WAYS FOR IMPROVING THE TRAINING QUALITY OF CIVIL ENGINEERING IN DEVELOPING COUNTRIES

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ABSTRACT

Training quality civil engineers in developing countries is not an easy task given the economic conditions and tight budget for lab activities or on-the-job internships. This situation has been a headache to educators in Vietnam for decades. In order to partially mend this problem, for years, the Ministry of Education & Training of Vietnam imposed fix quotas for the number of Civil Engineering students recruited by each school each year. This is no longer effective now when most universities and colleges in Vietnam have moved from the cohort system to the credit-hour system, and students are free to transfer from one major to another. Using the case study at Duy Tan University in Vietnam, this paper argues that by adopting a series of computer and real-world simulations, the training quality problem for Civil Engineering students can be solved to a significant degree. In effect, at the freshman and sophomore levels, students may practice their lab work and experiments on construction mock-up models and/or construction simulation kits in order to learn how to apply theoretical knowledge in reality such as building concrete blocks, retaining walls, designing truss bridges, etc. From the junior level on, computer simulations will be largely used to teach scenarios and/or phenomena which may not be experimentally reproduced like structural collapse, building explosion, earthquake, etc. The main advantage here is that numerical and computing simulations help students arrive at their learning outcomes much faster while they do not cost that much. As for the senior project and internship, it has been realized that many construction companies or construction consulting firms did not provide students with the complete learning experiences needed during their internship. By creating a simulated settings for the senior projects with students and staff members playing different mock roles besides the actual project being carried out in the actual internship, students can greatly improve on their learning curve for industrial skills and knowledge. While this method does run certain academic and industrial risks, quantitative proofs from our survey have shown improved results in the skill-building process of our students besides their improved level of satisfaction for the complete training process.

KEYWORDS

CDIO Standard 3, 5, 6, Civil Engineering, internship, computer simulation, construction mock-up models

1. INTRODUCTION

Civil Engineering as one of the oldest engineering tracks is a broad discipline that incorporates many different tracks of other engineering and scientific knowledge, including structural design, fluid dynamics, soil mechanics, etc. These together with an increasing number of mandatory practices and strict regulations in the Civil Engineering industry today have put more pressure on Civil Engineering educators around the world to deliver the best quality education possible for their students. In 2007, under the guidance of the CDIO Framework, Guangjing set up a design-directed curriculum model for Civil Engineering in which students would be able to learn from a board array of various engineering disciplines to support their work in Civil Engineering projects while being trained on their interpersonal skills and project-management knowledge at the same time (Guangjing, 2007). Then, in 2009, Vigild and other educators at the Denmark Technology University proposed the creation of design-build projects for Civil Engineering and Architecture programs (Vigild, 2009). And yet in 2011, Krogsbøll came up with four different models of CDIO-based projects for Civil Engineering programs (Krogsbøll, 2011).

These above CDIO-based models for teaching and learning in Civil Engineering while being very effective in enhancing the quality of both theoretical and practical training are generally only suitable for small-sized classes. It is increasingly more difficult to carry out these project models in Vietnam, where the class size is usually from at least 50 students or more. The amounts of time and money needed to run experiments and to build prototypes in every Civil Engineering course are simply over the current capability of every university in Vietnam. As in the case of the Faculty of Civil Engineering at Duy Tan University, we can only carry out CDIO-based project models in a few courses. In order to overcome this reality and increase the number of courses with CDIO-based projects in Civil Engineering, the faculty members in Civil Engineering at Duy Tan University have realized that by taking advantage of computer simulations as well as simulated settings resembling real-world situations, it will become very feasible and cost effective to create a quality CDIO learning environment. Students will arrive at the expected learning outcomes even much faster while requiring less lab space and materials. A series of case studies for CDIO project courses from the sophomore to junior to senior levels at Duy Tan University will provide a good description of how this can be done and why we should make more use of computer and real-world simulations in the field of Civil Engineering for our CDIO deployment.

2. CDIO PROJECTS IN CIVIL ENGINEERING UTILIZING SIMULATION TOOLS AT DTU

Our CDIO projects in Civil Engineering at the sophomore, junior and senior levels all focus on dealing with some natural problems or disasters in Vietnam, namely floods, hurricanes, landslides and earthquake. The projects are all set up on building blocks of knowledge from other courses with clear parameters and requirements at the sophomore and junior levels and open-ended needs at the senior level. The learning outcomes of these projects are also well-defined and frequently reviewed by the Board of Science of the Faculty of Civil Engineering.

2.1 Carton-Paper Retaining Wall Project

This CDIO project is at the sophomore level with the aim to test students' knowledge and skills in surveying, hydraulics, statics, and soil mechanics as well as to examine students' ability to integrate and apply such skills and knowledge into reality. Usually, students will need to do surveying on characteristics of the slope; to examine the erosion rate of fluid flows on such slope, taking into account the permeability coefficient; and ultimately, to calculate the bearing capacity of the retaining wall being made of carton paper.

In the first place, it is important to ask students to manually do the above calculations so that they will not easily forget the lesson in the future. However, if students have to continue to do these manual calculations after the first time as they try to revise their retaining wall model to make it better, they simply will have to spend so much time repeating the same work. Using the manual approach, at most, students can only revise their retaining wall model twice in this CDIO project. Instead, by using either FIDES-GeoStability or Plaxis software to build up the simulated model of the retaining wall on computer, students can test the bearing capacity of their wall in so many different scenarios from landslide to flood to fluctuating levels of soil moisture, etc. simply by only a few mouse clicks to change the testing parameters. The use of simulation software in this CDIO project during the last semester basically had changed the learning outcome of this course from building a retaining wall model and calculating its bearing capacity to building a retaining wall model with the optimal bearing capacity. The subsequent actual test of the retaining wall models made from carton paper also became more of a heated competition between the students since they now had all the necessary tools to refine their prototypes any time.

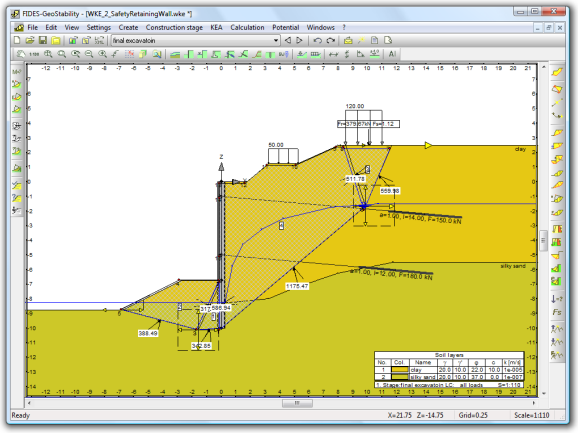


Figure 1. Retaining wall model simulations by FIDES-GeoStability (KEA)

Figure 2. Test of retaining wall models made from carton paper

2.2 O-Thuoc Bridge Design Project

This CDIO project is at the junior level, and its purpose is to test students' knowledge about structural analysis and design as well as about strength of various materials. Two major tasks for students in this project are (1) to formulate a structural design for a bridge with a specified span length, and (2) to choose the material which will optimize the loading strength of their bridge design.

More than often, students would refer to some bridge design already available from the Internet or from friends who already took the class before, and then tried to improve on that design. This was a wrong approach right from the first place because students did not get to try out the designs of their own and/or learn from their mistakes. In turn, that already-available bridge design also predetermined their choice of material to a great extent. In fact, at the end of the project, when we asked why they chose certain material for their bridge design, very few could respond well to that. Moreover, many students mistook the real purpose behind our competition of their bridge designs made out of chopsticks. Many actually tried to win the competition by optimizing their design for the material being used, which is bamboo wood or lumber without recognizing the fact that it was used to relatively compare one bridge design to another in a public competition since we could not have had them make the real bridges. Indeed, questions about their understanding of structural analysis and material strength or mechanics around their own bridge design were really how we tried to evaluate their projects. As a result, as we introduced SAP2000 and Etab to this CDIO project, students' mindset and approach was totally changed. Students can now model any structural design of their bridge on computer, and test out the ratio between the bridge weight to the maximum loading weight the bridge can sustain using any type of material, be it wood or iron or steel or some composite. The computer simulation also helps students cut down on their time and effort for making the bridge prototype: usually, they needed to make 3 to 5 bridge models to arrive at a satisfactory one for the competition; now, they only need to make 1 to at most 2 models. The learning outcomes of this CDIO project course indeed have been re-emphasized in a much clearer manner to our students through the use of computer simulations.

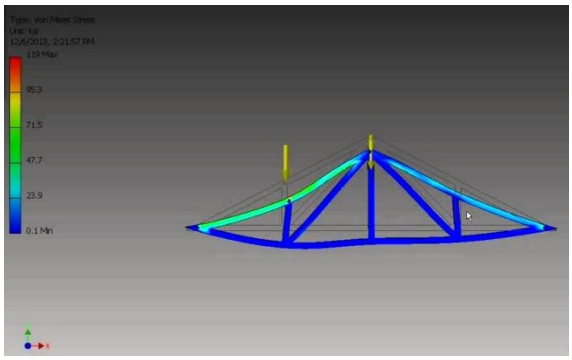


Figure 3. Modeling of a bridge design by SAP2000 software

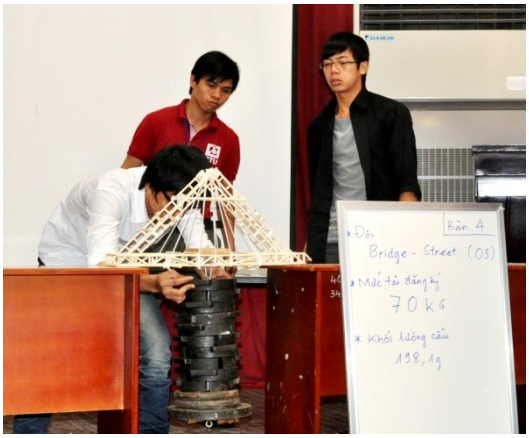


Figure 4. Competition in the the '*O Thuoc Bridge Design*' project

2.3 Earthquake-Resistant Building Project

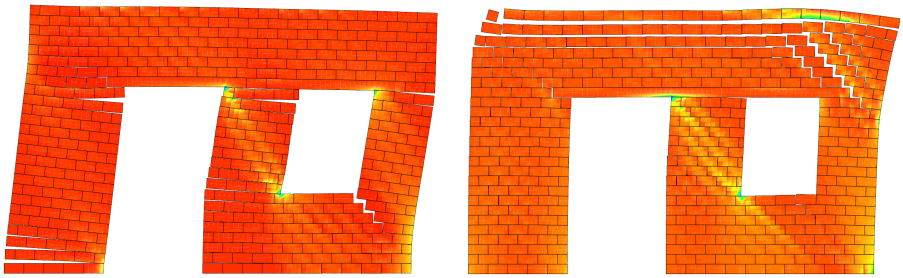
This CDIO project is at the senior level and has the goal of assessing students' application and integration of knowledge from different Civil Engineering sub-fields of structural dynamics, structural analysis, strength of materials, skyscraper design, etc. The project prototype here is supposed to be the design model of a tall building so that it can be tested against earthquake of different magnitudes and intensity.

Figure 5. Modeling and making the earthquake-resistant building frames

Unlike previously mentioned projects, it is hard to assess with absolute accuracy whether one design is better than another through some systematic calculations here because earthquake can always occurs differently from one place to another as well as from one time to another in the same place. The only reliable way to assess the strength of a building in event of an earthquake is to test its design in some computer simulation or on an earthquake simulated machine. As a result, the Faculty of Civil Engineering at Duy Tan University has adopted the complete evaluation criteria set of the international IDEERS competition (Introducing and Demonstrating Earthquake

Engineering Research in Schools) in Taiwan for this CDIO project class. Unfortunately, we do not have enough funding to acquire a simulated earthquake machine which is worth hundreds of thousand dollars; as a result, we had move to adopt the Cast3M software for this project. The good thing about the Cast3M software is that it helps identify the locations of cracks caused by earthquake on building structures and through those, it will be able to identify which aspects the structural design of a building is weak on in event of an earthquake. Because of this software, our students now learn more about the nature of earthquake at different magnitudes rather than just focusing on making strong structural models to stand the test of theoretically-simulated earthquake only. In fact, by examining the cracks on walls of houses in the earthquake at Song Tranh, Tra My, Vietnam in 2013, our students and their mentors have been able to reconstruct the simulated earthquake of the time on computer and also published a scientific paper about how houses in Song Tranh should be built to avoid such damages next time some earthquake hits again.

Figure 6. Cracks found on the walls of houses at Song Tranh, Tra My, Vietnam after the earthquake of 5.1 Richter in May 2013



(a) *(b)*

Figure 7. Modelling of typical walls under effect of an earthquake, with (a) and without (b) reinforced concrete lintels. Yellow zones indicate locations of the compressive stresses.

2.4 Simulated Construction Project Management Work:

A recent study of our students' internship experiences at local construction companies and construction consulting firms has revealed that many of our students

did not receive a complete set of training on essential skills and specialties. The overloading number of interns at many companies has driven down the quality of most internships. While it is possible to set up joint internship programs which are structured to include both our university mentors and corporate personnel in addition to clearly-defined learning outcomes for the students, not every company welcomes the idea either because they are too busy or because they simply do not have the resource to run such programs given their conditions in Vietnam. To make it up for this, the Faculty of Civil Engineering at Duy Tan University has recently borrowed from the idea of simulated case studies of our Medical School, in which we hired people to act as if they were having a certain illness profile and our medical students would practice interviewing and consulting for these "faked" patients. Applying the same doctrine and approach, during the last semester, our Faculty of Civil Engineering has set up a series of case studies in which our mentors were playing the roles of clients, architects, construction quality-assurance personnel, construction project managers, construction consultants in various fields, etc. to get students involved in simulated scenarios, in which they need to practice their skills for negotiation, documentation, problem-solving, and decision-making. While this effort was hailed for its novelty, in a number of situations, when students tried to adopt unfamiliar practice or approach, our mentors were not able to provide then with accurate or satisfactory evaluations because they had not been trained well enough for this new effort. In addition, right now, most of the simulated settings are only for short case studies rather than for some complete projects; as a result, some faculty members have become concerned that not all of the related skills and know-how needed for a specific case study are well-integrated into these classes, and it would be hard for our students to learn from discrete pieces of clues and tricks. This is not to mention of the fact that not all of our mentors have real-world experiences, and their acting may not resemble what actually is happening in the construction industry in Vietnam.

3. SURVEY & DISCUSSION

In order to verify the validity and relevance of our efforts to embed computer and real-world simulations into our CDIO project courses, it is important to assess students' performance and perception of the new approach. As a result, we have prepared a survey, focusing on identifying students' perceived improvements in the following areas:

- Problem-solving
- Knowledge discovery
- System thinking
- Personal skills
- Professional skills
- Teamwork skills

A Likert rating scale of 1 to 5 was adopted for the survey with 1 for Strong Disagree, 2 for Disagree, 3 for Neutral, 4 for Agree, and 5 for Strongly Agree. The survey is expected to help find significant improvements in some of these above performance and skillset areas.

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Student ID:	Student 's Name:	Date:
Student's Program:		Tick One

1: Strongly Disagree - 2: Disagree - 3: Neutral - 4: Agree - 5: Strongly Agree

No.	Problem Solving	1	2	3	4	5
1	The simulations call for additional brainstorming time between team members before arriving at the end outcomes.					
2	The simulations help me ask the right question and identify the right problem at any point in the project.					
3	The simulations help me identify the relationship between various problems in the project.					
4	The simulations require me and my team to follow through some development model or life cycle to carry out a specified CDIO project.					
5	I have a better grade on my CDIO project due to the support of simulations.					
No.	Knowledge Discovery	1	2	3	4	5
6	Through simulations, I have developed better knowledge in Statics, Dynamics and Mechanics.					
7	Through simulations, I have developed better knowledge in Structural Analysis and Design.					
8	Through simulations, I have developed better knowledge in real-world construction technologies and practices.					
9	Through simulations, I have developed better knowledge in Construction Project Management.					
No.	Systematic Thinking	1	2	3	4	5
10	The simulations help me identify problems based current constraints and potentials.					
11	The simulations help me immediately identify the inputs and outputs for any problem or process emerged in the project.					
12	The simulations help me envision problems that may emerge from current solutions of the project.					
13	The simulations help me better integrate knowledge from different fields of Statics, Dynamics, Hydraulics, Structural Analysis, Strength of Materials, Soil Mechanics, Construction Practices, Project Management, etc. in my thinking.					
No.	Personal Skills	1	2	3	4	5
14	I feel calm and confident working on CDIO projects with the support of computer simulations.					
15	The simulations help me become efficient in my CDIO project work.					
16	The simulations help me become accurate and productive in my CDIO project work.					
17	The simulations help me become innovative in my CDIO project work.					
18	I do feel as though I have to be too dependent on the support of simulations.					
19	If I make a mistake in my work, I can always go back and change					

	the parameters in my simulation to make it right.					
20	The simulations make me feel enjoying the work of a Civil Engineer.					
No.	Professional Skills	1	2	3	4	5
21	My communication teams improve to a great extent as a result of the new CDIO project settings.					
22	Working with simulations in the projects require me to better manage my time.					
23	Various parameters in the simulations provide me with a clearer list of resources needed for the project, and as a result, I found it easier to identify and coordinate resources for certain work.					
24	The simulations allow me to become more flexible in my project work, and help relieve me of great amount of stress compared to before.					
No.	Teamwork Skills	1	2	3	4	5
25	Simulations help us learn more about negotiation and communication skills.					
26	Simulations help us resolve team conflicts quicker and easier.					
27	I did do coaching and received coaching from other team members in the settings of the new simulations for our CDIO projects.					
28	I would not mind managing a team in a project if given the responsibility.					
29	If the team cannot work out the solution together, each member can work on simulation independently to arrive at effective results.					

Preliminary feedbacks from our students have shown a surge in the interest for the use of computer and real-world simulations in CDIO projects in Civil Engineering at Duy Tan University. We have carried out the survey on 112 students of the civil engineering programs and the results are shown in Figure 8.

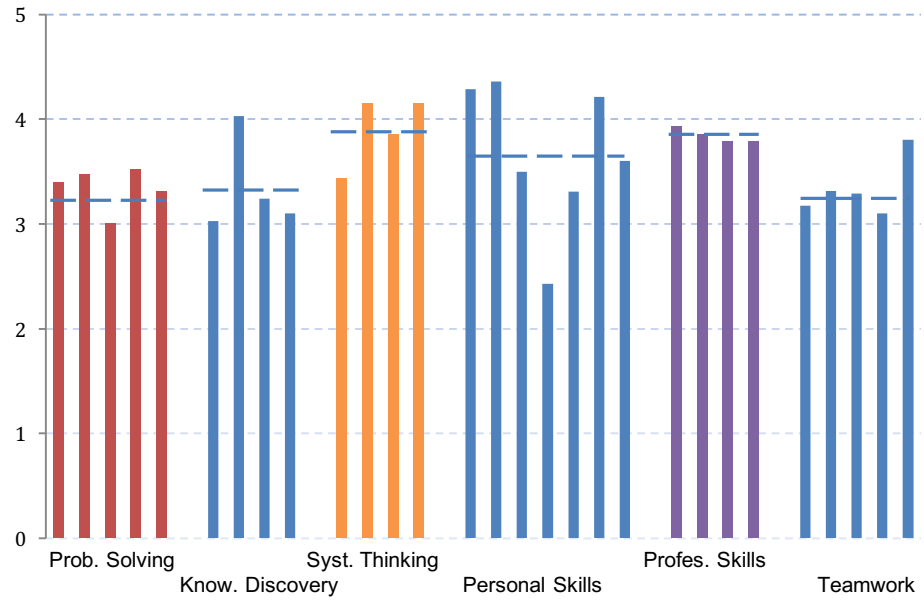

Figure 8. Survey result of DTU students about the improvements after simulation implements

The result shows that three groups of System thinking, Personal skills and Professonal skills got the improvements, exept that at Question 17 - *The simulations help me become*

innovative in my CDIO project work? At this aspect, we can see that the simulation sometimes might destroy the innovative ideas. The averages of other groups are around level 3 (Neutral) which shows the simulations not help students to improve the Problem-solving, Knowledge discovery and Teamwork skills.

4. CONCLUSION

While there is more to discuss about the use of computer and real-world simulations in CDIO projects in Civil Engineering at Duy Tan University, one clear benefit for certain up to this point is that the approach helps save great amounts of time, money and other resources on the part of our Faculty of Civil Engineering. In addition, students appear to have better experiences with the Conceive and Design phases in their CDIO projects besides better understanding of the learning outcomes behind each project which lead to the improvements of System thinking, Personal skills and Professonal skills. The new approach also requires more preparation efforts on the part of the Civil Engineering faculty members; however, those who completed their preparation work turned out to have easier time handling the class and monitoring their students' work. This actually brought about greater time for evaluation and feedbacks, which is a strong improvement in terms of our training quality.

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