Out-of-Classroom Experiential Learning For Students' Learning in Structural Engineering

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ABSTRACT

Structural engineering modules in Diploma in Civil Engineering and Management (DCEM) course are traditionally perceived by students as "abstract", "dry" and "hard to visualize". Students tend to have difficulties in grasping the basic concepts of structural behaviour. Conventional ways of teaching have shortcomings in terms of motivating students learning structural engineering.

In the context of Conceiving, Designing, Implementing, and Operating (CDIO) framework, this paper discusses the approach conceived and implemented by the module team to make the learning more meaningful and promote student understanding. In particular, "Structural Review" and "Structural Competition" have been used to motivate and enhance students' learning of structural analysis.

Student survey results have demonstrated that the use of fun-based learning activities and competitions increased student's motivation and interest in learning structural engineering as well as developing better problem solving skills.

The paper concludes that the use of these approaches, leveraging on appropriate information technologies, can provide powerful motivational strategies and encourage students to be more participative and creative in their learning.

KEYWORDS

Experiential Learning, Structural Competition, Structural Review, Problem Solving Skills, CDIO Framework, Motivational Strategies.

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INTRODUCTION

Students learn in many ways – by seeing and hearing; reflecting and acting; reasoning logically and intuitively; memorizing and visualizing; drawing analogies and building mathematical models. Teaching methods also vary. Some lecture, others demonstrate or discuss; some focus on principles and others on applications; some emphasize memory and others understanding. How much a student learns in a class is governed in part by that student's learning ability, prior preparation and also the compatibility of his of her learning style and the lecturer's teaching style.
Mismatches exist between common learning styles of students and traditional teaching styles of lecturers. In consequence, students become bored and inattentive in class, do poorly on tests, and get discouraged about the courses, the curriculum and themselves, and in some cases change to other courses or drop out of the course.
At present, the learning environment for our students is the fairly passive lecture-discussion format where lecturers talk and students listen.
Experiential Learning [1] enables students to experience and learn whereas the lecturer is to explore, provide and facilitates students' learning.

Students from the Diploma in Civil Engineering and Management (DCEM), traditionally have difficulties in grasping the concepts of structural behaviour. They tend to do learning by concentrating on manipulation of equations and memorising particular solutions which obscures the underlying important concepts and principles. These students are usually weak in their foundational knowledge of Mathematics and Physics. They could not appreciate the abstract nature of the underlying basic concepts involved as well as the behaviour of the structures.

On the other hand, the approach at present to teaching these modules by lecturers usually includes a series of lectures on physical laws, mathematical tools and methods for structural analysis and design by using methodology which consecutively subdivides a real world structure into extremely small subcomponents, focusing on a particular element, detaching it from all other connected structural members and then reducing it to a notation system of structural symbols, mathematical equations and annotations. Structural modules delivered in this way will only get students too much involved in calculation tedium and almost never attempts to connect detailed analysis back to broader structure design and construction principles, which results in not seeing the wood from trees.

To address problems existing in the staff teaching and student learning of structural modules, initiatives which are aiming at improving students performance in these structural modules have been proposed by the module team. These initiatives are mainly on four basic areas: increase in active and hands-on learning, emphasis on problem formulation and solution, more focus on concept learning and enhancement of learning feedback mechanisms.

Applying the "CDIO" concept, students experience the 4 stages of C-D-I-O while doing their course work. This is to ensure that students master the fundamental concepts of structural engineering. Module teams believe that abstract structural concepts will become meaningful when students could experience "real-life" phenomena. The goal of experiential teaching and learning is to motivate students to learn curriculum materials and to increase their intrinsic interests in further learning.

OUT- OF - CLASSROOM EXPERIENTIAL LEARNING

Experiential learning uses various tools like games, simulations, role plays and stories in classrooms. The experiential learning mindset changes the way the teachers and students view knowledge. Knowledge is no longer just some letters on a page. It becomes active, something that is transacted with in life or life-like situations. It starts to make teachers experience as the providers, and not just transmitters of the written word. Students become knowledge creators (for themselves) as well as knowledge gatherers.

Besides changing student roles, experiential learning requires a change in the role of teachers. When students are active learners, their endeavours often take them outside the classroom walls. Because action precedes attempts to synthesize knowledge, teachers generally cannot plan a curriculum unit as a neat, predictable package. Teachers become active learners, too, experimenting together with their students, reflecting upon the learning activities they have designed, and responding to their students' reactions to the activities. In this way, teachers themselves become more active; they come to view themselves as more than just recipients of institution's policy and curriculum decisions.

Experiential education [2] empowers students to take responsibility for their own learning; because it requires new roles of students, teachers, and administrators. It can provide a different, more engaging way of treating academic content through the combination of action and reflection.

Staff who is very comfortable with traditional way of delivering lectures remains unconvinced that more interactive teaching will lead to increased student learning and hence improved student performance. Colleagues whom we have talked with are also concerned that the time and effort required for curriculum revision from traditional way of teaching to more interactive teaching would be prohibitive, that their students would learn less content, that outcomes could not be reliably assessed. Such changes would take students and staff alike out of their current comfort zones.

To address the validity of these concerns and to shift our teaching from quantity of learning to quality of learning [3], authors spoke to lecturers who are teaching structural modules and carried out brain-storming sessions. A motivational learning strategy, i.e. interactive and collaborative learning was thus recommended by the authors. The strategy geared towards teaching is the holistic approach which is multifaceted, encompassing a wide variety of creative methods and techniques based on current theories and research of how people learn best. The strategy suggests that teaching focus be put on conceptual understanding of structural behaviour and analytical and design skills of structural systems while allocating more time on interactive learning of students by encouraging collaborative activities. The learning techniques could enhance retention and performance, and hence students become effective learners.

The Background

The module "Structural Analysis & Simulation" is a year-long 2nd year core module from the Diploma in Civil Engineering and Management (DCEM). The perception of this module by many students is "abstract", "dry" and "hard to visualise". Over the past 4 years, the module team had gradually incorporated course-works that require students to explore, participate and apply their knowledge to analyse the various unique structural systems on campus.

The two implemented course-works are designed based on "Out- of Classroom Experiential Learning" concept, i.e. students are involved physically, using their hands to do some works for these two course-works.

These course-works adopted the CDIO framework, i.e. students experience the 4 stages of C-D-I-O while doing their course works. Module teams believe that abstract structural concepts will become meaningful when students could experience "real-life" phenomena.

ARCHIEVING OUT- OF – CLASSROOM EXPERIENTIAL APPROACH BY CONCEIVING, DESIGNING, IMPLEMENTING, OPERATING FUN – FILLED COMPETITIONS AND REAL LIFE ASSIGNMENTS

The interactive and collaborative learning strategy requires students less dependence on rote learning, repetitive tests and a 'one size fits all' type of instruction, and more on experiential discovery, engaged learning, the learning of life-long skills, and the building of character through innovative and effective teaching approaches [4].

In order to motivate students to learn structural engineering modules, real time and fun-filled course-works cum competitions on structural analysis and design were conceived in addition to lecture and tutorials sessions. Learning of structural engineering modules now becomes a joyful experience through following the Conceive, Design, Implement and Operate stages of collaborative learning activities.

"Structural Competition"

Students will be assigned to this course work in semester II of each academic year; by then they would have been taught about 75% of the module contents. This assessment requires them to build a bridge truss model made of short timber sticks of about 2 mm diameter.
Students are applying the core knowledge in structural engineering to pitch their skills and knowledge among their peers. They will be able to see, compare and discuss merits and weaknesses of their and peers' designs.

Models made by students will be tested on the "Structural Simulator" shown in Figure 1 which was developed and fabricated in-house.
The "Structural Simulator" is a mini-instructional bench scale portable laboratory and can be used to do demonstrations and test competitions. It has the ability to display real-time responses of test results. The structural simulation process facilitates real-time comparisons between the analytical predictions and the experimental data.

Preparing the students:

The project brief about the course-work will be prepared and up-loaded into "BlackBoard" (Singapore Polytechnic's e_Learning platform) together with the supplementary Power Point document of some of the past years tested models. Students will be briefed on the characteristic of axial force members, material properties, joining techniques and load distribution pattern.

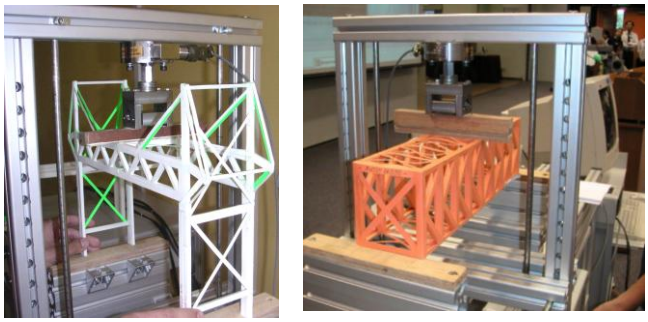

Figure 1. The Structural Simulator

The course-work

The target of the competition is to pursue the highest load-self weight ratio. One point load is applied at the middle of the model via the 100 mm wide loading head.

For the load testing, a vertical load will be gradually applied at the centre point on top of the bridge model. The graph of load versus mid-span deflection will be plotted online. Loading will be increased until the failure of the model. Failure is considered being reached by either of the two conditions: (1) With a monotonic increasing of deformations, the current load level drops below 85% of the previous highest load level; (2) The deflection at the middle of the span exceeds 15 mm.

Relevant CDIO clauses

The following four CDIO clauses are adopted for this course-work:

- Conceive Stage – CDIO Clause 4.3.3:
  Select and Identify suitable truss system for the model
- Design Stage – CDIO Clause 4.4.1:
  Synthesize the chosen truss system by using structural software
- Implementation Stage – CDIO Clause 4.5.3
  Model fabrication process
- Operation Stage - CDIO Clause 4.5.5
  Model testing

"Structural Review"

This course-work is planned for students to explore and to appreciate real structural systems on campus. They learn about structural systems through textbooks, student notes, etc. in which simplifications are already made in many situations. For example, the support conditions, loadings and member profiles. In this assessment, students are to apply knowledge gained from this module as well as from other related modules as well, e.g. the methods learnt in Geomatics to obtain actual dimensions of the structure. After the completion of this experiential learning assessment, students will have better understanding of the performance and behaviour of real structural systems. They will have clearer visualization of how forces and moments are being transferred from the members to supports. Four on campus structural systems are identified and students are required to choose one of these systems as their topic. They need to model the actual structural systems into mathematical models. These proposed structural systems are:

a. SP W515 – Roof Truss
b. SP Phase III Linked Bridge @ T20/21.
c. SP Phase V Linked Bridge @ T12A / T14
d. SP linked walk-way between T12 and T11A.

Students are required to obtain actual measurements on site. They could use their knowledge acquired in Geomatics module to obtain the overall length, width and height of the chosen structures. They have to also assess the dead loads and live loads imposed on the structures by performing appropriate loadings transfer from roof / deck slab to the supporting structural members.

Preparing the students

The project brief about the course-work will be prepared and up-loaded into “BlackBoard” together with the supplementary Power-Point document about the proposed structural systems. Students will be briefed on the proposed structural characteristics, e.g. structural models, support conditions, types of loadings, materials, etc. Lists of live load and dead load for different usage conditions are given and students will be taught how to assign these loadings to the structural system for various usages.

The course-work

This course-work requires students to get-out of their classrooms, into the actual world (i.e. the campus) to do on-site assessment. They will model the actual structures with appropriate loadings on the structure models for analysis using the structural software, SAP2000 [4].
Students are to submit written reports by the due date; and to present their works during tutorial session. Bonus marks will be awarded in two areas: i.e. early submission and adopting “Flash” animation to display structural behaviour.

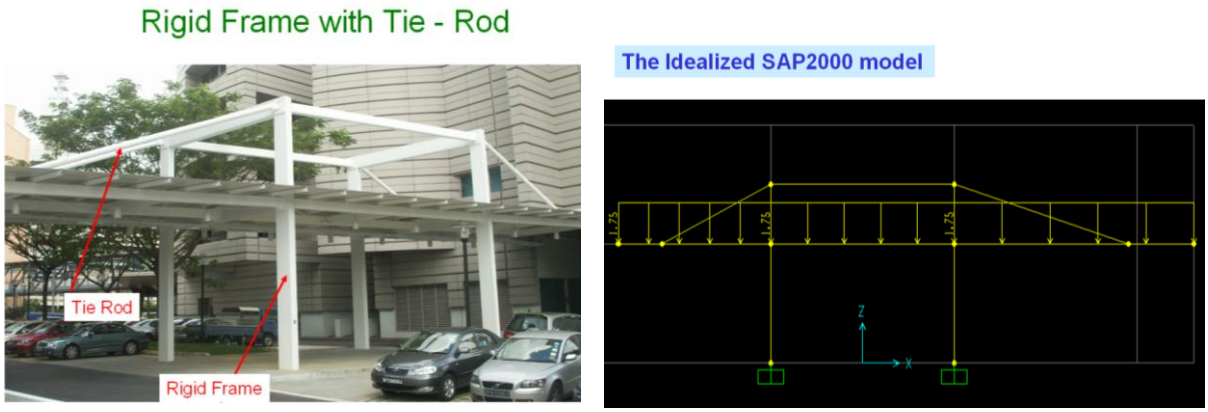

Figure 2. SP new linked walk-way between T12 and T11A

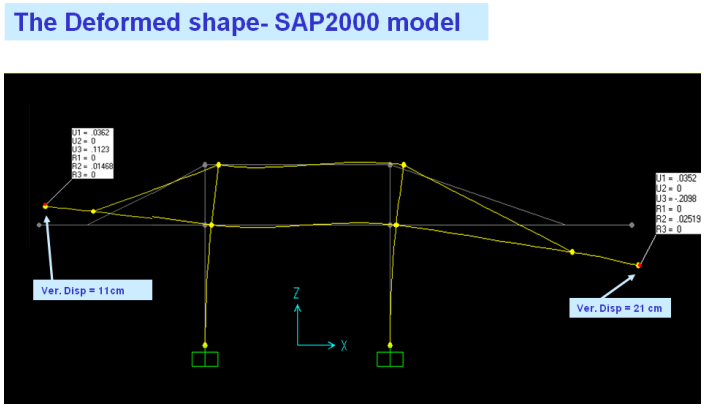

Figure 3. The SAP2000 model

EXPERIEMTIAL LEARNING – MOTIVATING STUDENTS' LEARNING OF STRUCTURAL ENGINEERING WITH REAL – LIFE COURSE WORK AND COMPETITION

"Structural Competition" and *"Structural Review"* have been conducted for a few years. In order to have better understanding and accurate evaluation of the effectiveness of the interactive and collaborative learning strategy, the module team conducted a Black-Board based students' survey. For every question, students need to rate on the scale of "1" to "5" (1- Least, 5- Excellent) in the following areas for both "BEFORE" and "AFTER" these real-life course work and competition:

1) Able to apply knowledge of basic structural fundamental concepts.
2) Able to identify problem, formulate solutions.
3) Able to communicate effectively within the team.
4) Able to function effectively as an individual team member / team leader for the team.

About 100 students participated in the survey; the outcomes of the survey are as shown below. Comments are made *w.r.t*. responses for scale point 4 and 5.

1) Able to apply knowledge of basic structural fundamental concepts:

	Before	After
1	1.45%	1.45%
2	2.90%	0.00%
3	47.83%	17.39%
4	33.33%	50.73%
5	14.49%	30.44%

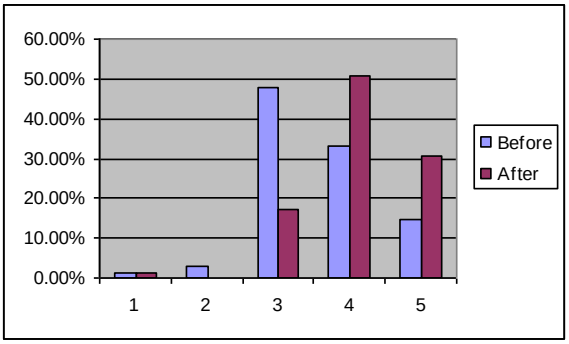

Figure 4 Apply knowledge of basic structural fundamental concepts

Module Team's Comments: Majority (After =81.17% vs. Before = 47.82%) indicated that they were able to apply the knowledge of basic structural fundamental concepts after these course works.

2) Able to identify problem, formulate solutions

	Before	After
1	1.45%	0.00%
2	10.15%	0.00%
3	37.68%	23.19%
4	36.23%	52.17%
5	13.04%	24.64%

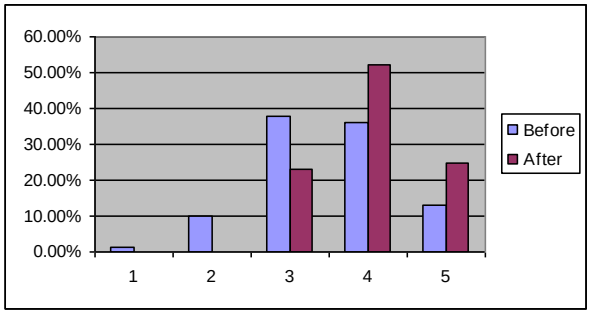

Figure 5 Identify problem, formulate solutions

Module Team's Comments: (After=76.81% vs. Before = 49.27%) of students indicated that they were better in formulating solutions for problem after these course works.

3) Able to communicate effectively within the team.

	Before	After
1	0.00%	0.00%
2	5.80%	4%
3	20.29%	15.94%
4	40.58%	36.23%
5	33.33%	43.48%

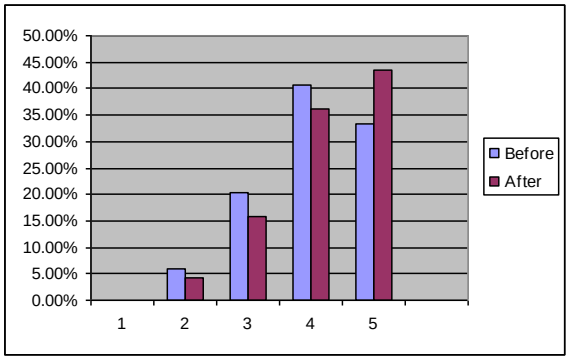

Figure 6 Communicate effectively within the team

Module Team's Comments: Majority (After =79.71% vs. Before = 73.91%) indicated that they are able to communicate more effectively after having gone through these course works.

4) Able to function effectively as an individual team member / team leader for the team.

	Before	After
1	0.00%	0.00%
2	7.25%	0.00%
3	27.54%	24.64%
4	43.48%	39.13%
5	21.74%	36.23%

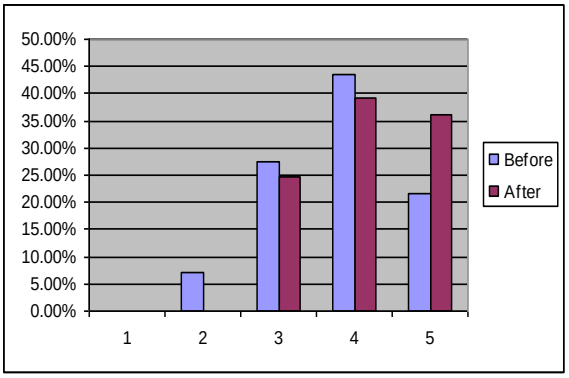

Figure 7 Function effectively as a team

Module Team's' Comments: Majority (After = 75.36% vs. Before = 65.22%) indicated that they had gained much experience in functioning effectively as a team leader / member

The module team is encouraged by the outcomes of the quantitative survey and qualitative responses by the students. Majority of the students (approx 76%) had benefited much from the above two fun-filled experiential learning activities. Students' learning has been greatly motivated and enhanced. Students can now understand better the structural behaviours and the important underlining concepts. They also can now apply textbook structural theories to the real world applications.

The module team also observed in general that students do not view the structural engineering modules as something that are abstract, virtual and difficult to learn.

Some of the students' comments – "Structural Competition"

- Overall, it is a very meaningful experience for both me and my team-mates because we learnt the ups and downs of doing something as a group.
- It was an enjoyable experience to be able to do the bridge competition. This gave us the opportunity to put what we learnt during class lesson into actual use.
- I learnt a lot in this project because it is very interesting and exciting. It also gives me a rough idea on how a real life bridge is constructed.
- Through this project, i understand the important of team effort and also the toughness of build a structure. it require time and human resource to complete the entire project. Hence, I enjoy this project fully.
- Teamwork is essential for the success of our project and no man can work alone.

Some of the students' comments – "Structural Review"

- I hope to have more of such project or assignments be introduced in class to enhance our knowledge of what we learnt in class with relation to everyday structure. This would help us to understand better when we actually see structures outside the classroom.
- This outside classroom work is very useful as it is better then looking at papers. This time doing outside work help to visualise how the structural will be able to bend, deform and how to prevent it from becoming structural unstable.
- I have a better understanding on how to calculate the dead and live loads. In addition, I have became more familiarize with the software. Lastly, I got to apply what I have learnt in class to this project.
- In order to gain my knowledge on trusses, I have searched out information from the internet as well as the school library books to help me have a better understanding about the different types of trusses.
- This course-work gives me a chance to apply the knowledge we learned form the books and enhance the relationship between team-mates.

CONCULSIONS

Out-of-Classroom experiential learning through the activities of "Structural Competition" and "Structural Review" is effective in motivating students to acquire domain knowledge. The initiative by module team supports the skills in problem formulation and modelling in the field of structural engineering. It adopts the CDIO approach and has enhanced students' fundamental concept of structural engineering.

The module teams have achieved the following learning outcomes:

- Engaged learning (less drill and practice)
- Differentiated teaching (less "one-size-fits-all" instruction)
- Guiding, facilitating, modelling (less telling)
- Formative and qualitative assessing (less summative and quantitative testing)
- Spirit of innovation and enterprise (less set formulae, standard answers)

The interactive experiential learning activities have greatly motivated students' learning interests in structural engineering modules, improved their understanding of structural behaviours and developed better problem solving skills which are essential in engineering discipline. Students found that the experience is unique, exciting, and practical. They have enjoyed the learning process and they also have given positive feedback about these experiential learning processes. The experience gained is significant and valuable that many of them have agreed that they would not forget the structural concepts that they have learnt through these experiential learning activities.

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Biographical Information

Rose Huang is the module coordinator of "Structural Analysis & Simulation". This module is one of the three capstone modules of the Diploma in Civil Engineering and Management which has adopted CDIO framework.
Her current scholarly interests are in structural simulation and experiential learning in the area of curriculum development.

Ong Chee Fatt (Dr.) is the co-lecturer of "Structural Analysis & Simulation" module. He is interested in application of the CDIO approach in engineering education.

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