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Physical environment as a 3-D textbook: design and development of a prototype

Seng Yeap Kong*, Naziaty Mohd Yaacob and Ati Rosemary Mohd Ariffin

Department of Architecture, Faculty of Built Environment, University of Malaya, Kuala Lumpur, Malaysia

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The use of the physical environment as a three-dimensional (3-D) textbook is not a common practice in educational facilities design. Previous researches documented that little progress has been made to incorporate environmental education (EE) into architecture, especially among the conventional designers who are often constrained by the budget and building area requirements. This article presents an exploratory project to develop a prototype for the 3-D textbook. The author does not formulate ideas and concept based on the pre-determined specs in a design brief. Instead, the design solution evolved through a qualitative case study conducted at the Green School in Bali, Indonesia. Data were collected through a series of interviews and on-site observations. The qualitative findings uncovered four design features for the 3-D textbook. A prototype was subsequently developed using the design features as a blueprint. The prototype serves as a testing ground for new ideas as well as a platform to promote awareness and acceptance of the 3-D textbook among the practitioners. Consequently, this article attempted a significant proposition to bring together architecture and EE, thus potentially contributing to a field of knowledge that embraces design and education.

Keywords: Green school; 3-D textbook; architecture; environmental education; prototype

1. Introduction

Architecture has the power to shape the life and behaviours of mankind (Taylor & Enggass, 2009; Wever, 2012). An interesting comment on this interaction is given by a renowned architect, Frank Lloyd Wright. He claimed that the architectural design of a house can cause the divorce of a married couple within weeks (Orr, 2000). Buildings are not merely machines as Le Corbusier would have it (Orr, 1993). The built environment is a form of pedagogy that never fails to instruct (McClintock & McClintock, 1968; Orr, 2000; Powers, 2004). 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 three-dimensional (3-D) textbook.

However, the use of the physical environment as a 3-D textbook is not a common practice in educational facilities design (Orr, 1993). Taylor and Enggass (2009) noted that the design and development of the 3-D textbook is still in its infancy, and needs further

*Corresponding author. Email: k_sengyeap@um.edu.my

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exploration and experimentation. Furthermore, previous researches documented that little progress has been made to incorporate environmental education (EE) into architectural design, especially among the conventional practitioners who are often constrained by the budget and building area requirements (Lackney, 2009; Orr, 1997, 2000; Rauch, 2000; Weston, 1996). As a result, a need exists to develop a prototype for the 3-D textbook as a platform for new ideas to emerge. More importantly, the information and experience gained through the prototype can be passed on for others to learn from.

The aim of this article is to utilize a qualitative case study to develop a prototype for a 3-D textbook that could be adopted by practitioners and future researchers in this direction. The author does not formulate ideas and concept based on the pre-determined specs in a design brief. Instead, the design solution evolved through a qualitative case analysis which describes and interprets a 3-D textbook from the children’s perspective. Looking into the minds of the children enables the author to better comprehend what children find interesting and meaningful about their school environment (James & Bixler, 2008). This echoes with Deasy’s (1974) suggestion that design solutions should be understood by investigating the reactions of the users rather than focusing on the intentions of the designers.

The following discussion consists of four sections. Firstly, a brief literature review is presented to provide the relevant setting to this research. Secondly, the research methodology and methods for this study are elaborated. Subsequently, the results are presented by relating the findings to the four emerged themes and a prototype. Finally, the findings are discussed in relation to the existing theories and researches.

2. Literature review

“Architecture as Pedagogy” by Orr (1993, 1997) highlighted that built and natural environments carry pedagogical value and these are power tools that influence the act of teaching and learning. Orr (1997) suggested that EE can be embedded into the built environment where every building could tell a story. He 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 that teaches as effectively as any lessons that are usually taught in the buildings. 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, Ryan, & Tilbury, 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. They promote a comprehensive approach to environmental learning by connecting EE concepts with school facility and educational architecture as well as curricula. Additionally, they encourage children’s participation in the decision-making for campus design and environmental management within the curriculum (Wang, 2004).

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 concept that links early childhood education to physical settings such as childcare centres and kindergartens (Edwards, Gandini, & Forman, 2012; Thornton & Brunton, 2007; Wurm, 2005). Reggio Emilia 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, Stremmel, & Hill, 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 40 years interpreting philosophy and curriculum into architectural programmes which are subsequently transformed to actual physical designs. Her writings resonated with Orr’s recommendation that buildings and landscape can be used to reflect similar to what we are teaching children 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. Educators, can, if they are aware of the opportunities offered by the designed or natural world, turn “objects” into “thoughts” for children’s 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.

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, education happens through the interaction with the surroundings (Khalil, 2012). Taylor (1993) used the term “knowing eye” to explain how students may learn from the physical settings. The knowing eye is defined as a type of visual literacy that enables architects to see and critically analyse the physical world (Taylor & Enggass, 2009). Architects undergo special training that sharpens their perception, enhances their sensitivity and assists them to develop an artistic sense of the environment (Demirbaş & Demirkan, 2003). However, the knowing eye is not an exclusive privilege architects possess (Arnheim, 1997; Grandin, 2006; Northern & Downs, 2002). In fact, children 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 pedagogical tool (Learning through Landscape, 2012). The knowing eye is not only 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).

Furthermore, 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 ecology and economics. Subsequently, Orr suggests that the issue of ethics will be engaged in any decision-making process (Environment and School Initiatives, 2012). For example, the question of ecological and human costs relating to the various materials imposed in building. Additionally, Mitchell (2005) and Lynam (2007) documented that the physical environment carries 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, Fielding, & Lackney, 2009). Badarnah (2009), Van der Ryn and Cowan (1996) also documented that there is evidence of a curriculum in applied ecology within the built environment. Other researchers including Nair, Fielding, and Lackney (2009) suggested to design school buildings as a living laboratory to treat and recycle wastewater through an ecologically engineered system which will be studied and operated by the children. Lastly, Ford (2007) and Rauch (2000) noted that school buildings can extend ecological competence by inviting the participation of children. New knowledge and skills would be
constructed through the children’s involvement in the maintenance and operation of the school. Thus, children in ecological literacy schools (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).

3. Methodology

This article represented evidence collected, analysed, interpreted and discussed from the first phase of a three-year-long research aimed to develop and test the effectiveness of a design model for 3-D textbook. The research was implemented in two phases in accordance to an evidenced-based design framework (Brandt, Chong, & Martin, 2010; Kopec, Sinclair, & Matthes, 2012; Lippman, 2010). A case study was conducted in the first phase, where evidences were gathered from observations and interviews done at the Green School in Bali. The reason for collecting qualitative data initially was that the design criteria were not known and that these variables needed to be developed based on a case study. From the results of this qualitative study, the author further developed the theoretical framework that emerged from the literature review. Subsequently, a quasi experiment was conducted to generalize the initial findings through prototyping and user testing, which was used to track the implications of the design implementation. The author wished to acknowledge that the remaining sections of this article focused specifically on the first phase of this longitudinal research. The qualitative findings and prototype generated through the case study would be further tested and validated over a larger sample in the above-mentioned quasi-experiment and hopefully to be published later.

3.1 Case study

The Green School in Bali, Indonesia was identified as the ideal case study based on a purposeful sampling method. The school represented a significant attempt to reunite the two disciplines of architecture and EE. 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 was designed as a live example of sustainable living. Classrooms were constructed out of bamboo, alang-alang grass, mud and other local resources (Figure 1). Most of the buildings in the campus had no walls, allowing for natural ventilation to take place while the sustainable elements like the compost toilet and biogas reactor became a part and parcel of the EE syllabus (Figure 2). The Green school symbolizes the first of its kind learning facility that presents as a valuable case study for a 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.

3.1.1 Data collection

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 the individuals’ expressed feelings about the environment. Thus, the individual interview was deemed to be more
appropriate compared to other qualitative research methods, such as the focus group method (Gaskell, 2000). The author also acknowledged that focus group was not suitable for the present study for 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 children tended to be left out during focus group sessions. It was found out later that these children were not comfortable in expressing their opinion in front of their peers. The author had subsequently consulted a professor and an associate professor from a university who specialized in elementary school research. Their advice was to conduct a face-to-face individual interview to build a rampart trust with the children so that they could express themselves better and confidently. Thirdly, as the qualitative data emphasized 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 uncover the underlying attributes of a 3-D textbook which reflects the main research aim (Fredrickson & Anderson, 1999). All children in the primary years were included in the on-site observation while the in-depth interviews were only conducted with selected fifth-graders. In addition, discussions and brief interviews were carried out with selected teachers, administration staff and the project architect of the Green school, Bali, used as multiple sources of evidence to address the limitation imposed by individual interviews. The added data supported and clarified the information gathered from the children’s interviews.

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 (Kasalı & Doğan, 2010). The author also collected an extensive number of field notes, sketches and photos to record on the spatial information relating to students’ activities. In terms 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 (Zeisel, 1981). The author took photographs of the outdoor traces and indoor traces to generate possible issues for further discussion during the interview sessions (Fredrickson & Anderson, 1999). The focus was to understand what a physical setting might reflect and what intention might be behind it.

Maximum variation sampling was adopted to select children for the in-depth interview sessions (Creswell, 2007, p. 127). Three fifth-graders identified to be of “good, average and weak” according to their academic achievements, were interviewed each day. They were asked to draw pictures illustrating their perceptions of the Green School before the interviews (Malone & Tranter, 2003). Instructions were kept to the minimum and non-prescriptive so that each child could express their thoughts and feelings spontaneously through their drawings. The open ended interview questions also encouraged the children to express at length their experience as users of the Green School. 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).

3.1.2 Data analysis

All interviews were recorded and transcribed. The transcripts were content-analysed together with field notes and children’s drawings. The analysis process was guided by the grounded theory methodology as suggested by Corbin and Strauss (2008). This procedure included reading of relevant sections of the transcripts and filed notes to identify recurring words, phrases or sentences. This open coding procedure reduced the database to a small set of themes, allowing for the development of salient categories of information supported by text (Corbin & Strauss, 2008). Commonalities between these themes enabled the emergence of a central phenomenon under which associated sub-categories were grouped (Creswell, 1998). Subsequently, the database was reviewed to offer insight into specific coding categories that explained the central phenomena. When the fairly developed themes were revealed, the author moved to selective coding, whereby the key interest of the analysis was to generate statements and propositions that interrelate these themes (Strauss & Corbin, 1990). The author verified the descriptions and interpretations by
conducting peer review sessions with interested colleagues as well as employing an external audit to review the research procedure and product periodically (Creswell, 2007).

3.2 Prototype development
Upon the completion of the case study, the author liaised with the Faculty of Built Environment to carry out experimentation, testing and design of a prototype. The author spent a significant amount of time with the academic staffs, during which time and efforts were made to incorporate the findings from the case study into the prototype. 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 (Figure 3). Subsequently, additional mock-ups were constructed ranging from simple and cheap materials to complex working models of the specific components. 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.

4. Results and discussion
The themes were interpreted in categories that best describe the attributes that characterize a 3-D textbook from the children’s point of view. The four themes that emerged from the case study were: (1) apparent clue, (2) nature-inspired design, (3) innovative solution, (4) active setting. For the purpose of this study, the themes provide for dimensions to explore

Figure 3. Experimentation and testing were conducted in a lab (left) or using simulation software (right).
in a bigger framework of understanding EE and translating the themes into ideas in architecture.

### 4.1 Apparent clue

The first theme was termed as “apparent clue” 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. Bamboo was used as a replacement for rainforest timber as a construction material, where it was exposed, expressed and celebrated in each building. 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 also an extension of the Green School’s educational and design philosophy. This simple yet elegant furniture was light weight, inexpensive and movable for a variety of teaching requirements. 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. The Green School used locally available materials to minimize transportation costs and ensured support for local craftsmen and labourers. 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. 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.”

Field notes further 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 a biogas reactor. The vortex generator diverted water from the adjacent Ajung River to form a vortex 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 the water vortex power plant to explore the 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 take place.

### 4.2 Nature-inspired design

The subsequent theme was “nature-inspired design” which described the design of the Green School that integrated the surrounding environment as part of the educational spaces. The Green School promoted indoor-outdoor connectivity by providing convenient access to the greenery. Flora and fauna were always close-at-hand, inviting students for further exploration and discovery. 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 outdoors and preferred open classrooms with no walls. It reunited the outdoor and indoor environments and it had the benefit of linking students to their surrounding environments.

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. As noted by a student, “no major change to the site was done...the school planning respects the environment and climate.” Additionally, the adjacent Ajung River provided a readily available and accessible setting for EE to take place. Students were allowed to explore the river or collect specimens under the guidance of their teacher. Field notes and interviews documented that the site features like rainforest, contour and trees 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.

4.3 Innovative solution

Interviews and observational data documented that the children regarded their school as a source of “innovative solution”. 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. The Green School campus was full of unusual and unique buildings that were designed to engage children’s minds. 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. A student explained, “I think it is good where they try to make different things...the Heart of the School is an orange peel.” In short, buildings in the campus were acknowledged as being functional as well as inspiring. These buildings stood proud as a form of teaching tool that encouraged students to continually challenge the traditional standard in hope of generating superior and novel resolutions.

The Green School encouraged a closed waste cycle through creative design and construction. 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. 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. On the other hand, windscreens, side and rear windows were painted white and used as white boards in the classrooms. A new usage or application was developed for the windshields without losing their 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 a 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.”

4.4 Active setting

Field notes revealed that students were not merely passive observers. Instead, they were actively interacting with the natural and built environment in their daily learning. This suggested the final theme – “active setting”, where it depicted the possible use of a 3-D textbook to promote the notion of “learning by doing”. Interviews disclosed that the design of the buildings and landscape in the Green School was open-ended. Thus, the students and teachers were allowed to transform the spaces in a variety of ways. In other words, the learning environment was designed to be multipurpose. It could be adapted to different learning activities in and out of the classrooms. Field notes documented that the students utilized these open-ended and information rich environments to acquire new understanding either by individual exploration or with the support of others. For instance, field notes indicated that the rice fields were utilized as farming space for group learning. The same settings could also support self-discovery by allowing individual students to explore the ecosystem, food chain and different species of fauna during their free time. The student-created garden also 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 Green School was also designed as a living context for essential life skills training. The campus promoted students’ participation in the operation and maintenance of the school ground and facilities to promote life skills alongside environmental values. This included taking care of the livestock in a stable, watering plants and undertaking building repairs. The Green School also promoted project-based activities that enabled the children to modify physical settings within the campus. The school ground was treated as a platform for students to practise construction, preservation and conservation. For instance, the fifth-graders were responsible for the demolition, design and rebuild of a chicken coop for the school. 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 models to check the safety and stability of structure.”

4.5 Prototype development

Working with the interdisciplinary partners, the author developed a prototype for the 3-D textbook based on the findings from the Green School, Bali (Figure 4). The author wishes to acknowledge that the prototype included in the following discussion is an unbuilt project in Malaysia. It does not advance beyond the schematic design stage because the construction is more costly than anticipated. However, the innovations generated through this pilot project can be used to demonstrate the learning opportunity offered by a 3-D textbook.

Findings from the Green School highlighted the importance of making materials, services and ecological processes “apparent” to the children. Thus, the prototype displayed and celebrated discarded items as environmentally friendly materials. Reclaimed components, such as a second-hand door and window, were tapped for its
potential secondary use. Recyclables like tins and bottles were displayed throughout the façades (Figure 5). Moreover, the prototype exposed and celebrated the water cycle within the campus as a pedagogical tool (Figure 6). A comprehensive water management system was developed to educate the children about the conservation of natural resources. Rain water would be collected from the roof top for irrigation and toilet flushing. The grey water generated would be treated in a root zone area before being channelled into a rain water interactive pool. Additionally, black water would be collected in a composting unit before being treated in a green house which was powered by photovoltaic panels. The composting unit also generated biogas for cooking and manure for gardening.

Additionally, findings from the Green School disclosed the significance of “nature-inspired design”. Thus, the prototype was designed to work with nature. It responded to its site by integrating itself with the existing ecosystem. It was strategically located next to a forest reserve where an abundance of dried leaves and garden wastes were available for composting. Thus, a vertical composting wall was designed for the decomposition of organic waste and thus helped to return nutrients to the soil (Figure 7). The organic fertilizer generated by the composting wall could also be used in the farming plot to grow vegetable and fruit.

Figure 5. Part elevation of a typical classroom from reclaimed materials.
Furthermore, findings from the Green School revealed that “innovative solution” was an important criterion for the 3-D textbook. Thus, the walls of the classrooms were used as a collage, consisting of numerous tins and bottles (Figure 5). Salvaged products would be reused creatively to inspire children toward sustainable waste management. For instance, children could clean, cut, and reassemble the cardboard to form the window louvers, while second-hand bricks were used as topping for footpaths. In addition, the classrooms served as an art studio for children to perform various experimentations with waste products. It supported and promoted the exploration of recycled arts and crafts within the campus.

Findings from the Green School also highlighted that the 3-D textbook should have an “active setting” instead of a passive environment. Therefore, the façade, colour scheme and aesthetic appearance of the prototype could be continuously altered through project-based activities. For instance, a “Design, Build and Operate Workshop” could be organized so that the children could take part in the renovation or extension of their school. Additionally, the children would be in charge of the daily operation and maintenance. They were expected to perform building repairs, recycling, composting, farming and gardening under the guidance of their teachers or technicians.
5. Discussion

The themes of “apparent clue” emphasize the notion of making the invisible visible. The findings from the current research disclose that exposed material is the key criterion in expressing environmental messages (Shapiro, 2012). For instance, the Green School uses bamboo to reflect their commitment towards sustainability while the prototype 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 (Baird, 2002; Day & Midbjer, 2007). It reinforces earlier claim that architectural elements such as building materials, finishes and walls can be active learning tools if they are visible and accessible to the students (Van der Ryn & Cowan, 1996). The current research also promote the expression of building services and ecological system rather than suppressing these processes (Baird, 2001). 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 in the prototype. These exposed and accessible systems can help students to deconstruct the hidden campus curriculum, leading to enhanced environmental performances (Winter & Cotton, 2012). Visible and sustainable practices also enabled environmental issues to be communicated through the physical environment (Ferris, Norman, & Sempik, 2001; Gough, 2005). Particularly, it promotes constructive dialogue around campus sustainability and self reflection, which can be transformative and translate into pro-environmental behaviour change (Eagly & Chaiken, 1993; Kaisera, Oerkeb, & Bognerb, 2007; Ryan, 1991).

The theme of “nature-inspired design” promotes the transformation of nature into a pedagogical tool with particular emphasis on the local environment (Ellis, 2004; Howley, Howley, Camper, & Perko, 2011). 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 (Hutchison, 2004). The findings support previous research related to the notion of learning landscapes (Bargmann & Levy, 1998; Brown, 1998). 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 (Williams & Brown, 2011). 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 (Duhn, 2012; Johnson, 2011; Knez, 2005). For example, the Green School makes use of the river and contour to teach important lessons about “place” while the prototype exposed students to composting through the decomposition of organic waste on-site. This is in line with other studies which suggest that constant interaction with outdoor settings such as garden, schoolyard and Natural Park can lead to improved environmental performances (e.g., Cronin-Jones, 2000; Eagles & Demare, 1999; Farmer, Knapp, & Benton, 2007; Jensen, 2002; Kruse & Card, 2004; Leeming, Dwyer, Porter, & Cobern, 1993).

The theme of “innovative solution” acknowledges that inventive architecture plays a key role in the transformative route of producing sustainability thinkers (Bowers, 1995). It echoes with other scholars that any design’s aesthetic should reflect innovative solution by capturing a true sense of connectedness to sustainability (Jones, 2002; McClintock & McClintock, 1968). A green building must be aesthetically pleasing as well as enhancing pro-environmental performance among the users (Yeang, 2006). Thus, architecture and EE need to be juggled together to develop a new ecology-based aesthetic for architecture. 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-like school. Additionally, the prototype 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.

The theme of “active setting” acknowledges that school ought to be flexible in the use of space and materials (Nair et al., 2009). This is in line with the notion of a multipurpose environment that offers children many choices, provokes them to engage in many activities and allows them to act on and transform the learning settings in many ways (Lackney, 2009). Findings from the current research also emphasize the importance of connecting students to the operation and maintenance of the school (Higgs & McMillan, 2006). Up-keeping provides learning experiences in stewardship and pride of space. It also assists students in developing a new skill or environmental awareness (Foster, 2001; Karliner, 2005; Schelly, Cross, Franzen, Hall, & Reeve, 2012). Students’ involvement as caretakers of their schools acts as catalyst for the discussions about sustainability and gives them opportunities to attempt new, sustainable behaviour (Petersen, Murray, Platt, & Shunturov, 2007). Scholars noted that green maintenance and operation enables schools to foster learning about EE and the adoption of pro-environmental behaviour without the need to preach or proselytize, thus avoiding the problems associated with overt advocacy (Rauch, 2000; Sterling, 2001; Wagstaff & Wilson, 1988). Apart from the daily routine, children can also take part in longer projects such as building construction and organic gardening. Through participation in the design and building process, they may take the lead in the conversion of their school to sustainable practices (Ellis, 2003; Mackey, 2012; Van Wagenberg, Krasner, & Krasner, 1981). It enables the children to express their ideas in sustainability, as well as demonstrating these to others (Berryman & Breighner, 1994).

6. Conclusions

In summary, the author takes the position that a school ought to be planned and designed as to enlighten the children of their powers and duties in environmental conservation. Thus, from an architectural point of view, it is equally important to ask what children are learning in school and what they would learn from the school. This article directs our attention to the under explored subject in a school environment. It offers an insight to the design of physical environment that supports and advances EE learning. Particularly, it reveals the important attributes of a 3-D textbook. This research also provides a detailed account of children’s reactions and perceptions towards the 3-D textbook with a potential contribution to a field of knowledge that embraces design and education. It also presents a number of experimentations with new materials and processes in educational facilities design that are worthy of research, reflection and further testing. The findings serve as a basis for the practitioners who are interested in challenging the boundaries of school architecture in the tropics. It encourages the architects and educators to continuously uplift the standard of school design without being overly constrained by the conventional norms.

The prototype and the discussions generated in this article 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, the author hopes 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 hoped that architects and educators will take these lessons and apply them in educational facilities or other contexts. Nevertheless,
high-quality architecture is more than rote application of rules. It is innovative problem-solving at its best, wholly addressing requirements, including the human need for delight and invention. In short, the author believes that all sites provide learning opportunities for students and community. Thus, good design should attempt 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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