THE CREATION OF CDIO WORKSPACE FOR ENVIRONMENTAL MANAGEMENT AND WATER TECHNOLOGY

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ABSTRACT

Fostering active learning and creation of workspaces are central to pedagogic principles in the CDIO initiative. Workspaces are seen as vehicles to create conducive learning environments, which enable a wide range of active and social learning. By creating a common workspace, active learning elements can be effectively infused into modules of the course program.

This paper presents the creation of a CDIO workspace at Hydraulic and Environmental Engineering Laboratory for students from the diploma course of Civil Engineering & Management as well as Diploma in Environmental Management and Water Technology at the School of The Architecture and the Built Environment, Singapore Polytechnic. It outlines the present utilization of the workspace, which includes time-tabled teaching and learning, preparation work for projects such as group brainstorming and model building, organization of activities like competition, as well as self learning.

Positive acceptance was concluded according to the feedback from both staff and students concerning perceived usefulness and effectiveness in enhancing teaching and learning. Some issues for further development and improvement are also discussed in the conclusions.

KEY WORDS :

Learning Space, Hydraulic, Environmental, Engineering Education, CDIO

INTRODUCTION

Fostering active learning by creation of workspaces is central to pedagogic principles in the CDIO initiative[1]. Work spaces are conducive learning environments, which enable a wide range of active social learning. By creating a common learning space, active learning elements can be effectively infused into relevant subjects of the course program. CDIO Workspaces, as rationalized in Standard 6 [2], are believed to be the most conducive learning environment as they are student-centered, user-friendly, accessible and interactive [3,4].

Driven by the concerted efforts in a constant search for a more effective education model in an ever changing world, the School of Architecture and the Built Environment (ABE) at Singapore Polytechnic has taken concrete steps to adapt and implement CDIO initiative for the Diploma for Civil Engineering & Management (DCEM) and Diploma in Environmental Management & Water Technology (DEWT) courses. In the coursework for students from the DCEM and DEWT courses, there are capstone projects for year 1, year 2 and the final year. Workspaces are needed for students to conceive, design, implement and operate the product. As a result, an integrated CDIO Workspace for teaching and learning of subjects such as Hydraulics and Hydrology, Environmental Engineering, Water and Waste Water Technology was created within Hydraulic/Environmental Engineering Laboratory.

This paper presents the creation of a learning space within Hydraulic/Environmental Engineering Laboratory at the School of Architecture and the Built Environment, Singapore Polytechnic.

The observed usage patterns of the learning space are identified and evaluation of effectiveness on students learning as well as the impact on the delivery of the subject content are made in comparison to the teaching and learning approaches before the creation of the workspace. Positive feedback was received from both staff and students concerning perceived usefulness and effectiveness in enhancing teaching and learning. Some issues for further development and improvement are also discussed in the conclusions.

PARADIGM SHIFT FROM CONTENT TO CONTEXT OF ENGINEERING EDUCATION

As in any engineering education, new technology and learning styles of students change. At the School of Architecture and the Built Environment, Singapore Polytechnic, the teaching of Hydraulics and Hydrology, Environmental Engineering, Water and Waste Water Technology can be supplemented by internet technology and resources available in the library and many other resources. Classroom teaching in a didactic form as a means for acquiring new knowledge is becoming less critical to students. Therefore, in the modern day education, it is paramount to engage students in their learning or they will be engaged by something else.

Traditional approaches in the teaching of engineering subjects are typically built around lectures, tutorials and laboratory experiments. The fundamental concepts and basic theories are normally taught in a classroom or lecture theater setting. The tutorial classes are normally conducted as problem solving sessions for dedicatedly crafted questions within the topics taught. Practical experiments in laboratory, which are normally not within close proximity of classrooms and lecture theaters, only play a limited role in supplementing the teaching and students' understanding of core concepts. Overall the focus is on the transmission of content of engineering knowledge. Whereas this type of approach is well structured, it inherits many drawbacks such as lacking active and student-centered learning. It tends to inculcate passive learning and is dominated by the imparting of technical knowledge rather than an active discovery of knowledge. The change in the patterns of students learning requires the emphasis in engineering education to be shifted from content to context, from traditional teacher-centered to student-centered learning. The CDIO initiative provides a convenient framework to meet the challenges of engineering education.

Creation of learning space by integrating different teaching and learning resources into a conducive environment was identified as one of the key infrastructures for answering the call for paradigm shift in engineering education. Within ABE, the earlier experiences of creating engineering workspaces and learning spaces[5,6] have build up the case to create additional learning space for hydraulic and environmental engineering education.

THE CREATION OF LEARNING SPACE IN HYDRAULIC /ENVIRONMENTAL ENGINEERING LABORATORY

According to CDIO Standard 5 – Design-Implement Experience [2], the curriculum has to include two or more design-implement experiences, including one at a basic level and one at an advanced level [2]. For DEWT course, in year 1 the students have to design and re-assemble a mobile water treatment working model for their capstone project. Students will have to propose water treatment processes, prepare 2D and 3D drawings, and build the physical model.

CDIO Standard 6 requires engineering workspaces and laboratories to support and encourage hands-on learning of product, process, and system building, disciplinary knowledge and social learning. There are different criteria for learning spaces for conceiving, for designing, for implementing and for operating [3].

There have been earlier successes in creating learning spaces in Singapore Polytechnic [5,6]. Since the implementation of CDIO framework for DCEM and DEWT courses, new learning paces have been created at T3A03 and W515 for CDIO activities. Table 1 shows engineering workspaces for CDIO activities adjacent to existing laboratories.

Table 1
Engineering Workspaces in the Existing Laboratories

	Stages	Location	Adjacent laboratories	Engineering workspaces for CDIO activities
1	Conceive	W515/T3A03	Material Testing/ Geomatics	Design and other general discussions
2	Design	W417/T304/T305	Structural Mechanics Lab/ e-studios with application software	Design, testing of structural models, virtual design and computer simulation of civil engineering models
3	Implement	W515/W514	Project lab	Blueprint reading/Trellis construction, concrete beam casting
4	Operate	W511 (Hydraulic/Env. Engg Lab)	Environmental engineering and geotechnical laboratories	Hydraulic equipment & channels, Soil testing, design of water treatment model/operation of Desalination Working Plant and MBR model

The learning space referred to in this paper was created within the Hydraulic/Environmental Engineering Laboratory as shown in Table 1 as item 4. The plan view for the layout is shown in Figure 1. A total of S$195,000.00 was invested into the creation of the infrastructure for the learning space excluding costs for tools, equipments and facilities. It was hoped that the creation of new learning spaces in the hydraulics/Environmental Engineering Laboratory will help supplement more engineering workspaces for CDIO activities.

A typical interior view of learning space is shown in Figure 2. Besides the conventional laboratory tools and facilities around, major equipments such as desalination plant and membrane bio-reactor (MBR) for capstone projects are also at the close proximity of the learning space.

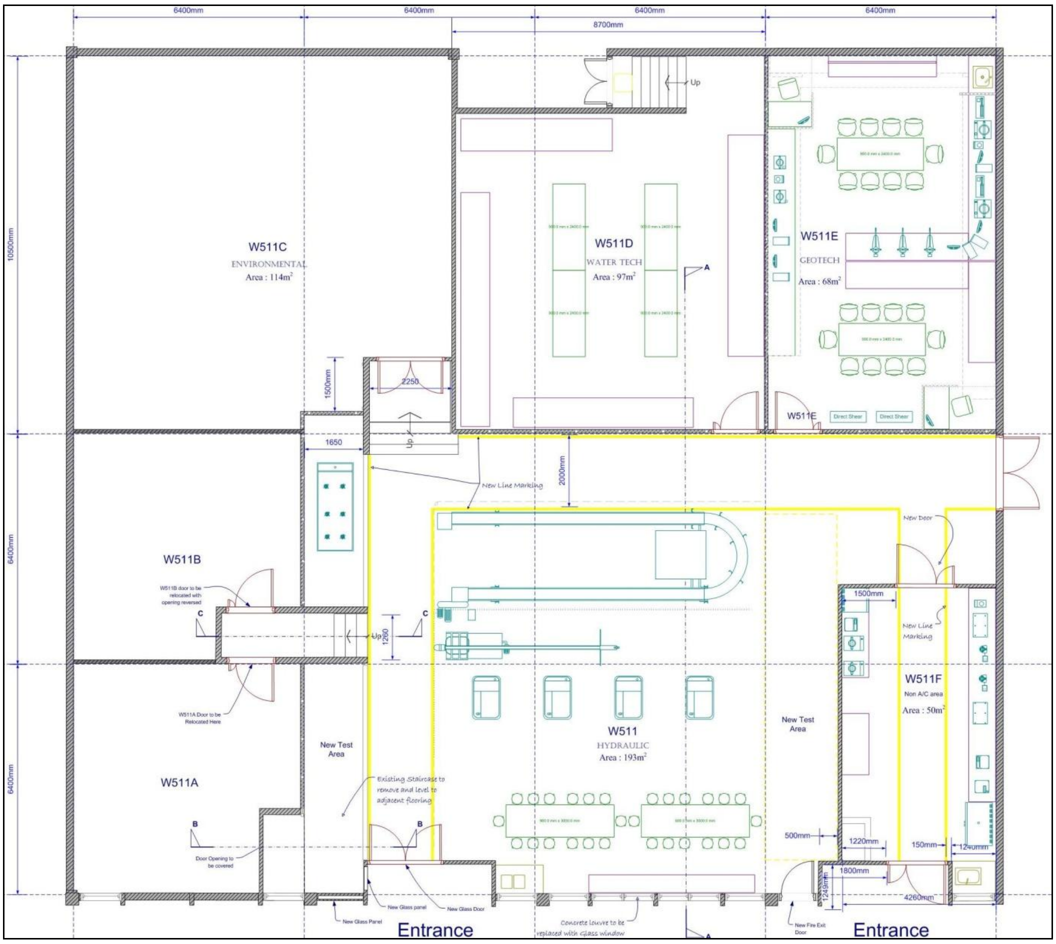


Figure 1. Layout of Work spaces in Hydraulic / Environmental Engineering laboratory

Figure 2. The learning space showing discussion tables in Hydraulic /Environment Engineering Laboratory

Figure 3. DEWT students are working on the year 1 project of mobile water treatment model in the learning space

Figure 3 shows a group of year 1 students working on their capstone project in another part of W511. This is a capstone project for DEWT year 1 students. It requires them to design and assemble a simple working model of water treatment kit for treating storm water to drinking water standard. Figure 4 shows the picture of Desalination plant which is the major equipment for year 2 capstone project. Students are required to understand the desalination processes based on reverse osmosis and to operate the working desalination plant in the laboratory. The MBR, as shown in Figure 5, has been designed, implemented and operated by final year students for one of the final year projects. It will be used as for teaching waste water treatment. As test kits and other equipment are at the close proximity to these working models, students can also learn in context when they collect water or waste water samples for analysis.

Figure 4. Desalination plant in the laboratory

Figure 5. The Membrane Bio-reactor

THE OBSERVED USAGE OF THE LEARNING SPACE

Teaching and learning in the learning space as compared to the traditional ways

Engineering concept is traditionally taught through lectures in classrooms. Theoretical concepts and calculations may be illustrated on white boards. With the creation of learning space at the Hydraulic/Environmental Engineering Laboratory, students have more hands-on learning experience in designing and operating the engineering systems to assimilate, digest and utilize the contents covered in class room setting at the context level. This is evident when the reverse osmosis desalination process is taught by using a mini desalination plant installed in the laboratory. Not only do the students see a real-world reverse osmosis desalination plant, they can identify the physical components in the plant and relate the symbols indicated in the process flow chart. They are also are also given the opportunity to operate the desalination plant under different operating scenarios. When fundamental theories and engineering concepts are illustrated with real-world equipment or machines, context learning is playing a more important role than content learning. When a real-world working plant is there for students to operate, the learning is no longer passive.

In addition, the air-conditioned laboratory is accessible to students when there is no ongoing scheduled class. Students are encouraged to do their projects, tutorials and discussions at the laboratory. They are also free to read various environmental and water engineering journals and magazines which are readily available at the laboratory. Such facilities have provided students with great opportunities for social learning.

The increase of the utilization rate, as shown in Table 2, reflects the actual utilization of the learning spaces by the scheduled classes taking advantage of the enhanced hand-on facilities with the implementation of CDIO framework.

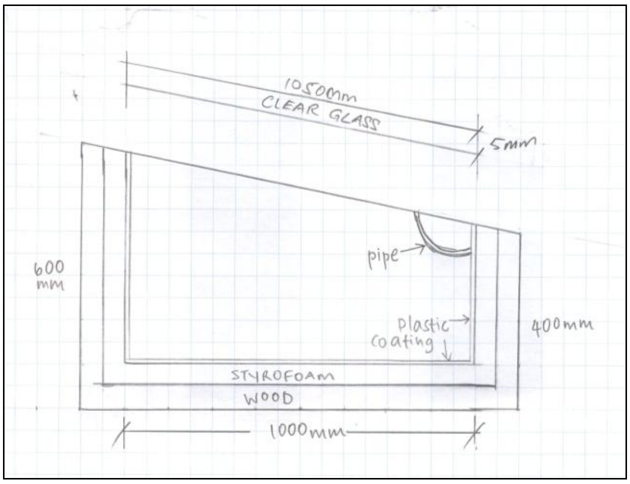
Table 2
Utilization rate before and after implementation of CDIO framework

		Existing Learning Spaces	Before Implementation of CDIO	After Implementation of CDIO	% increase
1	Conceive	W515/T3A03	45.20 %	80.95 %	35.75 %
2	Design	W417/T304/T305	4.80 %	80.24 %	75.44 %
3	Implement	W515/W514	45.20 %	80.95 %	35.75 %
4	Operate	W511	57.10 %	65.40 %	8.3 %

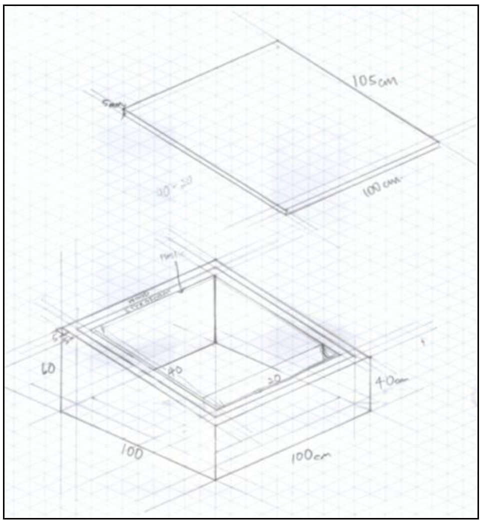
Final year project in CDIO approach

Many projects have been completed in the learning space. As a typical example, a final year project was taken to highlight the functional usage of the learning space in a CDIO framework. The objective of the project was to develop working models for seawater desalination using solar energy.

The brain storming session during the first meeting of the group held at the learning space can be registered as conceiving stage of the project. Preliminary thoughts and ideas were collated and recorded as draft sketches as shown in Figure 6.



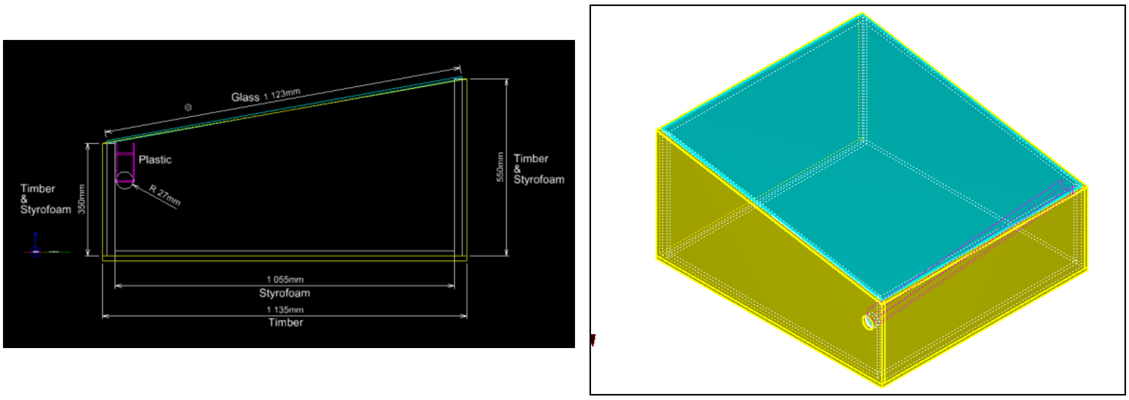
(a) Side view



(b) 3D isometric view

Figure 6. Concept stage : Preliminary sketches of the project

During the design stage, the group used another learning space with dedicated software tools, T304/T305 (refer to Table 1) for computer aided design and drafting as well as design for materials and cost estimation. Sample computer drawings are as shown in Figure 7. The estimated material quantities are tabulated in Table 3.



(a) Side view of the proposed model (b) 3D view of the proposed model

Figure 7. Design stage : Design output from CADD

Table 3

Design/Implementation stage: Materials list and quantities for model building

Materials	Dimensions	Quantities
Aluminum foil	-	1 roll
Glass	L 110cm x B 100cm x Thk 0.8cm	3 pieces
Glass delivery	-	1 time charge
PVC roll	137cm x 68cm	1 roll
PVC roll	137cm x 600cm	1 roll
PVC roll	137cm x 200cm	1 roll
PVC casing	2.5cm x 1cm x 235cm	2 unit
Silicone	-	1 tube
Styrofoam board	L 91cm x B 68cm x Thk 2.5cm	6 pieces
Styrofoam board	L 91cm x B 68cm x Thk 2.5cm	9 pieces
Styrofoam board	L 68cm x B 32cm x Thk 2.5cm	1 piece
Wood	L 240cm x B120cm x Thk 1.5cm	6 pieces

The implementation stage of the project is reflected as model building phase which took place within the learning space in Hydraulic/Environmental Engineering Laboratory. Photos in Figure 8 were taken during this stage of the project.

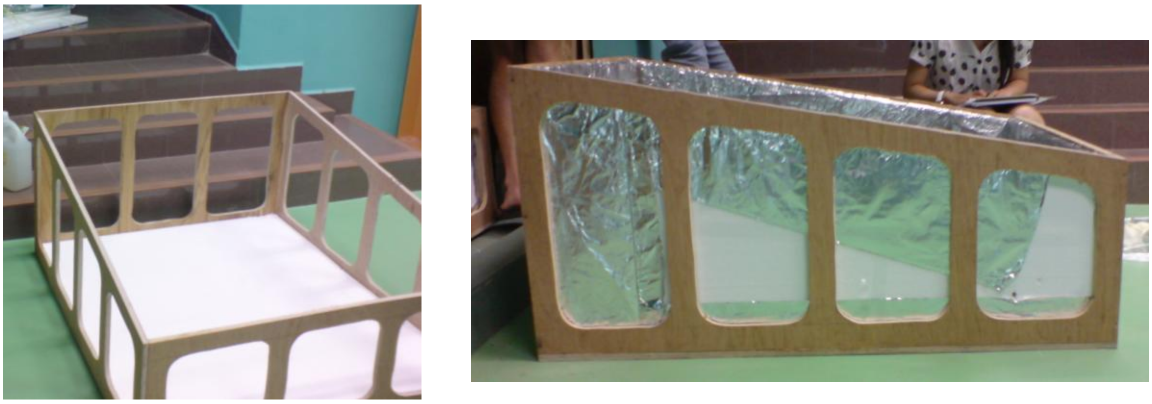


Figure 8. Implementation stage: Product building in progress

The testing on the performance of the finished model can be classified as Operation stage. Though the testing was conducted outside of learning space as it has requires the sunlight. However the proximity of the measurement tools facilitated the testing of the prototype. Figure 9 shows some photos during the Operation stage of the project.

Figure 9. Operation stage : Testing of the product

Learning journey for Schools

CDIO activities have given relevance and meaning to polytechnic students. They can also benefit the students from secondary schools. The School of Electrical & Electronic Engineering (EEE) and School of Architecture and the Built Environment jointly organized a "Clean Energy and Water Challenge" for 180 Raffles Girls' School (RGS) students on 11 Mar 2009. For the RGS girls it was a part of their "Learning Journey." For the clean energy of the challenge, EEE, which has also embarked on CDIO initiatives, organized with a solar boat race competition. Students design, fabricate and race their boats in a water channel.

Figure 10. Students are discussing about the filtration system

Figure 11. Students are building the filtration system

Figure 12. Students are testing the filtration system

For the clean water challenge, ABE organized the CDIO activity at the Hydraulic/Environmental Engineering Laboratory. The clean water challenge involves the design, building up of a simple filtration system to remove fine particles and colour from given "wastewater" samples. The hands-on session had proven to be effective in arousing the interest to water technology and increasing the awareness of water resource management. Figures 10-12 show some photos taken during the event.

PEDAGOGICAL PRINCIPLES AND DESIGN-IMPLEMENT EXPERIENCES

It is well known that lecturing alone is a relatively ineffective pedagogical tool for promoting conceptual understanding. Real learning takes place when there is creation of new knowledge by applying basic fundamental knowledge [4]. There are two distinct ways to transform experience, by reflection or action. When the students work in teams in the engineering work space they take charge of their own learning as compared to working on standardized laboratory experiments. Since learning is both cognitive and motivational, capstone projects in the learning spaces created in the laboratory will cause students to refer to the cognitive processes that have taken place in the classrooms. Moreover they will be more motivated to read ahead and beyond their lessons to be ahead in their projects. There are limited opportunities for students to have "experiential learning" and hands-on from computer-simulation, field trips, community service, and work experience [5][6]. CDIO activities in engineering work spaces will bridge the gap between real-world and classroom teaching.

Unlike consumer gadgets, architecture models, aesthetic design products, environmental and water technology projects require the support of chemicals, test kits, equipment, materials for fabrication and at least a table size space for the realization of product. System testing and improvements require ready access to tools, chemicals and equipment that are available in the newly created engineering workspaces. CDIO workspace is also playing an indispensable role in facilitating students learning as infrastructure for engineering education.

CONCLUSIONS

The learning space in Hydraulic / Environmental Engineering Laboratory was created with the consideration of CDIO model for Engineering education. The creation of engineering workspaces allows students to carry out the engineering processes with the immediate support of testing equipment and facilitation as well as laboratory personnel. There is immediate transfer of laboratory skills that they learn in other modules. Learning within the engineering workspaces is more intensive in the simulated working environments. Tools, equipment, materials and parts of the products can be shared, recycled for the next round of use. It is evident that multiple modes of learning such as active learning and social learning are nurtured, facilitated in the learning space. The creation of such learning spaces within the existing laboratory increases the utilization rate of the laboratory as well.

Feedback from staff and students using the workspaces has been generally positive. Most of the facilities are well used. Industry and public awareness of engineering has been improved through laboratory tours during SP's Open House and by holding of competitions for secondary school students during the annual Engineering Week. The effectiveness of the learning space in enhancing students learning was observed comparing to the traditional approaches as it fosters social learning, active learning and can be easily integrated into project based learning and problem based learning. There are plans to further improve the integration of learning space with lecturing and tutorials so as to create a balanced learning environment that is able to suit the different learning activities and diverse modes of learning.

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