothesis was refined 'Students who interact with the 3-D textbook would demonstrate more pro-recycling attitudes as compared to their peers who have not interacted, after controlling for the effect of pretest scores'. The evidence arising from this research does support this hypothesis. ANCOVA analysis discloses that when controlling for pretest score, there is a significant positive effect ($p<.05$) of the 3-D textbook on participant's pro-recycling attitudes. A profound and reasonable explanation of the above findings is that the 3-D textbook provided an appropriate opportunity and setting for child-environment interaction where it helps to establish emotional bonds and positive attitudes toward the physical settings and recycling issues. The participants were actively involved in the DBO of the 3-D textbook. Meaning is generated from their participation where ideas and concepts of the 3-D textbook as a learning environment are reinforced. The 3-D textbook also enables the participants to personalize the environment and to share with their peers significant issues of recycling as well as externalizing its expressions. The involvement of participants in the architectural and learning processes promotes the interactions of each individual student with his or her surroundings and thus contributes towards ecologically conscious attitudes and decisions.

The findings also disclosed that the 3-D textbook was a "trigger" which caused the participants to link the physical settings with a pro-environmental construct. The design and visual impact of this architectural intervention was found to be the core factor that foster pro-recycling attitude. The 3-D textbook, which was designed and constructed from reclaimed materials, strengthens the values and ideas of sustainable waste management. It is a strong and clear visual signage that reminds the participants to recycle as well as promoting accessible and durable attitudes change. The participants regarded the 3-D textbook as a persuasive sign that promote and teach new reasons for recycling in and beyond the campus. The findings reveal the opportunity to use the 3-D textbook as a symbol or a persuasion for recycling and therefore promote the development of positive attitudes.

H3: Students would engage in more pro-environmental behaviour (EB) when they interact with the 3-D textbook than when they receive no treatment.

Following completion of Phase 1, and the decision to focus on one of the desirable outcomes for further research, the hypothesis was refined 'Students who interact with a 3-D textbook would engage in more recycling behaviour as compared to their peers who have not interacted, after controlling for the effect of pretest scores'. The evidence arising from this research does support this hypothesis. ANCOVA analysis discloses that when controlling for pretest score, there is a significant positive effect ($p<.05$) of the 3-D textbook on participant's pro-recycling behaviour.

The 3-D textbook can be regarded as an antecedent strategy because it provides prompting and helps to remove barrier in recycling before the placement of the conduct (e.g. gathering recyclables, delivering recyclables to a recycle zone, etc). The 3-D textbook, constructed from reclaimed materials, acts as a medium to convey the message of sustainable waste management to the students. It also provided a convenient drop-off for recyclables within the campus. Additionally, it helps to make the sorting of waste more interesting with minimum effort involved. It is capable of making recycling more meaningful by changing the participants' emphasizing point from how time-consuming it is to how fast the collage wall or composting wall fill; or alter their perception by highlighting they are working with a recyclable resource rather than garbage.

The 3-D textbook can also be classified as a consequence strategy because it tries to promote recycling behaviour through placing a consequence or feedback contingent upon the behaviour. For instance, the 3-D textbook has collage walls which indicate the number of bottles collected, enabling the participants to scrutinize the outcomes of their conduct. It provides students with clear and direct feedback on the environmental impact of activities and technologies as a mechanism for engaging, educating and motivating the students to make desirable changes in environmental behaviour. It appears that the 3-D textbook allows physical environment to facilitate study on recycling and the adoption of recycling behaviour, exclusive of proselytizing, thus overcome the challenges regarding to explicit advocacy. It sets a consistent behavioural standard and creates a holistic approach to recycling behaviour by modelling recycling practices, creating a context for hands-on learning and transferring the notions related with the recycling from theoretical concepts to practical implementations. Particularly, the 3-D textbook generates a practical study ambience in which the students can easily observes and then understands the environmental impacts of design choices and personal behaviour on the processes and cycles of matter through the campus.

RQ2: How do students perceive the impacts of the 3-D textbook on their environmental knowledge, attitudes and behaviour?

Following completion of Phase 1, and the decision to focus on one of the desirable outcomes for further research, the research question was refined ‘How do participants of a quasi experiment perceive the impacts of the 3-D textbook on their pro-recycling knowledge, attitudes and behaviour?'. It was found that participants' descriptions of their experiences during the intervention trial were consistent with the quantitative findings. The participants perceived that the 3-D textbook contributed positively to their pro-recycling knowledge, attitudes and behaviour. However, the improvement in performance of the participants appears to be related to a number of setting attributes. In Phase 2, students' perceptions of what setting attributes influenced their knowledge, attitudes and behaviour suggest that the defining characteristics of the 3-D textbook are: 1) informative environment with apparent clues; 2) eco-friendly building that worked with the surrounding; 3) innovative design & solution; 4) flexible spaces for hands-on activities. These findings are consistent with the design features identified in Phase 1.

The theme of 'informative environment with apparent clues' emphasizes on the notion of making the invisible visible. By making the recycling processes apparent and accessible to the participants, the 3-D textbook can help to link narrow, blinkered, linear systems into closed-cycle communities of production. The participants disclosed that exposed materials, technology, building services and ecological processes promote dialogue concerning the value of recycling. Additionally, participants' description of an 'eco-friendly building that worked with the surrounding' is consistent with the ecological design principles, which emphasizes on the integration of built environment with nature's processes. The 3-D textbook uses the site contexts and outdoor settings to transform awareness in waste management. For instance, the organic and inorganic waste generated from the site and nearby neighbourhood was reclaimed and incorporated as useful inputs to the 3-D textbook, articulating an implicit hope that students might do the same. Additionally, an organic farming plot was used as an outdoor learning environment for the participants to grow vegetables and fruits. Therefore, the 3-D textbook reminds the participants of the recycling and composting processes present within the built and natural environments, making the flow of resources more immediate and close-at-hand.

The qualitative findings also highlight the importance of “innovative design & solution” in the context of waste management. Reclaimed materials or buildings are effective teaching tool that stir students’ imagination and promotes alternative and sustainable resolutions within the campus. In the current study, the appearance and aesthetic of the 3-D textbook is bounded by the conditions and limitations inherent to the abandoned sources (i.e. their amount, their dimension, their appearance, etc.). The participants worked within a defined palette of urban discards which helped to foster experimentation and innovation. Materials exploration allows them to develop an understanding on the unique qualities of recycling and to develop a respect for the use of reclaimed materials in built environment. Lastly, the theme of ‘flexible spaces for hands-on activities’ is consistent with the research literature, which suggests that school ought to be flexible in the use of space and materials. The 3-D textbook provides a multipurpose space for hands-on learning where the participants can carry out various recycling work, all in a completely flexible space. It also assists the participants in developing new skill or environmental awareness by involving them in the operation and maintenance procedures. The architectural process of the 3-D Textbook has also been made into a form of special project, empowering the participants in the making and management of the spaces they occupy. Through this proactive process of design and construction, participants learn the value of recycling and waste reduction. It invariably attracts more interest and support for recycling activity within the campus.

6.3 IMPLICATIONS

6.3.1 Theoretical Implications

This research has exploited largely two streams of literature. Firstly, the literature related to educational facilities design and secondly, the EE literature. In relation to both of these, different perspectives have been discussed. The main area of research to which this study has aimed at contributing is the research on educational facilities design with a particular emphasis on the 3-D textbook. EE literature has therefore been utilized to convey its ideas and point of views into the discourse of this architectural intervention. It helps to construct a clearer perspective on the effectiveness of the 3-D textbook to improve environmental performances. In the following, the author will recap the most significant theoretical contributions that this study has made to the educational facilities design research. Additionally, the author will also discuss the contributions that this study has made to theories of environmental psychology, or moreover, to the theoretical discourse associated to environment-behaviour. This stream of literature was also utilized in establishing the theoretical framework (Chapter 2) and throughout the case study (Chapter 4) and quasi experiment (Chapter 5).

In any scientific research, the most remarkable cause of its acceptability is, undoubtedly, the credibility and novelty of the results (Ulkuniemi, 2003). Consequently, the theoretical contributions of a study need to be consciously constructed and placed before the audience. The current research provides a systematic analysis and design methods to reunite architecture and EE. The current study breaks new ground by revealing the process of designing and assessing the 3-D textbook. The core area that this research has aimed at contributing to is the development, conceptualization and analysis of the 3-D textbook from the students' perspective. The findings highlight the underlying design features behind the 3-D textbook and the effectiveness of this architectural intervention in promoting pro-recycling knowledge, attitudes and behaviour.

By studying the use of the 3-D textbook in the primary school context, this study generates a significant prophecy for the use of the physical environment as a pedagogical tool. As was argued earlier in Chapter 1, current schools in Malaysia have not paid enough attention to the use of this architectural intervention. Although the 3-D textbook represents the core foundation underlying the subjects discussed in EE, the attributes of this architectural intervention have not been elaborated. In this study, the design features of the 3-D textbook, namely ‘transparency’, ‘in one with nature’, ‘creativity & imagination’ and ‘active setting’, have been systematically explored, discussed and evaluated. It was found that every single feature symbolizes a vital issue from the students’ perspective, related with the learning opportunity offered by the physical environment. These identified features were further tested in Chapter 5 by assessing the impact of the 3-D textbook on recycling performances. The four features offer an essential contribution to the architectural research by identifying a set of design criteria leading to improved EE outcomes. It enables a more organized view of this architectural intervention in the EE literature. Particularly, it gives an understanding of the learning process through the child-place interaction. It provides an understanding of the 3-D textbook as an architectural process involving design, construction and operation. These give architectural and EE research a more thorough understanding of the impact of the 3-D textbook on EE outcomes. It creates different comprehensions for both research exploring learning outcomes and research that emphasizes about learning processes by examining the relationships between architecture and education.

Previous EE literature has focused more on traditional (e.g. classrooms) setting and involves primarily cognitive-based learning. However, the intervention that forms the basis of this current study is a 3-D textbook, with the overall goal of promoting pro-recycling knowledge, attitudes and behaviour. It can thus be argued that this study has given significant insights into the use of a non-traditional setting to promote both cognitive and affective development. Current EE interventions have focused more on lecture-based learning (e.g. Aird & Tomera, 1977), but it has increasingly been argued that equal attention should be given to hands-on activity involving direct experience (e.g. Duerden & Witt, 2010). Thus, another significant contribution that this research has for EE literature is with regard to the relationship between direct experiences and learning outcomes. The findings suggest that it is vital to expose students to the real-life learning, instead of merely concentrating on the abstract ideas in the books. The study has demonstrated that the act of 'learning by doing' is the driving force behind the improvement of EE outcomes. Also, in a similar vein, the study provides additional understanding to the psychological processes whereby architectural design lead to the change in knowledge, attitudes and behaviour. In other words, this research has attempted to contribute to the disciplines of environmental psychology and EE by increasing the understanding of the impact of direct experiences on environmental performances.

The empirical context of this study has been the environment-behaviour relationship, particularly, the effectiveness of the 3-D textbook to enhance EE outcomes. In past few years, there has been a remarkable keen passion in designing buildings that improve both the environmental and user performances (e.g. Janda, 2011). It was suggested that building occupants play a vital but poorly understood and frequently overlooked role in the built environment. This has been considered to be especially important in a school context. A diversity of physical, technical and economic models of the built environment have been presented which have provided some strategies to integrate user in building performance (e.g. Lutzenhiser, 1993). Apart from ensuring the technical development in existing buildings and designing new ones to superior standard, the models have suggested the design professionals to use physical environment as a medium for behaviour change and public education. This research can be considered as contributing to this branch of knowledge because it provides empirical evidence which link the physical settings with improved environmental performances (i.e. EK, EA and EB) among the building users.

This study has presented different design scenarios for educational facilities. The importance of children-driven architectural processes is brought to attention in Phase 1 and Phase 2. The analysis illustrates that the students, which are also the end-users, should have a voice in planning, designing and furnishing of their learning environments. By this way, it can be considered that this research is generating additional knowledge in relation to participation and user design. In other words, educational facilities should not just be built for the students but with them. Obviously, designing one's learning environment according to one's own ideas gives the students an opportunity for representation of self. By bringing their own taste to bear on the design, students can express their identity and creativity, as well as demonstrating this to others. All in all, user design will result in the desired identification of users with the educational facilities, and this would connect them to the spaces. Moreover, the current research argues that the scale of student design project is very much dependent on the learning objectives. Students can involve in the design of entire school grounds from the school yard to individual classrooms or indoor decoration and furnishing.

6.3.2 Practical Implications

The current study is a critical effort to explore and generate innovations for school reformation in Malaysia and other tropical countries with similar context. What emerged from this study is four design features for 3-D textbook with the aim of achieving functionality and efficiency as well as providing an educational experience of green issues. It represents a series of recommendations that are rendered by novel ideas through the amalgamation of architecture, sustainability and education. Therefore, the findings in this study suggest a few practical implications in the context of school design.

The current research benefits architects and environmental educators who are looking for a guide to transform physical settings into 3-D textbook. It brings to the practitioners' attention, the issues and criteria that need to be addressed in designing such innovative learning spaces. It is expected that the design features will be reviewed, enriched and perfected based on the feedbacks by design practitioners, EE communities and scholars from various disciplines. Furthermore, the design features that evolved through this study reflect the students' preference and inclination towards innovative, interactive and sustainable learning spaces. This should alert the practitioners to the need for a paradigm shift in educational architecture. The current study documented that sustainability in a school setting forms the intersection of interest in multiple disciplines. For instance, the 3-D textbook satisfies the needs of educational activities, as well as the ecological issues in the built environment. Thus, this study serves as a catalyst for the notion of cross-disciplinary investigations in school architecture. It encourages architects to integrate with different disciplines in the process of design, construction and operation. The outcome of this mutual cooperation is usually helpful and often rewarding. Apart from offering innovative architectural solutions, it assures the students of an imaginative and inspiring learning environment.

The current study suggests that building services, materials and technology ought to be illustrated and celebrated as a model of sustainability to the students. Environmental educators can capitalize on these transparent infrastructures to educate students about the mechanism of the real world. A plan to integrate EE into the design, construction and operation of a school should be in place, accompanied by training for environmental educators on how to utilize these exposed systems and processes as 3-D textbook. Taken a step further, school designers should work closely with the environmental educators in the initial design stage so that the resulting buildings and landscape could meet the educational goals better. Incorporating EE into the design brief and having the environmental educators to review the design progress can provide opportunities for interaction and collaboration between the design team and EE communities.

Furthermore, the current study reinforces a growing literature that argues that EE should not only focus on classroom based lecture but also interaction with nature. Given the preference towards the natural cycles and ecology in the students' dialogue, designers and environmental educators should seek to integrate the surrounding environment as a pedagogical tool to support and enhance EE. School designers should provide large openings or see-through glass wall in classrooms to promote the indoor-outdoor relationship. Green areas with flora and fauna can also be provided to complement indoor learning. For instance, allocating gardening spaces between classrooms so that environmental educators can extend the lessons on photosynthesis into these green areas. Moreover, school designers should take the various site features (e.g. contours, wetland, etc) under serious consideration when they design a school, keeping in mind that these existing ecosystems can serve as high quality learning spaces for the students.

The current research calls for creative facilities that could better equip the next generation with the problem-solving capability leading to ecological advancement. However, creativity in school design should not be confined to building forms and facades only. Instead, designers should strive to transform physical setting into a subject of inspiration by rendering creativity into the learning spaces. Additionally, the current study reveals that connecting students to the operation and maintenance of the school invariably assist them in developing new knowledge or ecological awareness. Thus, environmental educators should fully utilize the school ground as a medium to promote the act of 'learning by doing'. School designers should provide information rich and stimulating environment that invites children's participation and contribution (Fraser & Gestwicki, 2002). For instance, edible schoolyard can be allocated for students to grow fruits and vegetables as lunch. Additionally, informal mentor like gardener and technician can be assigned to the students as a means of exposing them to different aspects of training and skill. Furthermore, this study suggests that designers should create open-ended spaces that can be retrofitted by the students for different EE activities. One principal means of achieving this goal is to provide multipurpose space like an internal courtyard that can be easily modified to support organic farming, recycling, composting, etc.

6.4 LIMITATIONS

Each phase of the research presents different shortcomings which require to be taken into account when considering the study and its contributions. The fact that the data collected in Phase 1 was self-reported and that the author was unable to interview all students who studied in the Green School, Bali poses a limitation to the study. Additionally, the use of a single case study means that the findings cannot be generalized too broadly. The match between the particular research environment and other external settings can also be seen as a restriction to its external validity. However, against this limitation, it should be noted the mixed methods adopted for this current research allowed the qualitative findings to be follow-up by a quantitative study. As described by Creswell (1994), “the intent of qualitative research is not to generalize findings but to form a unique interpretation of events” (p. 158). Merriam (1998) and Janesick (1998) explains that the core objective of a qualitative research is not to make broad generalizations to different settings, but rather acquire a deep understanding of the processes of a study.

Additionally, Phase 1 was potentially threatened by the problems of reliability and validity in data collection and analyses. Qualitative research is commonly compromised by the biasness of researchers and insufficient sampling of respondents or cases. To overcome these issues, the author took mixed method approaches with diverse multi-dimensional sources of data emphasized on the child-environment interaction. The possibility of bias inherent in student interviews was overcome by on-site observation and teacher interviews to ensure that the qualitative data is rich, robust and comprehensive. During the time period of the case study, the author served as an observer in the Green School, Bali. A few strategies have been adopted to guard against potential bias in data collection and analysis (see Section 3.5.4).

Although the quasi experiment in Phase 2 has been able to conclude with some significant findings, the selection bias poses a threat to the internal validity. The participants for the quasi experiment were self-selected, instead of assigned by the author. There is considerable evidence that non-random assignment generates different results than random assignment does, more so when participants self-select into conditions than when others make the selection decision (Shadish, et al., 2001). A few strategies have been adopted to address this issue. Firstly, matching through cohort controls was implemented. The author utilized cohorts as the comparison group because they were considered to be less nonequivalent than most other non-matched groups would be. Secondly, cohort control was improved by adding a pretest. The pretest allows exploration of the potential size and direction of the selection bias by comparing cohort pretest means. Thus, it enables better assessment of regression, and it enters into better statistical adjustment for group nonequivalent. Lastly, internal control is implemented by drawing samples from the same school.

In Phase 2, the use of self-reported data and behavioural intentions measures are considered as a possible shortcoming as well. Halpenny (2010), Homburg and Stolberg (2006) mentioned about their alarming notice on taking self-reported data in their respective studies related with environmental behaviour. Corral-Verdugo and Figueredo (1999) pointed the risks on the validity of self-reports as well. However, Schahn et al. (2000) commented that human being has a common trend that they dedicate a minimal interest to give socially required replies. Kaiser et al. (2001) also support the validity of self-reports in predicting pro-environmental behaviours by comparing self-report technique with subjective and objective measures (cited in Halpenny, 2010). Lastly, the follow-up interviews conducted with the participants in Phase 2 were subject to errors associated with interviewee memory loss during the recollection of activities undertaken. The research accepted this as possible but unlikely to have occurred since the author kept field notes and the participants' journal entries as a triangulation method. The author did not find any obvious occurrence of such memory loss during the interviews.

6.5 RECOMMENDATIONS FOR FUTURE RESEARCH

It is vital, particularly for architects, to comprehend the ways in much various physical settings or contexts impact the educational outcomes in order to design more effective learning spaces. However, trying to understand the impact of designed environments on students' performances requires a substantial effort to perceive about multiple phases of complex relationship. Findings from this study offer some important insight into this issue and highlight additional questions which require further research in this field.

This study investigated the design of the 3-D textbook and how it impacts students' pro-recycling knowledge, attitudes and behaviour. Further research project should expand the scope by investigating the impact of this architectural intervention on other environmental performances (e.g. energy conservation, water savings, sustainable purchasing, etc). For instance, future researchers can collect behavioural response regarding a demonstration facility which acts as a 3-D textbook to bring about changes in energy conservation. The findings generated from this current study should be applied in the demonstration facility with an aim to exhibit, educate and empower the students about energy efficiency and sustainable living. Another area that deserved more research is the application of lessons from this study to other educational buildings such as children museum, aquaria or ecological learning centre. The discussion in Chapter 4 and Chapter 5 revealed the significant overlaps between architecture, education and sustainability, making lessons learned from the current study transferable to other building types. For instance, the concepts of revelatory design, innovation and experiential learning were represented strongly in museum design. Although the 3-D textbook has its theoretical basis and precedence in the context of school design, it is not commonly applied in other fields. It would be interesting to investigate how well this architectural intervention functions in different settings with different educational goals.

Other venues for further researches might be as follows:

- An in-depth study investigating the use of 3-D textbook in secondary school and university campus. Although the current study focus on the primary school, the findings generated can be applied to higher grades students with further research and modification.
- A study with a focus on renovating part of a school building into a test facility for 3-D textbook. The researchers should work with students in the process of design, construction and operation. Measure students understanding of sustainability when they occupy the renovated school, as compared to students attending traditional schools.
- The duration of treatment can be seen as a limitation to the quasi experiment in Phase 2. The quantitative results disclose that participants experience a growth in knowledge, attitudes and behaviour after interacting with the 3-D textbook for a period of two months. Future studies can be carried out to evaluate the impacts of longer periods of interaction with this architectural intervention on a wider range of primary school students. For instance, future

quasi experiments can involve students as young as standard one to interact with the 3-D textbook for a whole school year.

6.6 CONCLUSION

The research has thoroughly been completed and successfully found the answers to all the research questions. Chapter 1 highlights an urgent need to integrate architecture with EE and invites innovation in the way learning environments are constructed to collaborate with sustainability. Literature review discloses that the 3-D textbook can be a catalyst to facilitate this evolution. It is capable of bridging the gap between architecture and EE by embracing educational issues in sustainable design. Therefore, the aim of this thesis is to explore the design of the 3-D textbook and determine its effectiveness to improve the pro-EK, EA and EB among primary school students.

The qualitative findings in Phase 1 provide essential insights regarding the design of 3-D textbook and the role of the architecture in the teaching and learning of EE. The design features of the 3-D textbook have been uncovered and defined as ‘transparency’, ‘in one with nature’, ‘creativity & imagination’ and ‘active setting’. Each of these features is researched and explored in through discussion. Additionally, the effectiveness of the 3-D textbook has been evaluated in a quasi experiment in Phase 2. The quantitative results support the hypothesis that the students who interact with the 3-D textbook would demonstrate a significant growth in pro-recycling knowledge, attitudes and behaviour as compared to their peers who have not interacted, after controlling for the effect of pretest scores. Therefore, Phase 2 helps to validate Phase 1 findings by providing empirical evidence which links Phase 1 findings with improved EE outcomes.

In summary, this thesis developed a theoretical model for the 3-D textbook. It offers an insight to the design of physical environment that supports and advances EE learning. It provides a detailed account of students' reactions and perceptions towards the 3-D textbook with a potential contribution to a field of knowledge that embraces design and education. With the scarcity of scholarly literature on this subject, it breaks new ground by identifying four design features for the 3-D textbook. The findings and the discussions generated in this thesis may bring interest to scholars from a wide variety of disciplines, including architecture, EE and environmental psychology. The ideas here are not meant to restrict the design of educational facilities by dictating cookie-cutter solutions. Almost to the contrary, it tries to create a framework applicable to a multitude of situations and educational spaces, which in the end becomes a necessary factor of good design. It is hope that designers will take these lessons and apply them in educational facilities or other contexts. The author believes that all sites provide learning opportunities for students and community. Good design should attempts to interpret these opportunities by using the building and landscape as 3-D textbooks to aid teaching about resources efficiency, sun paths, daylighting, rainwater harvesting and so forth.

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APPENDICES

Appendix A

List of publication

Journal Articles

1. Kong, S.Y., Rao, S.P., Abdul-Rahman, H., & Wang, C. (2013). School as 3-D textbook for environmental education: Design model transforming physical environment to knowledge transmission instrument. *The Asia-Pacific Education Researcher*, 1-15. doi: 10.1007/s40299-013-0064-2
   (ISI-Cited Publication)

2. Kong, S.Y., Naziaty, M. Y., Rao, S. P., & Hashim, N. R. (2012). Incorporating waste into an experimental school prototype: Lessons regarding materials reclamation opportunities. *Waste Management & Research, 30*(12), 1251-1260.
   (ISI-Cited Publication)

3. Kong, S. Y., & Rao, S. P. (2012). An experimental school prototype: Integrating 3rs (reduce, reuse & recycle) concept into architectural design. *Journal of Design and Built Environment*, 10(1), 1-9.
   (Non-ISI/Non-SCOPUS Cited Publication)

4. Kong, S. Y., & Naziaty, M. Y., (2011). Design thesis manual (part 1/4) - Building type. *Architecture Malaysia*, 23(5), 48-49.
   (Non-ISI/Non-SCOPUS Cited Publication)

International Conferences

1. Kong, S. Y., Naziaty, M. Y., & Rao, S. P. (2011a). *An experimental school prototype: Engaging children's senses in 3R learning*. Paper presented at the International Conference on Solid Waste Management: Moving towards Sustainable Resource Management, Hong Kong, China.

2. Kong, S. Y., Naziaty, M. Y., & Rao, S. P. (2011b). *A qualitative exploration of the school's physical environment as a three-dimensional textbook in environmental education*. Paper presented at the 12th Association Pacific Rim Universities (APRU) Doctoral Students Conference, Beijing, China.

3. Kong, S. Y., Naziaty, M. Y., & Rao, S. P. (2011c). *Rethinking primary school architecture in Malaysia: Linking physical environment, sensory learning and environmental education*. Paper presented at the International Conference on Humanities, Penang, Malaysia.

APPENDICES

Appendix B

Phase 1: Student's interview

DEPARTMENT OF ARCHITECTURE
FACULTY OF BUILT ENVIRONMENT
UNIVERSITY OF MALAYA

STUDENT INTERVIEW

Reference code: _ _ /_ _ /_ _

Date _______________

Time _______________

School ____

Class Teacher _____________________________________

Name _____________________________________

Age ________________ Year Level _______________

Gender ______________

Mode of transport to school _________________

To be completed prior to interview:

<u>Drawing of 'My School'</u>

Draw me a picture of your school.

Please describe your picture to me. Label important places on it.

Draw me a picture of your school as you would like them to be, with any changes you would make.

Please describe your picture to me. Label important places on it.

**Clarify Anything from Observations*

<u>General Understanding</u>

1(a). Please briefly describe the Green School to me.

1(b). Looking at your first picture, can you please explain it to me and label the important places on it?

Place Use

2. Can you please list all the places that you use in your school? What activities do you usually do at these places? Do you learn anything from these places?

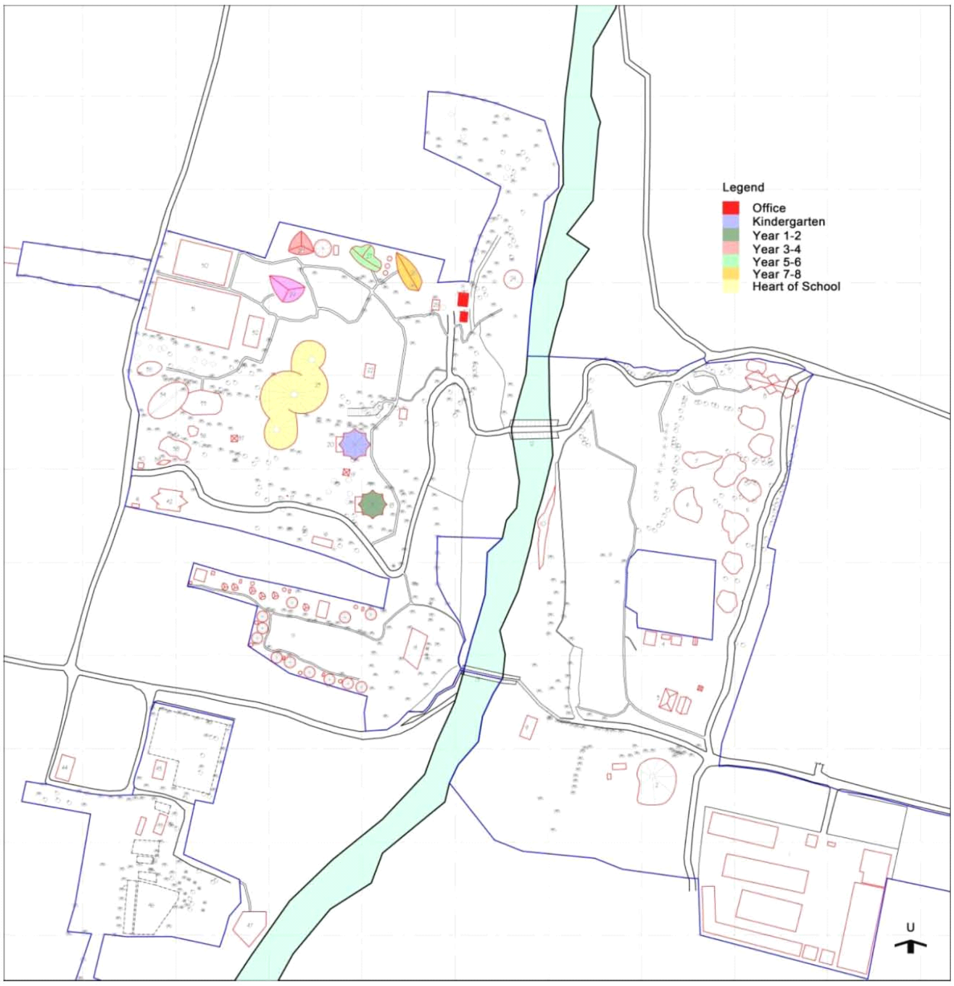
Places	Description of the places	Activity / EE	Lesson Learnt (if any)

Roaming Range

3. On this map of the school and schoolgrounds can you show me the places where you normally spend your recess or lunch time?

- during a hot day
- during a rainy day

**Clarify Anything from Observations*



Map of school

4(a) Where would you spend your time before the school start?

4(b) What do you usually do during this time?

How often would you do this? (tick box)

Almost every day [ ]
2 – 3 times per week [ ]
About once per week [ ]
About once per fortnight [ ]
Less than once per fortnight [ ]

5(a) Where would you spend your time when the school has finished?

5(b) What do you usually do during this time?

How often would you do this? (tick box)

Almost every day [ ]
2 – 3 times per week [ ]
About once per week [ ]
About once per fortnight [ ]
Less than once per fortnight [ ]

'Like and Dislike'

6. Tell me how you feel about your classroom and other school buildings. What you like and dislike about it?

Building(s)	Like	Dislike

**Clarify Anything from Observations*

Changes to School

7. Would you like the school to be changed? [IF YES] How?

8. Please show me and describe the drawing you made of the school with the changes you'd like to make.

9. Do you have anything further you would like to add?

APPENDICES

Appendix C

Phase 2: Questionnaires

DEPARTMENT OF ARCHITECTURE
FACULTY OF BUILT ENVIRONMENT
UNIVERSITY OF MALAYA

Reference code: _ _/_ _/_ _

Date *Tarikh* _______________ Time *Masa* ______________

School *Sekolah* ____ Class *Kelas* ______________

Class Teacher *Guru Kelas* ____________________________________

Name *Nama* _____________________________________ Age *Umur* _______________

Gender *Jantina* _____________ Race *Kaum* _____________

Section 1: Please tick [√] the relevant answer.
Bahagian 1: Sila tandakan [√] jawapan yang berkaitan.

	Strongly Disagree *Amat Tidak Bersetuju*	Disagree *Tidak bersetuju*	Agree *Setuju*	Strongly Agree *Amat Setuju*
1. I get upset when I see people mix recyclables and non-recyclables in their rubbish. *Saya berasa marah apabila saya melihat orang mencampurkan bahan boleh kitar semula dan bahan tidak boleh kitar semula dalam sampah mereka.*				
2. It makes me happy to see people separate food waste from their other trash. *Saya gembira melihat orang mengasingkan sisa makanan daripada sampah yang lain.*				
3. I get angry when I think of people who decline to recycle rainwater for irrigation. *Saya marah apabila saya berfikir tentang orang yang enggan mengitar semula air hujan untuk pengairan tanaman.*				
4. It makes me upset if waste water in a building is not recycled into fertilizer. *Saya berasa kecewa jika sisa air dari tandas tidak dikitar semula sebagai baja.*				
5. I am happy to see people reduce organic waste through the act of composting. *Saya berasa gembira apabila melihat orang mengurangkan sisa organik dengan melakukan kerja kompos.*				
6. I am frightened to think that people don't care about composting. *Saya berasa takut apabila berfikir tentang orang yang tidak mengambil berat tentang pengamalan kompos.*				

	Strongly Disagree *Amat Tidak Bersetuju*	Disagree *Tidak bersetuju*	Agree *Setuju*	Strongly Agree *Amat Setuju*
7. It makes me happy to see my family compost garden waste. *Saya gembira melihat keluarga mengkomposkan sisa taman.*				
8. I am sad to see composting in poorly ventilated areas. *Saya sedih melihat kerja kompos yang dilakukan di kawasan yang kurang pengudaraan.*				
9. It makes me upset to think of my friends not composting food waste from the canteen. *Saya kecewa apabila berfikir tentang kawan-kawan yang tidak mengkomposkan sisa makanan dari kantin.*				
10. I am happy to see organic farmers who use compost instead of chemicals. *Saya gembira melihat petani organik yang menggunakan kompos dan bukan bahan kimia.*				
11. It makes me happy if people compost fruit peel instead of discarding this resource. *Saya berasa gembira jika orang mengkomposkan kupas buah-buahan dan bukan membuang sumber ini.*				
12. I get upset when I think of the thrown away dried leaves that could be returned to the soil to support plant growth. *Saya berasa marah apabila saya berfikir tentang daun kering yang boleh dikembalikan kepada tanah untuk menyokong pertumbuhan tanaman telah dibuang.*				
13. It makes me happy when people use reclaimed materials to construct green buildings. *Saya gembira melihat bangunan bertema hijau yang dibina darpada bahan kitar semula.*				
14. I get angry when I think of the things people throw away that could be recycled. *Saya berasa marah apabila saya berfikir tentang benda yang orang buang tetapi boleh dikitar semula.*				
15. It makes me happy to see people buying products from recycled materials. *Saya berasa gembira melihat orang membeli produk buatan bahan kitar semula.*				

	Strongly Disagree *Amat Tidak Bersetuju*	Disagree *Tidak bersetuju*	Agree *Setuju*	Strongly Agree *Amat Setuju*
16. I am happy when my family uses recycled bottles, cans, and paper to make decoration for my house. *Saya berasa gembira apabila kelurga saya menggunakan botol, tin dan kertas kitar semula untuk membuat hiasan rumah saya.*				
17. I am happy to see my friends conducting experimentation on waste materials. *Saya gembira melihat rakan-rakan menjalankan uji kaji ke atas bahan-bahan buangan.*				
18. It makes me happy when my friends explore different ways to reuse a plastic bottle. *Saya gembira apabila rakan-rakan meneroka cara yang berlainan untuk menggunakan semula botol plastik.*				
19. It makes me happy to see people collect, sort, clean and reprocess waste within their community. *Saya gembira melihat orang mengumpul, mengasing, membersih dan memproses sisa dalam komuniti mereka.*				
20. I get upset to visit buildings without recycling facilities. *Saya berasa kecewa untuk melawat bangunan-bangunan yang tidak mempunyai kemudahan kitar semula.*				
21. I am happy to send discarded items to recycle centre nearby my house. *Saya gembira untuk menghantar bahan buangan ke pusat kitar semula berdekatan dengan rumah saya.*				
22. It frightened me to think of the large amount of waste generated by households. *Saya berasa takut apabila berfikir tentang sejumlah besar sisa yang dihasilkan oleh isi rumah.*				
23. It makes me sad to see my friends not practicing recycling in school. *Saya sedih melihat kawan-kawan saya tidak mengamalkan kitar semula di sekolah.*				
24. It makes me happy to see my friends participate in recycled art contest. *Saya gembira melihat kawan-kawan saya mengambil bahagian dalam pertandingan seni yang menggunakan bahan kitar semula.*				

Section 2: Please tick [√] the relevant answer.
Bahagian 2: Sila tandakan [√] jawapan yang berkaitan.

	Not at all *Langsung tidak*	Seldom *Jarang*	Often *Kerap*	Very Often *Amat Kerap*
1. I have asked my parents not to buy products that are not recyclable. *Saya telah meminta ibu bapa saya supaya tidak membeli produk yang tidak boleh dikitar semula.*				
2. I separate food waste from other trash in my house. *Saya memisahkan sisa makanan daripada sampah yang lain dalam rumah saya.*				
3. I recycle collected rainwater for irrigation. *Saya mengitar semula air hujan untuk pengairan tanaman.*				
4. I read stories and news about eco-buildings which conserve resources by recycling water, materials or energy. *Saya telah membaca kisah-kisah dan berita tentang bangunan bertema "eko" yang memulihara sumber dengan mengitar semula air, bahan atau tenaga.*				
5. I have asked others to compost in order to reduce the amount of organic waste generated. *Saya telah meminta orang lain kompos untuk mengurangkan jumlah sisa organik yang dihasilkan.*				
6. I have talked to my parents about how to compost. *Saya telah berbincang dengan ibu bapa saya tentang cara untuk kompos.*				
7. I have asked my neighbors to compost their garden waste. *Saya telah meminta jiran-jiran untuk mengkomposkan sisa taman mereka.*				
8. I have asked others to put up composting bins in well ventilated areas. *Saya telah meminta orang lain meletakkan tong kompos di kawasan-kawasan yang mempunyai pengudaraan yang baik.*				
9. I help to compost food waste from the canteen. *Saya membantu kompos sisa makanan dari kantin.*				
10. I do organic farming by using compost instead of chemicals. *Saya melakukan pertanian organik dengan menggunakan kompos dan bukan bahan kimia.*				

	Not at all *Langsung tidak*	Seldom *Jarang*	Often *Kerap*	Very Often *Amat Kerap*
11. I collect and compost organic waste in my house. *Saya mengumpul dan kompos sisa organik di rumah saya.*				
12. I have talked to my friends about how dried leaves could be returned to soil as nutrient for plant growth. *Saya telah berbincang dengan rakan-rakan tentang bagaimana daun-daun kering boleh dikembalikan ke tanah sebagai nutrien untuk pertumbuhan tanaman.*				
13. I have discussed with my parents about using recycled materials in building design and construction. *Saya telah berbincang dengan ibu bapa tentang penggunaan bahan-bahan kitar semula dalam reka bentuk dan pembinaan bangunan.*				
14. I have asked others to recycle instead of throwing away. *Saya telah meminta orang lain untuk kitar semula dan bukannya membuang.*				
15. I have asked my parents to buy products from recycled materials. *Saya telah meminta ibu bapa untuk membeli barangan daripada bahan kitar semula.*				
16. I have asked others what innovations could be done to transform recyclables into decoration. *Saya telah meminta pendapat orang lain apakah inovasi yang boleh dilakukan untuk mengubah bahan kitar semula kepada hiasan.*				
17. I conduct test to determine the properties of different waste materials. *Saya menjalankan ujian untuk menentukan sifat-sifat bahan buangan yang berbeza.*				
18. I explore different ways of reusing aluminium can and plastic bottle. *Saya telah meneroka cara yang berlainan untuk menggunakan semula tin aluminium dan botol plastik.*				
19. I collect, sort, clean and reprocess waste in my school. *Saya mengumpul, megasing, membersih dan memproses semula bahan buangan di sekolah saya.*				
20. I have put up and maintain recycle bins in my house. *Saya telah meletakkan dan menjaga tong kitar semula di rumah saya.*				

	Not at all *Langsung tidak*	Seldom *Jarang*	Often *Kerap*	Very Often *Amat Kerap*
21. I collect and separate my family trash for recycling. *Saya mengumpul dan memisahkan sampah keluarga saya untuk kitar semula.*	☹	😐	☺	😀
22. I have passed out information about the amount and type of recyclables in my school. *Saya telah menyebarkan maklumat tentang jumlah dan jenis bahan kitar semula di sekolah saya.*	☹	😐	☺	😀
23. I go from class to class asking students to support school-based recycling. *Saya pergi ke kelas-kelas untuk meminta pelajar menyokong kitar semula di sekolah.*	☹	😐	☺	😀
24. I have participated in recycled project in my school. *Saya telah mengambil bahagian dalam projek kitar semula di sekolah saya.*	☹	😐	☺	😀

Section 3: Please circle the correct answer.
Bahagian 3: Sila bulatkan jawapan yang betul.

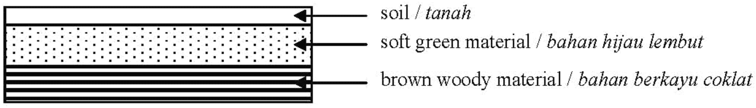
1. An item which cannot be recycled and use again is
   Satu benda yang yang tidak boleh dikitar semula adalah
   a. disposable diapers
      lampin pakai buang
   b. newspaper
      suratkhabar
   c. aluminium cans
      tin aluminium
   d. motor oil
      minyak motor

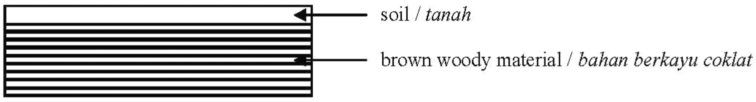
2. Which of the following is an organic waste?
   Manakah antara berikut adalah sisa organik?
   a. metal can
      tin besi
   b. concrete
      konkrit
   c. grass cuttings
      keratan rumput
   d. glass bottle
      botol kaca

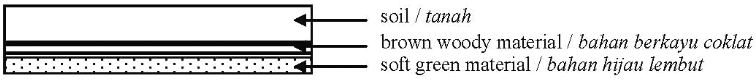
3. Rain water
   Air hujan
   a. should be just channeled into the drains
      sepatutnya disalurkan ke longkang sahaja
   b. can be used for toilet flushing
      boleh digunakan untuk mencurahkan tandas
   c. is a dirty resource
      adalah satu sumber yang kotor
   d. cannot be reused
      tidak boleh diguna semula

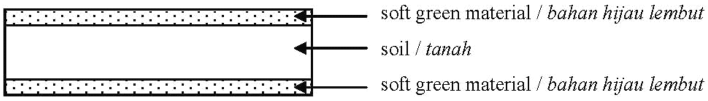
4. Why is recycling important?
Apakah kepentingan kitar semula?
a. It helps the country to make more money.
Ia membantu negara untuk mengaut lebih banyak keuntungan.
b. It pollutes the environment.
Ia mencemarkan alam sekitar.
c. It helps to conserve resources.
Ia membantu untuk memulihara sumber-sumber alam.
d. None of the above because it is not important at all.
Tiada di atas kerana ia tidak penting sama sekali.

5. Which of the following diagram represent the correct compost pile?
Manakah antara berikut merupakan longgokan kompos yang betul?

a.


b.


c.


d.


6. Composting is
Kerja kompos adalah
a. a chemical product manufactured by factory.
produk kimia yang dibuat oleh kilang.
b. about making more money.
tentang mengaut lebih banyak keuntungan.
c. a recycling process in nature by turning organic waste into fertilizer.
satu proses kitar semula dalam alam semula jadi dengan menukarkan sisa organik kepada baja.
d. harmful to flora and fauna.
berbahaya kepada flora dan fauna.

7. Which of the following cannot be used for composting?
Manakah antara berikut tidak boleh digunakan untuk kerja kompos?
a. grass cuttings
keratan rumput
b. left-over vegetables
baki sayur-sayuran
c. stone
batu
d. fruits
buah-buahan

8. Which of the environmental condition below does not affect the composting process?
Manakah antara keadaan alam di bawah tidak menjejaskan proses kompos?
a. humidity *kelembapan*
b. acoustic *akustik*
c. temperature *suhu*
d. ventilation *pengudaraan*

9. Food waste from the canteen should be
Sisa makanan dari kantin sepatutnya
a. burned *dibakar*
b. sent to landfill *dihantar ke tapak pelupusan*
c. composted *dikomposkan*
d. thrown into a river *dibuang ke dalam sungai*

10. Organic farmers use ______ as fertilizer.
Petani organik menggunakan ______ sebagai baja.
a. garden leftover *sisa taman*
b. fruit and vegetable peeling *kupas buah-buahan dan sayur-sayuran*
c. animal manures *najis haiwan*
d. all the above *semua di atas*

11. Which of the following is false?
Manakah antara berikut adalah salah?
a. Composting can be carried out either indoor or outdoor.
Kerja kompos boleh dilakukan sama ada di dalam atau di luar bangunan.
b. Not all animal manures are suitable for organic farming.
Bukan semua najis haiwan sesuai digunakan untuk pertanian organik.
c. Organic wastes give away bad odor and thus should be sent to landfill.
Bahan-bahan buangan organik memberikan bau dan oleh itu harus dihantar ke tapak pelupusan.
d. Kitchen waste can be decomposed.
Sisa dapur boleh dikomposkan.

12. Which of the following statement is TRUE?
Antara pernyataan berikut yang manakah adalah BENAR?
a. Dried leaves and grass cuttings can be composted.
Daun-daun kering dan keratan rumput boleh dijadikan baja kompos.
b. Recycling does not generate job opportunity for the people.
Kitar semula tidak menjana peluang pekerjaan untuk rakyat.
c. If we use recycled paper, we will cut down more trees.
Jika kita menggunakan kertas kitar semula, kita akan menebang lebih banyak pokok.
d. Landfill is the best way for waste management.
Tapak pelupusan adalah cara yang terbaik untuk pengurusan sampah.

13. Which of the following is FALSE?
Antara berikut yang manakah adalah PALSU?
a. At home, I can always recycle plastic bottles, aluminum cans and newspaper.
Di rumah, saya boleh kitar semula botol plastik, tin aluminium dan akhbar.
b. Waste and salvaged materials cannot be used for building design and construction
Bahan buangan tidak boleh digunakan untuk reka bentuk dan pembinaan bangunan.
c. Aluminum cans can be recycled over and over again.
Tin aluminium boleh dikitar semula berulang-ulang kali.
d. Paper should be put into blue color recycle bin.
Kertas hendaklah dimasukkan ke dalam bin kitar semula berwarna biru.

14. The main problem with “throwing away” is that
Masalah utama dengan “membuang” adalah
   a. more waste ended up in landfill
   lebih banyak sisa akan dikumpulkan di tapak pelupusan
   b. it generates extra income for the country
   ia menjana pendapatan tambahan kepeda negara
   c. it attract rats and other pests
   ia menarik perhatian tikus dan makhluk perosak yang lain
   d. it prevent farming of nearby land
   ia mengelakkan aktiviti pertanian di kawasan berhampiran

15. The logo on your left can normally be found on paper or cardboard packaging. What does it signifies?
Logo di sebelah kiri anda biasanya boleh didapati di atas bungkusan kertas atau kadbod. Apakah ia melambangkan?
   a. The supplier of packaging has financially contributed to the cost of recovery and recycling.
   Pembekal bungkusan telah memberikan sumbangan kewangan kepada kos pemulihan dan kitar semula.
   b. The packaging is made from recycled materials.
   Bungkusan itu dibuat daripada bahan kitar semula.
   c. The packaging will be recycled.
   Bungkusan itu akan dikitar semula.
   d. The packaging is recyclable.
   Bungkusan itu boleh dikitar semula.

16. Recycled items can be
Barang-barang kitar semula boleh
   a. sent to landfill.
   dihantar ke tapak pelupusan.
   b. buried in nearby fields.
   ditanamkan di padang yang berdekatan.
   c. used to make art and crafts.
   digunakan untuk membuat kraftangan.
   d. sent to an isolated island.
   dihantar ke pulau terpencil.

17. 

The above symbol found on a shampoo bottle means
Simbol di atas yang terdapat pada botol syampu bermakna

a. the bottle can only be recycled twice
botol hanya boleh dikitar semula dua kali
b. the bottle can only be recycled once
botol hanya boleh dikitar semula sekali
c. the bottle is made from Type 2 plastic - HDPE
botol itu dibuat dari plastik Jenis 2 - HDPE
d. none of the above
bukan semua di atas

18. Your house was renovated recently and you have a lot of left-over wood planks in your house, you can
Rumah anda telah diubahsuai baru-baru ini dan anda mempunyai banyak papan kayu yang berlebihan di rumah, anda boleh

a. just throw it away.
membuangkannya.
b. buried it.
menanamkannya.
c. use it to build a pet house for your cat.
menggunakan ia untuk membina sebuah rumah kecil untuk kucing kesayangan anda.
d. burn it.
membakarkannya.

19. I can recycle by
Saya boleh kitar semula dengan

a. throwing my rubbish to my neighbour's house.
membuang sampah saya ke rumah jiran.
b. dumping aluminum cans in an open field.
membuang tin aluminium di satu padang terbuka.
c. sending plastic bottles to landfill.
menghantar botol plastik ke tapak pelupusan.
d. collecting, separating and sending recyclables to collection centres
mengumpul, mengasingkan dan menghantar bahan kitar semula ke pusat pengumpulan.

20. Recycling is
Kitar semula adalah
a. about throwing things away only.
hanya berkenaan tentang pembuangan sampah.
b. a process involving collection, separation and processing of waste into new products.
satu proses yang melibatkan pengumpulan, pemisahan dan pemprosesan sampah menjadi produk baru
c. an activity for adults only.
satu aktiviti untuk orang dewasa sahaja.
d. about spending more money for waste management.
tentang menghabiskan lebih banyak wang dalam kerja pengurusan sampah sarap.

21. Which of the following cannot be sent to local recycle centre?
Antara berikut yang manakah tidak boleh dihantar ke pusat kitar semula tempatan?
a. shampoo bottle
botol syampu
b. metal can
tin besi
c. corrugated cardboard
kadbod beralur
d. compact disc (CD)
cakera padat (CD)

22. Which of the following should not be put into recycle bins?
Antara berikut yang manakah tidak boleh dimasukkan ke dalam tong kitar semula?
a. Used aluminum cans
Aluminium tin yang telah digunakan
b. Plastic and rubber toys
Alat permainan daripada plastik dan getah
c. Colourful magazines
Majalah berwarna-warni
d. Broken plastic bottles
Botol plastik yang telah rosak

23. Which of the following party should be responsible for a school-based recycling program?
Yang manakah pihak yang berikut harus bertanggungjawab atas program kitar semula berasaskan sekolah?
a. local waste operator
pengendali sisa tempatan
b. teacher
guru
c. student
pelajar
d. all the above
semua di atas

24. Which of the following is true?
Manakah antara yang berikut adalah benar?
a. Recycling in school only involves learning through textbook.
Kitar semula di sekolah hanya melibatkan pembelajaran melalui buku teks.
b. Waste can be repurposed into beautiful sculpture in the school garden.
Bahan buangan boleh dijadikan hiasan yang indah di taman sekolah.
c. Recycled art project is a waste of time and money.
Projek seni dikitar semula adalah satu pembaziran masa dan wang.
d. Recycling activities in school will cause negative impact on students' academic performance.
Aktiviti-aktiviti kitar semula di sekolah akan menyebabkan kesan negatif terhadap prestasi akademik pelajar.