

An experimental school prototype: Integrating 3rs (reduce, reuse & recycle) concept into architectural design

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The authors conducted a design project to examine the use of school as an ecological learning hub for children. Specifically, this study explores the ecological innovations that transform physical environment into three-dimensional textbooks for environmental education. A series of design workshops were carried out to gain interdisciplinary input for ecological school design. The findings suggest to integrate the concept of 3Rs (Reduce, Reuse & Recycle) into the physical environment. As a result, an experimental school prototype is developed. It represents a series of recommendations that are rendered by novel ideas through the amalgamation of architecture, ecology and education. These findings promote the development of sustainable and interactive learning spaces through cross-disciplinary investigations in school architecture. Designers and practitioners interested in educational facilities design would find this article useful.

Keywords: *Eco-school, 3-D textbook, architecture, 3Rs, children*

1. INTRODUCTION

There is a growing body of evidence that built and natural environment could be utilized as pedagogical tools to facilitate the act of teaching and learning in the school (Taylor, 1993; Taylor & Enggass, 2009). This idea is built upon the notion that children could construct new knowledge and skill through their interaction with the surrounding environments. Similarly, much has been written in the fields of architecture and environmental psychology that physical environment is not merely a backdrop for educational activities (Amedeo & Dyck, 2003; Anthony, 1987; Kasali & Dogan, 2010; Orr, 1993; Orr, 1997; Peatross & Peponis, 1995). Instead, buildings and landscape carry pedagogical value that reinforces the lessons taught in the classroom. For example, why just read about rainwater harvesting or renewable energy when, with just a slight inducement of design creativity, children can see these wonders first hand? (Innovative Design Inc, 2009). This has directed various scholars to investigate the possibility of designing a school as a three-dimensional (3-D) textbook for environmental education (EE) and thus transforming the school into an ecological learning hub for children (Taylor, 1993; Taylor & Enggass, 2009). As noted by Graham (2003), “there is no better place to teach the children... about how to live

sustainably with the earth and to repair the damage done, than at their school” (p. 259).

This article expands the current body of knowledge on the concept of school as an ecological learning hub, with a focus on a tropical country with vast biodiversity: Malaysia. Bonding the expertise from architecture, EE and ecology, the authors ask: How to design an ecological school from an interdisciplinary point of view? Answer to this subject is significant in various ways. Firstly, it examines the notion of ecological school 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 ecological school and its constituent parts to assist children’s environmental learning. It offers an entirely new perspective to educational facilities design by merging the disciplines of architecture, EE and ecology. The research outcomes 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. Furthermore, the research provides an insight into the use of green buildings as three-dimensional teaching tools for knowledge transmission in schools. Thus, sustainable architecture and technologies have been

acknowledged as critical factors that influences the outcome of this research.

The following discussion consists of five sections. Firstly, the school architecture and EE in Malaysia are presented to provide the relevant setting to this research. Secondly, the authors provide a brief literature review on the use of an ecological school as a 3-D textbook for children. Thirdly, the research method for this study is elaborated. Subsequently, the results are presented by relating the findings to 3Rs (Reduce, Reuse and Recycle) concept. Finally, significant implications of the findings are summarized as the conclusions.

2. ARCHITECTURE AND EE

Malaysia National News Agency reported that “there are 192 countries in the world, but 75 per cent of the world’s plant and animal species are found in 12 countries including Malaysia” (as cited in Daniel, et al., 2006, p. 1). As a tropical country that blessed with a rich biodiversity of flora and fauna, 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. Consequently, government and NGOs have deposited a lot of efforts in promoting EE, particularly among school children. Lateh and Muniandy (2010) documented that EE was given emphasis within the national education system as a result of the Education Planning Committee to implement EE across curricular at primary level.

Since the introduction of EE into the formal education in the 1980s, EE has undergone evolution and development throughout the years (Daniel, et al., 2006; Hassan, et al., 2009; Lateh & Muniandy, 2010). As a result, the syllabus has been reinforced and the learning material is updated. However, the growth of EE has primary focused on what is taught and how it is taught, the physical environment in which EE occurs has received very minimum attention (Sanoff, 2009). To date, the elementary schools in Malaysia are still based on the “Factory Model” which has been criticized by various scholars (Leland & Kasten, 2002; Orr, 1993; Orr, 2000; Taylor & Enggass, 2009). These factory-like school buildings are designed based on a pre-determined square-footage and budget. They merely function as a shelter for the act of teaching and learning to take place (Ford, 2007). As noted by Orr (1993), “the typical classroom empties quickly when not required to be used.

Why? The answer is unavoidable: it is most often an uninteresting and unpleasant place, designed to be functional and nothing more” (p. 227). Furthermore, Pallasmaa (OWP/P Architects Inc, et al., 2010) highlighted that the current school buildings fail to feed any of the senses except sight and, by doing so, it cuts off learning from life. His statement is supported by various scholars like Orr (2000), Ryn and Cowan (1996). They concluded that school buildings with factory-like architecture tend to isolate and detach children from the natural world. More importantly, the monotonous buildings are unable to foster environmental literacy as suggested by Orr (2000).

3. ECOLOGICAL SCHOOL AS 3-D TEXTBOOK FOR EE

The failure of the school based on the “Factory Model” has prompted the scholars to propose alternative strategy for school design to enhance environmental learning. Taylor and Enggass (2009) agree with Caines and Caine (1991) that regardless what we are doing, we are always operating in a physical context in space. Thus, they concluded that human’s natural ability to learn is directly linked to the constant interaction with the environment. As a result, they suggest to use an ecological school as 3-D textbooks for EE. Their suggestion concurs with Reggio Emilia’s education approach – “environment as the third teacher”. Reggio Emilia identifies three educators in a classroom at anytime, namely the teacher, the child and the environment (O’Donnell Wicklund, et al., 2010). Apparently, the school environment can contribute to children’s education if we treat the environment as an active and indispensable part of the learning process (Strong-Wilson & Ellis, 2007; Taylor & Enggass, 2009).

Treating academic buildings as pedagogical tool promises a number of benefits in the process of design, construction and operation. Orr (1993) documented that the act of building can be seen as an opportunity to stretch the educational experience across disciplinary boundary. Thus, he highlighted that the design of school is an opportunity to further explore the relationship between ecology and economics. For example, what is the total energy embodied in materials used in the structure? Subsequently, Orr noted that the issue of ethics is engage in any decision making process. For example, what ecological and human costs do various materials impose?

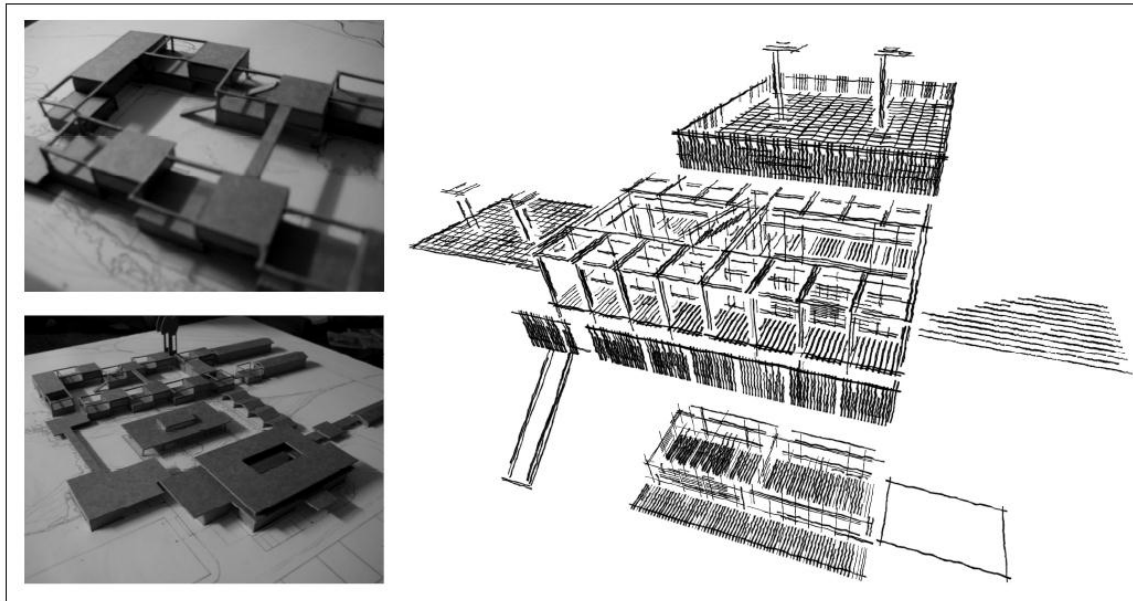


Figure 1: *Selected study model and drawing*

Additionally, Orr notes that there is a curriculum in applied ecology within the built environment. For example, buildings can be designed to recycle waste through miniature ecosystem which will be studied and maintained by the children. Lastly, Orr proposed that school buildings can extend ecological competence by inviting the participation of children. Thus, new knowledge and skills are constructed through the children's involvement in the maintenance and operation of the school.

However, designing an ecological school as 3-D textbooks for EE is still at its infancy stage. Thus, further explorations and investigations are needed to open up the road from theory towards practice. Furthermore, previous researches (Orr, 1993; Orr, 1997; Walden, 2009) documented that interdisciplinary collaboration is not a common practice in school design, especially among the conventional practitioners who are often constrained by specifications in a design brief. As a result, experimental design projects need to be conducted as a demonstration to promote cross-disciplinary approach in school design. Such projects can also serve as a testing ground for new ideas as well as a platform for knowledge exchange among various practitioners and researchers. More importantly, the information and experience gained through these projects can be passed on for others to learn from (Addis, 2006).

4. RESEARCH METHOD

The research was conducted as an experimental design project during the 2008/2009 academic year. The objective was to explore the ecological innovations that transform physical environment into 3-D textbooks for EE. The project was conceived as a platform for innovation as well as a catalyst for inspiration. The data presented in this paper was collected using two separate methods: field notes made during the design-decision making process and semi-structured interviews with experts at a series of design workshops.

In the beginning of the research, the authors established a design brief using literature review as a point of reference. Additionally, the authors organized site visits to various public schools to better comprehend the teaching and learning of EE. This allowed the authors to generate ideas and inspirations by observing from the real-life situation. Subsequently, the authors liaised with Faculty of Built Environment to carry out experimentation, testing and design. Furthermore, the authors spent a significant amount of time with the academic staffs in Faculty of Built Environment, during which time and efforts were made to develop design concept and ideas for an ecological school. The medium of communication were idea sketches, 2D/3D drawings and study model (Figure 1). In addition,

the authors kept diary entries and field notes to document the design activity.

Furthermore, the authors conducted a series of workshop discussion with a panel of experts to continually develop and refine the initial design. These experts were selected based on a purposeful sampling and consisted of four professional architects who had 20 years of experience in sustainable design. The panel was invited to serve as an external auditor to review the research project every three months as well as to give professional input on design, constructability, feasibility and practicality. Additionally, ecologists and environmental educators were also consulted to gain their valuable suggestions and opinions. The authors gathered the qualitative data through a series of semi-structured interviews where the following questions were asked. Whenever required, the authors would ask follow-up questions to probe for detailed explanations.

- 1) What are the significant features of an ecological school?
- 2) What are the ecological/educational concepts that can be integrated into a school's design?
- 3) In what ways does a green building or landscape promotes environmental learning?
- 4) What are the innovations that you would suggest for an ecological school in the tropics?

One of the authors had taken a more participatory role in the design process where he gave preliminary suggestions as prompts or cues for more meaningful discussion with the panel of experts. However, he remained unbiased throughout the data collection by taking care not to exclude any potential findings from the participants. Thus, the author's involvement in the workshop sessions only had minimum influence on the outcome of the discussions.

5. RESULTS

This following discussion on an experimental school prototype represented the first stage of a long-term research agenda on the study of ecological school in the tropics. The authors would like to use this article as a platform to share their findings and recommendations that could enlighten designers and educators in the future build of elementary

schools. The result promoted the use of sustainable design and technology in a school setting based on the contribution from interdisciplinary experts. More importantly, it attempted to reconnect children back to the rhythm and pattern of natural cycles.

Findings based upon analyses of field notes, interview and workshop discussion were presented below. The diagrams and images chosen for inclusion here were prepared by the authors to better illustrate the findings. The experimental school prototype was described as "Eco-Literacy School", defined as "school which promotes environmental literacy through the innovative use of physical environment as a 3-D textbook in EE". The overall architectural design is governed by the 3Rs (Reduce, Reuse and Recycle) concept in EE as suggested by various experts and professionals that participated in the research.

5.1 Reduce, Reuse and Recycle

During an interview conducted through email, an ecologist gave the following remark regarding the relationship between the built and natural environment:

...to me, the built environment is really a part of the natural environment. Except of course, the built environment is filled with human-made features therefore we can think of it as being highly "disturbed". Disturbed here means there are few or no trees, soil organisms, rivers etc. So what can architects do to make the built environment to function more like the "natural" environment?

The ecologist's comment had directed the research team to rethink about the linkage between built environment and nature. More importantly, the authors were keen to understand how children could fit into this complex relationship. The authors started to explore the possibility of designing a school that would promote harmony between man-made and nature. In addition, the authors investigated how children could develop ecological literacy and environmental awareness through their interaction with the physical settings. After a series of interviews and workshop discussions, an overarching concept that embraced

architecture, ecology and EE began to emerge. The notion of 3Rs, which consisted of “Reduce”, “Reuse” and “Recycle” was constantly used by the participants in discussing how to construct a symbiosis relationship between built environment and nature. Additionally, architects and environmental educators suggested to integrate the 3Rs concept into the built environment to transform the school into a three-dimensional textbook in EE. This was a breakthrough point in the research where it inspired and led to the development of a prototype school with ecological theme - Eco-Literacy School (Table 1).

A comprehensive water management system was developed for Eco-Literacy school in order to diminish the dependence on mains supply and facilitate the reuse of sewage. It also served as an opportunity for children to learn about water conservation. Rain water was collected from the roof top for toilet usage. Additionally, the grey water from the toilets was treated in a root zone area before being channeled into a rain water interactive pool. On the other hand, sewage was collected and treated to produce manure for gardening and biogas for cooking. Furthermore, passive ventilation was adopted for classrooms to minimize the energy consumption. Thermal comfort in the classroom was achieved by the aid of landscape, prevailing breeze and ceiling fan. A symbiosis relationship was established between the classroom and the surrounding greenery. The trees supplied fresh and cool air to the classroom while the buildings collected rainwater to recharge the ground water (Figure 2).

The effective use of materials and spaces minimized the waste of resources in Eco-Literacy-School. For instance, traditional roof only served as a shelter, but the roof garden in Eco-Literacy School was able to collect and filter rainwater for toilet flushing, improved the thermal insulation, enhanced biodiversity and provided extra opportunity for children to engage with nature. It promoted minimization of waste through resource efficiency. In addition, the school's spaces and structure were designed to be multipurpose and could be easily retrofitted for other usage. Thus, the Eco-Literacy School had the potential to be used as a community centre after the school hours.

Furthermore, the Eco-Literacy School was inspired by a unique way of designing and constructing with reclaimed and salvaged materials that otherwise ended in landfill. The

construction process consisted of two phases. The building professionals and contractor designed and constructed the concrete frame as the main permanent structure or known as the ‘Skeleton’ in Phase I. Crushed concrete from nearby demolition projects provided a rich source of recycled aggregate for foundation and concrete work. Subsequently, the local community was involved in Phase II for landscaping and installation of wall cassettes as the “Skin” or infill. The shelf-like wall cassettes were specially designed to store recyclable materials like bottles and aluminium cans that students brought from their home. In addition, the school was designed in the ‘kit-of-parts’ approach that facilitated deconstruction at the end of its life cycle. Most of the architectural components could be assembled and disassembled easily for reused and recycling purpose in the future. This would ensure that the materials were continuously in active service and diverted from landfill.

The concept of ‘Reuse’ is reflected in the installation of second-hand windows and doors that have been salvaged from nearby demolition projects. Children learn to appreciate or conserve resources and reuse things that others may regard as waste. Incorporating reclaimed materials in the school design is able to engage the sense of touch in children's learning. Constant use and contact with these reclaimed architectural components encouraged the children to be creative in finding new uses and applications for discarded items.

Additionally, children were expected to collect the dried leaves in their school compound to fill up the vertical composting wall. The wall provided a rich source of compost for gardening purpose. The open-tread staircase that faced the compost wall served as an observation platform for children to learn about biological compost process in nature. In addition, element of play was incorporated into the recycling lesson where the classroom wall served as an ‘art board’ that stored bottles and aluminium cans temporary before these recyclable items were sent to recycling centre. Wall cassettes that were filled up with bottles would eventually become a ‘Bottle Wall’ that created light and colour when sunlight passed through it. This hands-on multi-sensory approach was expected to be far more effective than the traditional classroom-based lecture that only involved learning through abstract representations.

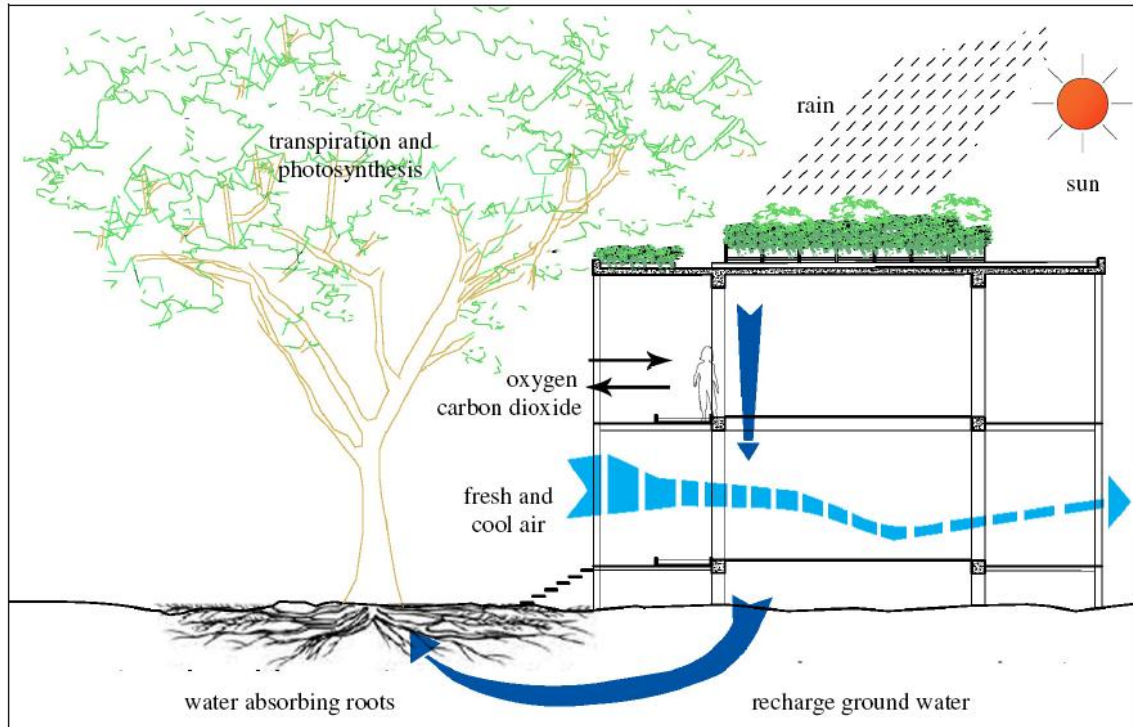


Figure 2: A symbiosis relationship

6. CONCLUSIONS

In summary, this 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 an experimental prototype with an underlying theme of Reduce, Reuse and Recycle. The Eco-Literacy School is conceived as a 3-D teaching tool 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, ecology and education. Therefore, the findings in this study suggest a few significant implications in the context of school design.

Firstly, the study documented that sustainability in a school setting forms the intersection of interest in three broad disciplines: architecture, ecology and education. For instance, the Eco-Literacy School satisfy the needs of educational activities, as well as the ecological issues in the built environment. Thus, this article serves as a catalyst for the notion of cross-disciplinary investigations in school architecture. It encourages architects to form a greater

collaboration with different disciplines in the process of design, construction and operation of educational facilities. The result of this cooperation is often rewarding. Apart from offering innovative architectural solutions, it assures our children of an imaginative and inspiring learning environment.

Secondly, this study presents a number of experimentations with new materials and processes in school architecture that worthy of research, reflection and further testing. The findings serve as a basis for architects who interested in challenging the design boundaries of educational facilities in the tropics. It encourages the architects to continuously uplift the standard of school design without being overly constrained by the conventional norms. The practitioners could incorporate some of the recommendations in the Eco-Literacy School for future built of elementary school in the tropics. Review and feedbacks by the practitioners and scholars will ensure the constant evolution of these experimental ideas.

Finally, this study reveals that “greening” the school environment is not solely about accomplishing efficiency in performance. Nevertheless, the practitioners should expand the

Table 1: Summary on the experimental school prototype

3Rs in Eco-Literacy School	Short Descriptions
REDUCE	
Rainwater harvesting	<ul style="list-style-type: none"> • Diminish the dependence on mains supply • Collect rainwater for non-potable usage • Lesson on water conservation for children
Passive ventilation in classrooms	<ul style="list-style-type: none"> • Minimize energy consumption • Cooling effect by the help of landscape, prevailing breeze and ceiling fan
Roof garden	<ul style="list-style-type: none"> • Multipurpose • Collect and filter rainwater with soil beds • Improve thermal insulation of the roof • Enhance biodiversity • Gardening plots for children
Flexibility in space planning	<ul style="list-style-type: none"> • Multipurpose and could be easily retrofitted • School could be used as a community centre
REUSE	
“Kit-of-parts” approach	<ul style="list-style-type: none"> • Facilitate construction and deconstruction • Assist in the reused of materials and components at the end of its life cycle
Use reclaimed materials	<ul style="list-style-type: none"> • Second-hand door and window salvaged from nearby demolition projects • Encourage children to reuse discarded items creatively
Treat and reuse sewage	<ul style="list-style-type: none"> • Turning human waste into manure and cooking gas • Assist learning on the transformation of waste to resource
RECYCLE	
Vertical composting wall	<ul style="list-style-type: none"> • Composting as an organic recycling process • Children collect and compost dried leaves as fertilizers
Wall cassettes for recycling activities	<ul style="list-style-type: none"> • Classroom wall as an ‘art board’ to store recyclables • Hands-on and multi-sensory approach in waste sorting and recycling

notion of green buildings to include the development of environmental awareness amongst the students. A well-design green building should be creative and interactive. It should speak of sustainability and transmit the message of environmental conservation directly to the users. It is therefore pertinent for architects to design green buildings as 3-D teaching tools in a school. This has been demonstrated through the Ecol-Literacy School where it unfolds the ecological processes in the built and natural environment to enlighten the students how they are connected to the larger ecosystem.

The authors have also identified a few research gaps that could be further explored. Although this research offer us interesting findings, but it does not take into account the valuable opinions and suggestions that could be obtained from the children. Additionally, more research is required to construct a clearer perceptive on the impact of an ecological school on a child's environmental learning. Furthermore, from the authors' interview sessions and literature review, they discover that only a limited understanding exists on the use of green buildings as 3-D teaching tools in a school setting. Thus, a case study can be conducted in a selected ecological school to shed some light on these phenomena. Qualitative data can be collected through in-depth interview and on-site observation. Children's interview will provide an insight to the child-place relationship, particularly, how green buildings might influence the EE teaching and learning. Additionally, on-site observation could be designed to record particular things such as how children use the school ground, how they response to different environmental stimuli and so on (Fredrickson & Anderson, 1999).

NOTES

The Eco-Literacy School is an unbuilt project that remains as a visionary school on the drawing boards. However, at the time of this writing, a full-size exemplar building is under construction in one of the public schools in Shah Alam, Malaysia. Ideas and innovations from the Eco-Literacy School were extracted and applied in this demonstration facility. The building was built with a large proportion of reclaimed materials and conceived as a 3-D textbook for environmental education. Additionally, children were given an opportunity to take part in the process of design, construction and operation. Further information on this exemplar building will be reported in another article.

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