A PROPOSAL OF THE C-D-I-E MODEL TO IMPROVE STUDENTS' INNOVATION CAPABILITY

Binh Dac HA, Dong T TRAN, Bao N LE

Duy Tan University, VIETNAM

ABSTRACT

Electrical & Electronic Engineering (EEE) study and research tracks are typical from other disciplines in that they are usually fast-changing and often require a high level of innovation on the part of both the learners and teachers. With the fact that Vietnamese higher education is shifting from an elite educational system to a universal one, it has introduced even more problems to most of our EEE students who do not receive sufficient innovation learning experiences as well as to our EEE instructors who lack adequate training on how to teach their students become more creative. Over the past three years, our Faculty of Electrical Engineering has learned many tough lessons about how to effectively administer the CDIO model to promote students' innovation capability under the current settings and conditions, and as a result, they have revised on the original CDIO model to propose the C-D-I-E model with the last new "E" letter standing for "Evaluate". The reason behind this has to do with the fact that for most of the EEE Capstone projects, we rarely could carry out the Operate phase given the limited amount of time for each project, and instead, if we can better "Evaluate" on the level of innovation of a given project, it will provide our students with better feedbacks on how they may improve on their work now or next time. Our C-D-I-E model has yielded certain fruitful results, and in this paper, we will go through three case studies of projects adopting this model, moving from a well-structured project to an open-ended one in order to assess its level of effectiveness across the spectrum.

KEYWORDS

Conceive-Design-Implement-Evaluate (C-D-I-E) model, CDIO Framework, CDIO Standard No. 5, 8, 10, creativity evaluation/assessment, EEE (Electrical & Electronic Engineering), innovation capability

1. INTRODUCTION:

In recent years, a major call by government officials as well as public figures in Vietnam is to turn the country into an innovation or entrepreneurial country (Adam Szirmai, 2011). At a less macro level, in higher education of Vietnam that call is to transform or create a new innovation-university model (Thomas J. Vallely, 2008). All of these were prompted from the fact that the economic reforms in the country over the years have helped accumulate enough resources for people to start thinking of making the country “soar up” like it has happened before in other Asian countries like Japan, Korea, Taiwan, Singapore, etc (Liu, 2010). For us, as the educators of the next generations of college students of Vietnam, the task is simply to make our students become more creative in their work and to be more proactive in their lifestyle approach so as to develop better career track when they enter the labor market. Years of rigid education and strictly-controlled curricula of the communist era have “killed off” the creativity mentality and motivation in the mindset of many generations of students in Vietnam (OECD, 2002).

While the Information Technology (IT) discipline receives the most attention and publicity for the movement toward innovation and entrepreneurship, the whole IT industry of Vietnam has been mostly focusing on “outsourcing” work (John, 2004). On the other hand, quite a number of electrical and electronic products of Vietnam have earned their names or at least a “Made in Vietnam” citing for the trademarks of some foreign investors. While the nature of job opportunities in EEE may not be as sophisticated as those for IT, there are usually many more job opportunities for EEE in Vietnam. As educators from various engineering fields, we believe that if Vietnam can approach the EEE industry in a novel way and manage to integrate IT features into packaged EEE products, it will definitely achieve more stable and long-term economic success, especially in the face of prevailing conditions for commercial piracy in Vietnam. The question for us as college educators then becomes how to teach our students about innovation and what level of innovation needed to satisfy the requirements of the current EEE industry of Vietnam.

Through our deployment of the CDIO model at Duy Tan University, answers to the above questions have become clearer as we earned more experience in the process. Innovation, as defined and/or implied by most knowledge models, is simply some improvements from the status-quo in terms of quality, functionality or appearance of some products or category of products (Fei, 2013) (Wang, 2013) (Zhang, 2013). At the extreme, if such improvement means making a totally new product and/or creating a new commercial demand or lifestyle need, that can be considered as a new invention or creation (Wu, 2013). In order to help students develop their own innovation capability, we need to equip them with:

1.1 A curiosity for existing problems in life,
1.2 A thirst for knowledge about how things are functioning (let it be a product, a machine, a software, etc.),
1.3 An ability to analyze and integrate data from different sources,
1.4 A habit of life-long self-learning,
1.5 A willingness to exchange knowledge,
1.6 A motivation for making new things (be it for better or for worse).

While we may be able to equip students with most of the above, it is usually difficult to help them with either the first 1.1 or the last 1.6 items. Some students will naturally develop their curiosity for existing problems in life, and some others seem to always have a motivation for making new things. Those with both of that curiosity and motivation usually will become successful entrepreneurs later on. The CDIO model adopted over the last couple of years at Duy Tan University have gone a long way in promoting an innovation spirit, especially amongst those faculties where the learning outcomes focus on making tangible products or product prototypes. Within our student communities, the habit of knowledge exchange and innovation thinking were also promoted to great extent. However, the uneven success (or failure) of CDIO in terms of developing students' innovation capability at different faculties has prompted university leaders to look into the reasons behind that.

2. C-D-I-E MODEL DESCRIPTIONS:

Being one the very successful faculties at Duy Tan University in the mission of enhancing students' innovation capability through CDIO, our Faculty of Electrical Engineering has realized that our success all comes from our meticulous evaluation of students' performance and constant feedbacks and encouragement for their work. The reason behind this is because our students always questioned us about whether their products or product prototypes will survive the test of time or in different markets around the world, and since we did not have time to completely carry out the Operate phase for most of their projects, we would have to do better evaluation of whatever they had done. So came our C-D-I-E model.

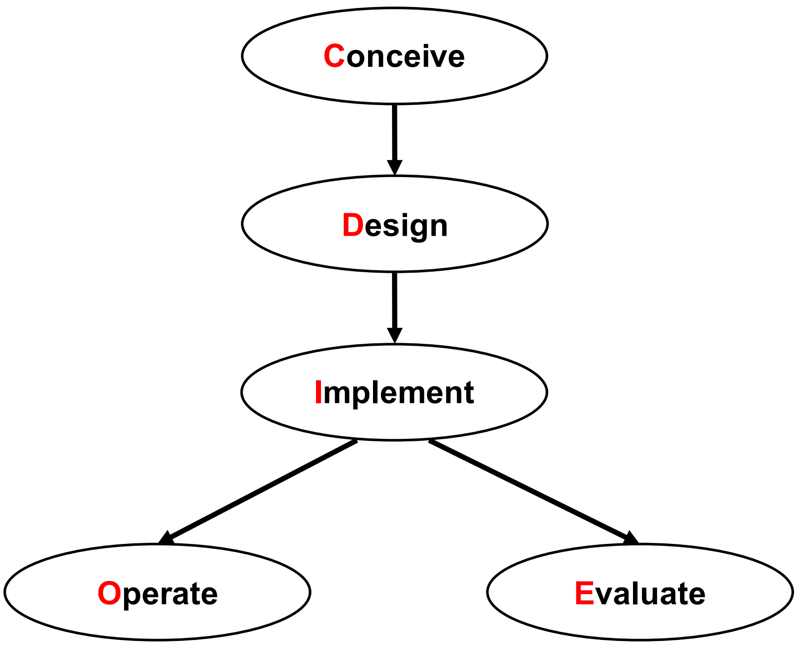

Figure 1. The Model of Conceive-Design-Implement-Evaluate (C-D-I-E model)

Our Evaluate component focuses on the following major evaluation criteria:

2.1 **Novelty or Originality** (of ideas, prototypes, or products): At the core of every project, the ideas which drive the project and facilitate creation of new products or prototypes are the most important items. Even if a project may not work out successfully, its driving ideas can still earn that project the highest grade if they are considered to be completely novel and original. Evaluation of the novelty and originality of ideas, however, are usually subjective; as a result, our Faculty of Electrical Engineering had set up a CDIO Project Evaluation Board to scan through all of its CDIO projects in any given semester. Students are required to write up an overview about the ideas of their projects, what are their benefits, who will get the benefits, how much protected the product will be from other substitutes, how long the product is expected to survive in its market niche, etc. Part of the reason for these overview write-ups is to help save the time and effort of the CDIO Project Evaluation Board, who have to work on a large number of CDIO projects.

2.2 **Logical Structures** (of the project): Given the project ideas, students would need to build up a roadmap for their projects; or more specifically, they need to select a product development life cycle and set up all the details of their project around such life cycle. While we always try to encourage new ideas from our students, we also warn them not to "reinvent the wheel" by developing some new product development life cycle of their own. For once, the allocated time for their project would not be enough for such an effort, and for another, a newly-developed project life cycle without going through the test of time like others being available on the market may not be reliable to any extent. The evaluation of the logical structures of the projects will be carried out directly by the project mentors throughout the whole timespan of their projects. For this, we had spent great amounts of time and money to retrain our faculty staff members on the knowledge and experience of product development life cycles as well as useful related tools.

2.3 **Design Effectiveness**: Design is an important component in every electrical and/or electronic engineering project, and the mentors of each project will go along with their students through the design phase for every little assessment or evaluation needed. Typical questions about how much money the new design costs, how much energy the design helps save, how convenient it is to integrate the new design with other designs, etc. should be on checklist of every design evaluation forms. However, not every mentor masters the skills and knowledge in various aspects of controller design or circuit design or sensor design, etc.; as a result, we had made great efforts to closely connect our faculty staff members together for mutual consultation whenever needed. In effect, this requires not only additional overtime pay but also the frequent championship of departmental leadership in specific categories of electrical and electronic projects.

2.4 **Market ability** (of the products or services): To assess the market ability of some students' products or product prototypes is a long shot even for our complete CDIO Project Evaluation Board. While the mentors can make any evaluation and grading on the projected marketability of their students' products and product prototypes, only a few projects which are evaluated as exceptional on the above-mentioned evaluation criteria will be chosen for faculty-wide evaluation of their marketability. Every instructor and student will have the chance to do their rating on the market ability of these project as part of a transparent and democratic process.

Within the framework of the traditional CDIO model, item 2.1 will be evaluated during the

Conceive phase, item 2.2 will be judged during the Design and Implement phases, and item 2.3 will be assessed during the Design phase; but within the scope of our new C-D-I-E model, all of the 2.1, 2.2, 2.3 and 2.4 items will be evaluated again in a much more comprehensive manner during the time period that was supposed to be for the Operate phase. Evaluations at this point tend to be more accurate now that we have had the students' products or product prototypes from their Implement phase. Students from different project teams are also encouraged to add in their comments on other teams' projects as well as on the evaluations of the involved mentors. In fact, this Evaluate phase has become very much a "bargaining" process amongst the students and their mentors about different aspects of their projects. This is very fruitful in helping students learn more from the feedbacks of different sources, and there is also plenty of time for students to gain new knowledge in the process, which is very much different from the short-time sessions of Q&A in any traditional board presentation.

3. C-D-I-E ASSESSMENT METHODOLOGY AND 3 CASE STUDIES DISCUSSION:

In order to assess the effectiveness of our new C-D-I-E model, the Faculty of Electrical Engineering has run a series of similar CDIO Capstone Project classes in parallel, of which some classes adopted the traditional CDIO model and others adopted the C-D-I-E model. At the end of these project classes, students were asked to participate in focus group discussions to identify what and how much they had learned from their projects. The following three case studies will signify the different results from the two models:

3.1 <u>CASE STUDY 1:</u>

In this sophomore-level CDIO Capstone Project course, students were asked to create a household product which helps "dry coconut chips". Students in traditional CDIO classes mostly started with their design work faster after doing research and review on products already available on the market. They mostly focused on either building the automatic relay to control the electrical current in the drying oven/machine to achieve effective drying results or redesigning the drying cabin space to maximize the oven efficiency. In contrast, because of the greater emphasis on the Novelty and Originality of their project ideas, students in C-D-I-E classes made up all kinds of new ideas: some used PID algorithm to control the exact temperature in the drying oven/machine at the user's desire, others put in tubes to effectively evaporate and extract all the moisture in the coconut chips, and yet, others designed new oven cabin to prevent the coconut chips from getting burned, etc. In any case, product prototypes from traditional CDIO classes tended to resemble those already available on the market with some additional improvements. On the other hand, product prototypes from C-D-I-E classes had totally-new concepts or focused on new features. Some of these worked, and some others did not. In total, product prototypes from traditional CDIO classes turned out to have better Design Effectiveness and Market ability while those from C-D-I-E classes achieved more Novelty and Originality. Still, students from C-D-I-E classes admitted that they had learned much more, and had spent so much time on the projects as if this were some higher-level project.

3.2 <u>CASE STUDY 2:</u>

Figure 2. Remote control project

In this junior-level CDIO Capstone Project course, students were asked to improve on the functionality of a television remote control. Students in traditional CDIO classes again mostly looked up users' comments about television remote controls on the Internet to determine what they needed to improve on: some changed the layout of the control buttons to make it more user-friendly, others change the circuit designs and sensors to achieve longer range in remote control, and the best was probably the one which removed most of the buttons and put in a touch screen for their television remote control. As for students in the C-D-I-E classes, some also came up with the same idea of using the touch screen for remote control, but there were also more interesting product prototypes like using gestures to control the TV through the Kinect (sensors) platform or integrating remote control features into smart phones simply by downloading some self-written apps. Eventually, some students even came up with the idea of integrating all the control of TVs, electric fans, A/C machines, etc. into one smart phone. Again, clearly enough, students in the C-D-I-E classes achieved greater Novelty and Originality for their project ideas, and while the Design Effectiveness and Market ability fluctuates from one project team to another no matter whether they were in the traditional CDIO classes or the new C-D-I-E ones, it seemed projects of those from the C-D-I-E classes yielded better future market prospects. It should be noted that since most projects from the traditional CDIO classes followed the traditional concept of a television remote control, they tended to have better logical structures and they followed along very well with their chosen product development cycle. In contrast, some projects in the C-D-I-E classes were not structured logically enough to meet their goals either because their scope were too broad and ambitious or because they were still ambiguous about their desired end outcomes for the project.

3.3 <u>CASE STUDY 3:</u>

In this senior-level CDIO Capstone Project course, students were sent to a rural area by the river and were asked to design some products of the top priority to the people living in that area. Given this open-ended project topic, students from the traditional CDIO classes eventually came to realize the importance of the Novelty and Originality in their project ideas. They were no different from students from the C-D-I-E classes about that point, and yet, there were certain differences: students from traditional CDIO classes tended to focus more on the technical capability of their teams for making a new product after their interviews with the locals living along the river about their utmost priority while students from the C-D-I-E classes spent time discussing and arguing about which problem on the list of the locals they should focus on and whether by solving that problem, they would be able to create some totally-new product - some product which would make a major difference. They worried less about the technical feasibility of their projected product because they believed one way or another they would get help in the process from their mentors or others throughout the duration of the project or during the Evaluate phase. As it turned out, students from both the traditional CDIO classes and the new C-D-I-E ones came up with all kinds of new and similar ideas of a flood-level warning system, a solar-powered water filtering system, an automatic watering system, an insect expelling machine, a solar-and-wind hybrid power supply system, etc., and while it was hard to judge projects through their names, when it came down to specific product features of similar projects, students from the C-D-I-E classes appeared to have more novel features even if some were not within their technical capability. In addition, students from the C-D-I-E classes tended to make the most use of their product development tools as their product design requirements were often more "open" and not as "predetermined" as those of students from the traditional CDIO classes, who in many unconscious ways usually predefined the limits of their product requirements through the scope of their technical capability. As a result, students in C-D-I-E classes also tended to achieve better design effectiveness for their products.

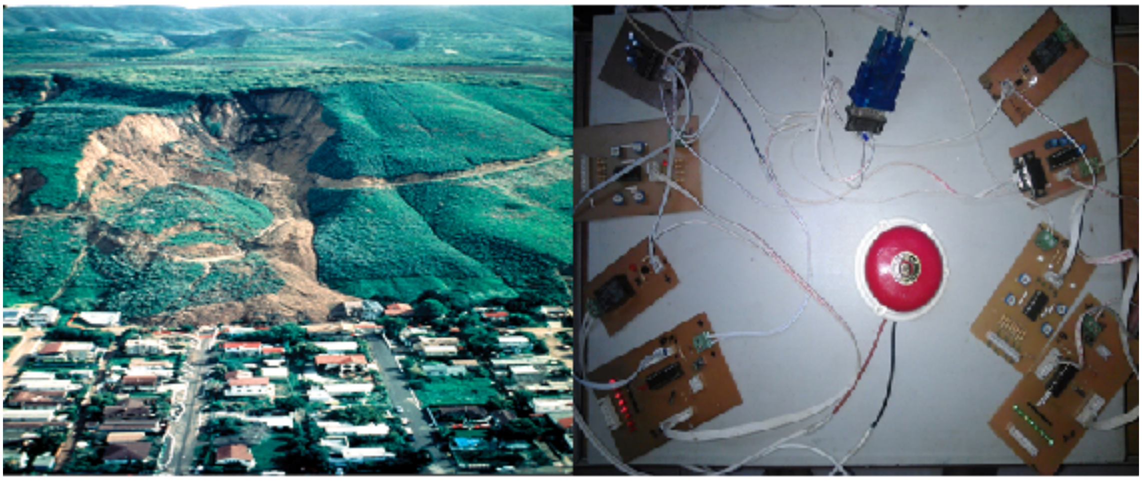

Figure 3. Top-priory-solution for Riverside rural area Project

As the case studies demonstrated, the C-D-I-E model helps promote students' innovation capability by stressing the importance of the Novelty and Originality of students' ideas while providing them with additional time and resource for better feedbacks and Evaluations. As a matter of fact, the adoption of the C-D-I-E model in CDIO Capstone Project courses by the Faculty of Electrical Engineering and Faculty of Information Technology at Duy Tan University has brought about a surge in the number of truly innovation projects during the last two years, as shown in Table 1 below.

Table 1. Number of Innovation Projects in the last 5 academic years

	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Faculty of EEE	3	1	4	27	26
Faculty of IT	1	2	1	14	11
Average of DTU	5.4	1.2	2.1	3.9	6.6

(Source: Department of Science & Technology Management, DTU)

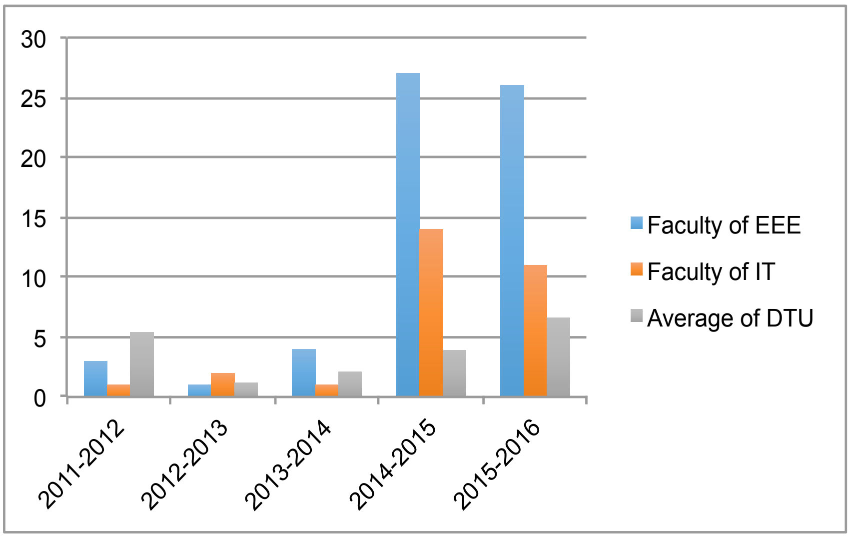

Figure 4. Bar Chart of the Number of Innovation Projects in the last 5 academic years

4. CONCLUSION:

Our study signified the fact that students in CDIO deployment usually do not receive a fair share of evaluation on their project work, which in turn will hinders the development of their innovation capability. The C-D-I-E model provides a good solution to this immediate problem, but an additional Evaluate phase alone would not be enough to enhance students' innovation capability and awareness. As a result, within our additional Evaluate phase, we have introduced a new and comprehensive set of major evaluation criteria for CDIO projects, namely the Novelty or Originality, Logical Structures, Design Effectiveness and Marketability of the project ideas, product, product prototypes, and other project related components. The emphasis on the degree of Novelty or Originality and Marketability of the C-D-I-E model clearly have enhanced students' motivation in creating innovation features in their project; however, the amount of Design Effectiveness and Logical Structures in a project still fluctuates between the new C-D-I-E model and the traditional CDIO one, depending how much structured the project topic is, which is worth additional future study of this subject.

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BIOGRAPHICAL INFORMATION

Binh D HA, Ph. D. is the Dean and Chairman of the Scientific Council of the Faculty of Electrical & Electronics Engineering, Duy Tan University. His current scholarly activities focus on the cultivation of social aspects in CDIO implementation.

Dong T TRAN, received B.S degree Electronics and Telecommunication Bachelor from Duy Tan University, Viet Nam in 2009, and M.S.degree in Computer Science from Duy Tan University, Vietnam, in 2012. He is currently the Vice Director at Center of Electrical Engineering (CEE), Duy Tan University. His research interests include image processing, design automation of embedded systems, FPGA design. He joined the CDIO program as a lecturer of Introduction to Electrical & Electronics Engineeringcourse in 2013.

Bao N LE is the Vice Provost of Duy Tan University. He is in charge of the Technology & Science division as well as the R&D Center of DTU. His interests are in data warehousing, OLTP, graphics and animation design.

Corresponding author

Dr. Dac Binh HA
Faculty of Electrical & Electronics Engineering, Duy Tan University, K7/25 Quang Trung, Da Nang, Vietnam
+84-974451806
hadacbinh@duytan.edu.vn