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Integration of Design Thinking and Conceive-Design-Implement-Operate within OBE Framework in Entrepreneurship Course for Civil Engineering Students

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ABSTRACT

Design thinking (DT) is a robust framework for creatively identifying and solving various human problems. It offers a systematic solution to train engineering student's critical and creative thinking to solve complex engineering problems. The DT method can be integrated with the conceive-design-implement-operate (CDIO) framework to develop personal skills together with inter-personal skills. This paper presents the outcomes attained by the final year civil engineering students from Technology Entrepreneurship (ENT600) course. Teaching delivery method and assessment of outcomes are very important to determine students' performance with regards to this course. The course outcomes were assessed using various assessment tools such as case study, assignment/project, report and presentation. Two (2) groups of students from ENT600 course were selected as case studies to generate a comparison between their outcomes' attainment using two different learning methods; namely the traditional OBE and DT-CDIO integrated approach, respectively. The case studies used the data obtained from ENT600 course which is offered to final year undergraduates at the Faculty Civil Engineering, UiTM Shah Alam. This study highlights the importance in using DT method as an effective teaching and learning method to tackle complex problems systematically by understanding the human needs (empathize), re-framing and defining the problem in human-centric ways (define), creating many ideas (ideate), adopting a hands-on approach (prototype) and finally developing a prototype/solution to the problem (test). The coefficient variation indicates a significant difference between the two group outcomes' attainment for the course. Thus, this study shows the difference between the students' attainment using different learning methods used. The study revealed the assessment using DT-CDDIO approach as a possible transformation agent that is able to improve the delivery and course outcomes' attainment. Therefore, a modification on assessment methods based on DT approach is proposed as an accompanying method to evaluate the outcomes' attainment.

Key Words: Design thinking, entrepreneurship, programme outcomes, engineering students

1. INTRODUCTION

Malaysia initiated the Outcome Based Education (OBE) in engineering education beginning in the year 2000. OBE is a paradigm shift from the teacher-centred to the student-centred learning, where its implementation require students to demonstrate that they have learned and acquired the required contents and skills. The new teaching and learning (T&L) approach transforms educational emphasis from focusing on traditional inputs, such as course credits earned and hours spent in class, to being focused on results or outcomes. It empirically measures the student performance, called programme outcomes (POs) (Mat Isa, Mohd Saman, & Mukri, 2017) .

Under International Engineering Alliance (IEA), one of the three (3) agreements governing mutual recognition of engineering qualifications and professional competence in respect of tertiary-level qualifications in engineering is Washington Accord (WA). Malaysia fulfils the requirements and became the 13th signatory to Washington Accord (WA) in 2009 (International Engineering Alliance, 2013). There are twelve (12) POs that are required to be attained by the engineering students upon their graduation. Seven (7) of the POs are related to complex engineering problems (CEP) and one (1) is related to complex engineering activities (CEA) (EAC, 2017). Therefore, one of the challenges is to incorporate complex engineering problems elements in the T&L activities. One of the CEP attributes is the depth of analysis instead of the obvious solution, which require abstract thinking, and originality in analysis to formulate suitable models are also expected.

The Conceive-Design-Implement-Operate or known as CDIO approach was initiated by the Massachusetts Institute of Technology (MIT) and has expanded to include engineering programme worldwide. Its project vision is to provide students with an education that stresses engineering fundamentals set in the context of Conceiving-Designing-Implementing-Operating (CDIO) real-world systems and products (Goodhew, 2012). The CDIO approach suits the Engineering Education Framework and help to enhance and improve the teaching and learning tools and practices in the current OBE programme. It emphasizes developing personal skill such as creative and critical thinking together with interpersonal skills such as communication and team working, active learning, experiential learning, engineering reasoning, problem solving and DT skills to solve CEP and carry out CEA. Overall, it provides a diversified approach which provides multiple solutions that fits the best under different constraints in any T&L activity.

Thus, using DT method offers a systematic solution to bolster engineering student's critical and creative thinking to solve CEP through CEA incorporating the CDIO concept. For Civil Engineering degree programme coded EC220, an entrepreneurship course known as "Technology Entrepreneurship" or ENT600 has been chosen to implement the CDIO approach in its lesson plan and at the same time to fulfil one of the programme outcomes to be attained by the students. This paper presents the implementation of DT and CDIO concept in ENT600 for Civil Engineering programme at UiTM Shah Alam.

2. BACKGROUND OF STUDY

2.1 Implementation of Conceive-Design-Implement-Operate

The Faculty of Civil Engineering, UiTM (FCE, UiTM) implementation of CDIO approach began with the understanding of the CDIO concepts, standards and syllabus through the lectures, lab observation and visits to Singapore Polytechnic in October 2011. Inspired by the success of CDIO collaborators and the benefit of its implementation, the FCE, UiTM has integrated CDIO concept into OBE in its diploma and degree programmes, by incorporating CDIO in its curriculum review in 2013 and was implemented in the same year (Mat Isa et al., 2017). The rationale of using the CDIO approach in engineering education is because the beginning engineers should be able to Conceive-Design-Implement-Operate complex value-added engineering products and systems in modern team-based environments. They should be able to participate in engineering processes, contribute to the development of engineering products, and do so while working in engineering organizations. This is the essence of the engineering profession.

2.2 Design Thinking Approach

Tim Brown, the Chief Executive Officer (CEO) of the IDEO, global design company defined Design Thinking "…. as a human-centred approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success (Brown, 2008). Design humanises technology, creates simple solutions to complex problems and changes the meanings of things. DT is an invaluable tool to think and act creatively. It is a method to understand the challenges and also to provide the means with which to conceive and develop solutions. This would be a simple but effective way of nurturing a new generation of instinctive lateral thinkers and problem solvers. DT is a design methodology which differs from traditional design approaches. Some authors characterize DT as more creative and user-centred than traditional design approaches. DT can be regarded as a problem-solving method or, by some definitions, a process for the resolution of problems.

DT process can be utilised to develop innovative ideas for social good. The learning from DT expresses engineering across borders to understand and analyse local environmental and social problems, design and prototype, co-create local solutions with local technology. Students can apply their creativity to develop appropriate technologies and sustainable solutions through co-creation. DT process involves three (3) domains namely: affective, psychomotor and cognitive, which are also important elements in OBE framework. DT is also regarded as an alternative approach to conduct research on collaborative learning with technology (Leinonen, & Durall, 2014). Unlike analytical thinking, which is associated with the "breaking down" of ideas, DT is a creative process based on the "building up" of ideas. Analytical approaches focus on narrowing the design choices, while DT focuses on going broad, at least during the early stages of the process (Baeck & Gremett, 2011).

DT outlines a process of five (5) steps to arrive at an innovative solution to a problem which are empathy, define, ideate, prototype and test based on Hasso-Plattner Institute of Design at Stanford University (Camacho, 2016) as shown in Figure 2.1.

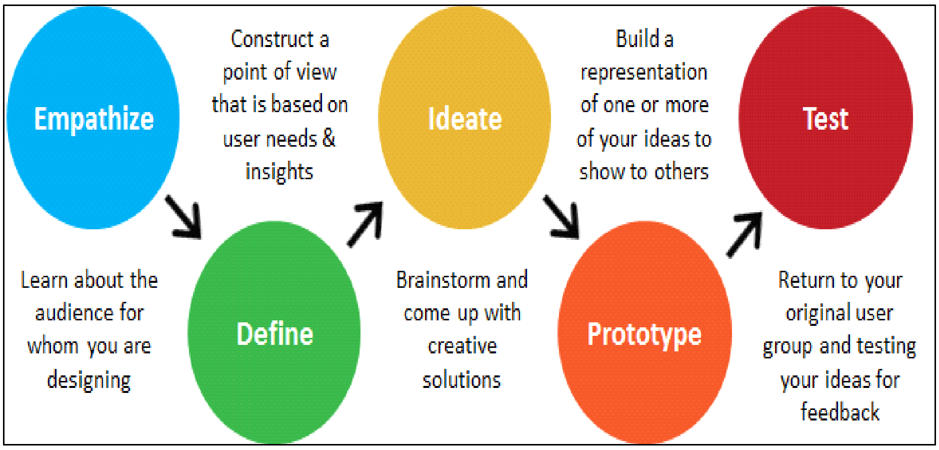

Figure 2.1: Design Thinking Process (Hasso-Plattner Institute of Design, University of Stanford)

Empathy is the centre piece of a human-centred design process to understand the way people do things and why, their physical and emotional needs, how they think about world, and what is meaningful to them, and how they interact with their environment, within the context of design challenge. There are three (3) actions to empathise which are observe, engage, watch and listen. Thus, interacting with, observing, and getting to know users to develop cognitive, affective, and experiential insights are required. In general, this stage involves immersive and direct interaction with users (e.g., participatory research), substantive efforts to develop deep empathy, and involvement of users throughout the design process (Fila, Mckilligan, & Guerin, 2018) .

Define means to construct a point of view (POV) that is based on the user needs and insights. Thus, framing and reframing the design problem as articulated design goals and criteria are required. Typically, the defined problem relies on insights from the empathize stage and reflects a critical and unbiased understanding of the challenges and needs of users. Define is bringing clarity and focus to the design space. To be design thinkers, students have to define the challenge based on what has been learned about user and context.

Ideate requires generation of concepts to address the defined problems. Ideate is the mode of the design process in which it concentrates on idea generation. Mentally, it represents a process of 'going wide' in terms of concepts and outcomes. Ideation provides both the fuel and also the source material for building prototypes and getting innovative solution into the hands of the users. Ideation is the chance to combine the understanding that we have the problem space and people that we are designing for with your imagination to generate solution concepts. Particularly early in a design project, ideation is about pushing for a widest possible range of ideas from which it can select, not simply findings a single best solution. The determination of the best solution will be discovered later, through user testing and feedback. Various forms of ideation are leveraged on: first to step beyond obvious solutions to increase the innovation potential of the solution set; to harness the collective perspectives and strengths of teams; to uncover unexpected areas of exploration; to create fluency (volume) and flexibility (variety); and most importantly to get obvious solutions out of the students' heads, and drive their team beyond them.

Prototype mode is the iterative generation of artefacts intended to answer questions that get it close to our final solution. In the early stages of a project that question may be broad, for example, "do my users enjoy cooking in a competitive manner?'. In these early stages, low-resolutions prototypes should be created that are quick and cheap to make (think minutes and cents) but can elicit useful feedback from users and colleagues. In later stages both prototype and question may get a little more refined. For example, a later stage prototype for the cooking project may be created that aims to find out: "do my users enjoy cooking with voice commands or visual commands". A prototype can be anything that a user can interact with – be it a wall of post-it-notes, a gadget that we put together, a role – playing activities, or even a storyboard. Ideally, we should gear toward something a user can experience. Walking someone through a scenario with a storyboard is good, but having them role-play through a physical environment that has been created will likely bring out more emotions and responses from that person. In order to avoid losing all the innovation potential, it should be generated through ideation, recommend a process of considered selection, by which it brings multiple ideas forward into prototyping, thus maintaining innovation potential. There are four (4) steps on how to prototype which are: (1) Start building, even if we are not sure what we are doing, the act of picking up some materials (post-it tape and found objects are good way to start) will be enough to get us going and don't spend too long on prototype; (2) Identify a variable, identify what is being tested with each prototype. (3) A prototype should answer a particular question when tested. (4) Build the user in mind by asking on the following questions: what do we hope to test with the user/ and what sorts of behaviour do we expect? Thus, by answering these questions will help focus our prototyping and help us receive meaningful feedback in the testing phase. The importance of conducting prototype are to ideate and problem-solve and use to communicate since a prototype is worth a thousand pictures. Furthermore, a prototype is an opportunity to have another, directed conversation with a user; to start a conversation.

Finally, the test mode is when feedback is solicited, about the prototypes that have been created, from users and have another opportunity to gain empathy for the people that we are designing for. Testing is another opportunity to understand our user, but unlike initial empathy mode, we have now likely done more framing of the problem and created prototypes to test. For a physical object, people could be asked to take it with them and use it within their normal routines. For an experience, a scenario in a location can be created that would capture the real situation. If testing a prototype in situ if not possible a more realistic situation can be framed by having users take on a role or task when approaching prototype.

In short, DT tackles complex problem by first empathising or understanding the human needs involved, then by re-framing and defining the problem in human-centric ways; third through ideating to create many ideas in ideation sessions; next is prototyping by adopting a hands-on approach in prototyping and finally, through Testing to develop a prototype/solution to the problem. The application of DT in engineering syllabus is very timely to ensure that the students are exposed to complex problems and get involved in complex engineering activities.

2.3 Integration of CDIO approach and Design Thinking Method

DT is needed to produce engineers who have the knowledge and experience specifically needed. On the other hand, the graduates have a unique array of personal, interpersonal and system – building experiences. The integration of DT process in CDIO is shown in Figure 2.2. It shows that DT exists in the Conceive and partially in Design and Implement stages.

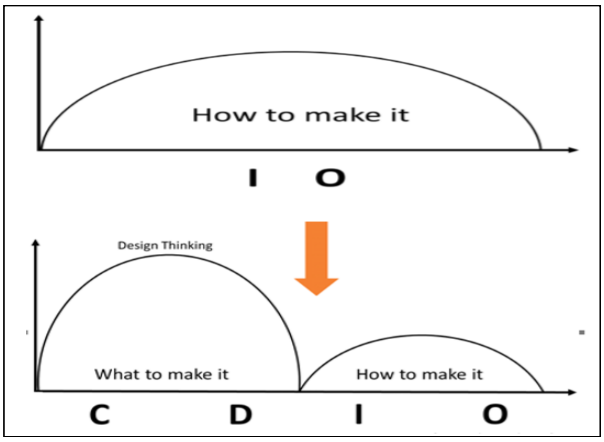

Figure 2.2: Integration of Design Thinking and CDIO Approach

The stage which involves Implement and Operate is the easiest step. For example, in a traditional type of construction contract, a complete design of building consists of drawings and specifications that are provided to the contractor, which are readily to be constructed. The design conceived by the consultant and client will be implemented and operated by the contractor (how to make it). It has been observed that the most difficult step in the CDIO process is the first step; "conceive".

Figure 2.3 represents the Singapore Polytechnic (SP) Design Thinking flow. It emphasises “deep user understanding” through detailed survey/ observation of users and subsequent analysis of the data collected.

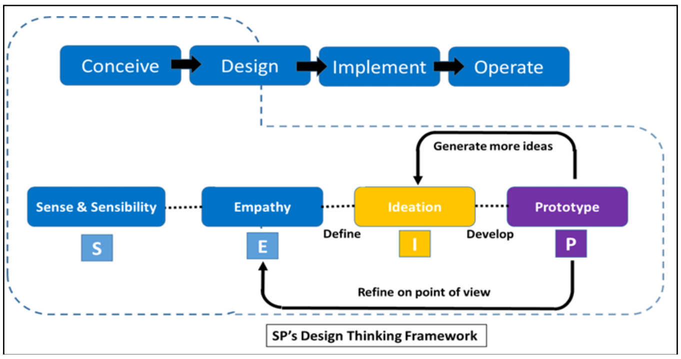

Figure 2.3 Singapore Polytechnics Design Thinking Framework

In the Empathy step, the team of designers (or engineers) make an effort to understand the user’s needs i.e. what kind of product or service the user really requires. This is done through a number of techniques such as survey and observation. Once the user requirements are well understood, the team moves on to the ideation step to brainstorm and propose possible solutions that may help to solve the user’s problem. Concept sketches can be drawn to capture the ideas. The process continued with prototype which often the proposed solutions are presented to the users for comments (so called as “quick and dirty prototypes”). It can be in the form of a model, a video, a skit, a comic strip or simply a good sketch. Then, the user feedback is used to refine the proposed solution. The team moves on to build a functional prototype, before the end users are once again engaged to test-drive the product or service. The flow is an iterative process. For example, if (during ideation) the team discovers that they do not really have sufficient understanding of the user requirements to propose a good solution, they may have to repeat the “Empathy” studies.

The DT process can be utilised to develop innovative ideas for social good. The learning from DT expresses engineering across borders to understand and analyse local environmental and social problems, design and prototype, co-create local solutions with local technology. Students can apply their creativity to develop appropriate technologies and sustainable solutions through co-creation.

For ENT 600 course in EC220 programme an integration of DT and CDIO is shown in Table 2.1 below.

Table 2.1: Integration of the DT ad CDIO elements

DT Elements	CDIO Elements
Empathize	Conceive
Ideate	Design
Design	
Prototype	Implement
Test	Operate

2.4 Direct and Explicit Assessment to Measure Students' Performance

In order to gather evidences of student learning, assessment efforts are categorized as direct and indirect measures. According to Maki (2004), direct methods prompt students to represent or demonstrate their learning or produce work so that evaluators can assess how well students' texts, responses and skills fit programme-level expectations. Thus, direct assessment means sample of actual student's work such as reports, exams, demonstrations, performances, and completed design works. The evaluators assess how well students meet the intended expectations. The strength of direct measurement is that it can capture a sample of what students can do, providing very strong evidence of student's learning. On the other hand, an indirect assessment provides opportunities for students to reflect on their learning, and inform the evaluators their perceptions of their learning experience. However, not everything can be demonstrated in a direct way, such as values, perceptions, feelings, and attitudes.

Examinations, tests, assignments and case studies are amongst the common tools used for direct and explicit measurements in most of engineering courses to reflect mostly the cognitive level of attainment. Presentation through viva, power point or poster presentation, are some of the tools used to address the affective domain while psychomotor domain is assessed through observation during practical test. Nevertheless, some measurements are subjective and may be prone to be perceptive bias. Any inconsistencies and perception biased assessment tools may indulge into ambiguous measurement leading to untrue attainment of the POs. In ENT600 course, test or examination is not carried out. Thus, case study, assignment to proposed new product development, report, blueprint and ENT day were used to assess the students. Each assessment is assigned different learning domains (affective, cognitive and psychomotor).

In addition, another direct assessment was proposed by the aid of rubrics as an important tool to ensure more objective outcomes that integrates all five DT elements. A sample of an assessment using rubrics with five main criteria based on the five-steps of DT as shown in Table 2.1 below.

Table 2.1: Rubrics with five main criteria based on the five-steps of design thinking

	1	2	3	4	5
	Level of empathise mode that benefit and fulfil the people/society's needs/requirements				
EMPATHISE	Not able to understand the preferences of people.	Able to generally observe, engage, watch and listen the people/society's needs	Able to moderately observe, engage, watch and listen the people/society's needs but not understand the preferences of people.	Able to substantially observe, engage, watch and listen the people/society's needs and understand the preferences of people with some actions taken.	Able to precisely observe, engage, watch and listen the people/society's needs and understand the preferences of people with clear actions as proof to reflect the empathy.
	Define the idea of design process that related to the point of view				

DEFINE	Not able to provide idea of design process that related to the point of view.	Able to provide focus and frame the point of view which inspires team members without evaluating competing ideas.	Able to provide focus and frame the point of view which inspires team members in evaluating competing ideas to make decisions dependently.	Able to provide focus and frame the point of view which inspires team members in evaluating competing ideas to make decisions independently in order to capture the hearts and minds of people solving some of the problems.	Able to provide focus and frame the point of view which inspires team members in evaluating competing ideas to make decisions independently in order to capture the hearts and minds of people to solve difficult task.
	Design ideas that engage and benefit the people/society with justification				
IDEATE	Able to design the idea which give only one (1) benefit to people/ society no idea justification	Able to design the idea broadly which give two (2) benefits to people or society and the idea justified with few relevant facts and information.	Able to design the idea moderately which give three (3) benefits to people or society and the idea justified with acceptable facts and gathering relevant information.	Able to design the idea substantially which give four (4) benefits to people or society and the idea justified with thinking through some facts and relevant information.	Able to design the idea precisely which give more than four (4) benefits to people or society and the idea justified with thinking through validated facts and relevant information.
	Develop an innovation potential and conducting prototype/model/system/process as to communicate, ideate and problem-solve				
PROTOTYPE	Not able to develop an innovation potential and conducting prototype.	Able to develop an innovation potential and conducting prototype without appropriate building process.	Able to develop an innovation potential and conducting prototype which covers building process however not within given time frame.	Able to develop an innovation potential and conducting prototype which covers building process within given time frame with intended parameters/variables and partially able to be tested.	Able to develop an innovation potential and conducting prototype which covers building process within given time frame with intended parameters/variables and eventually able to be tested.
	Assess feedback from user upon created prototype through testing				
TEST	Not able to assess feedback from user upon created prototype.	Able to assess feedback from user upon created prototype.	Able to assess feedback from user upon created prototype. However, the outcomes from the test cannot be used for the next iterations.	Able to assess feedback from user upon created prototype. The outcomes from the test can be used for the next iterations however, lacking to build empathy through observation and engagement.	Able to assess feedback from user upon created prototype. The outcomes from the test can be used for the next iterations, getting another opportunity to build empathy through observation and engagement and to refine related point of view.

Under CDIO elements based on complex elements in EAC Manual 2017, a sample of rubric is shown in Table 2.3.

Table 2.3: CDIO elements incorporating complex engineering problems

	1	2	3	4	5
	Involvement various resources for examples are human, equipment, money and materials				
RANGES OF RESOURCES	Able to carry out less than 30% C-D-I-O only 1 resource	Able to carry out C-D-I-O between 30% to 50% only 2 resources	Able to carry out C-D-I-O more than 50% using 3 resources	Able to carry out more than 70% C-D-I-O using 4 resources	Able to carry out more than 80% C-D-I-O using more than 4 resources
	Complete required work leading to no obvious/beyond normal solution				
SOLUTIONS	Able to complete less than 30% with correct (known) solution.	Able to complete between 30% to 50% C-D -I-O with correct (known) solution.	Able to complete more than 80% C-D-I-O with no obvious solution/beyond normal solution.	Able to complete more than 80% C-D-I-O with no obvious solution/beyond normal solution	Able to complete more than 80% C-D-I-O with no obvious solution/beyond normal solution.
STA	**Involvement of large team/ various stakeholders**				

	No involvement of stakeholders to carry out C-D-I-O	Involvement 1 stakeholder to carry out C-D-I-O	Involvement 2 stakeholders to carry out C-D-I-O	Involvement 3 stakeholders to carry out C-D-I-O	Involvement more than 3 stakeholders to carry out C-D-I-O
CONTRADICTING REQUIREMENT	**Contradicting requirements were evidenced**				
	No contradicting requirements	One contradicting requirement was evidenced in carrying out C-D-I-O	Two contradicting requirements was evidenced in carrying out C-D-I-O	Three contradicting requirement was evidenced in carrying out C-D-I-O	More than three contradicting requirements in carrying out C-D-I-O

DT and CDIO is an integrated design methodology which differs from traditional design approaches. This has been the motivation for the lecturer to apply DT with CDIO approach as a simple but effective way to nurture a new generation of instinctive lateral thinkers and problem solvers like engineering students.

3. METHODOLOGY

3.1 Research Approach

This study adopts a quantitative approach based on a secondary data namely; the results attained by the civil engineering students from the ENT600 course. An open-ended problem was given to a few groups of students (4 students per group), where each group is required to choose one small and medium enterprise (SMEs) in Malaysia and to collect as much information as possible about the companies (i.e. company background, product, marketing techniques, business performance, etc). The information can be collected through document reviews, personal interviews with the owners, observation, etc. Generally, each group needs to analyse the companies' problems and suggest relevant technology-based solutions to these problems and to enhance the performance of the company.

Two (2) different groups taking ENT600 course in Semester 8 (Year 4) were chosen for this study; the first group is the DT Group consists of 30 students and they were involved in the practice or implementation of DT and CDIO in their ENT projects. The second group is the Control Group who did not implemented DT in their projects. The students from both groups were from the same batch and were taught and facilitated by the same lecturer/instructor.

3.2 Assessment to measure the attainment of the course outcomes

There are three (3) course outcomes that are expected to be acquired by the students. Various assessment tools with different domains are used to assess the students from both groups. Table 3.1 shows a matrix table of the course outcomes, assessment tools and domain together with the percentage distribution of marks given.

Table 3.1: Mapping of course outcomes, assessment tools and domain together with the percentage distribution

Course Outcomes	Assessment Tool and Domain	% Distribution
CO1: Explain the concept and process related to principles of technology entrepreneurship using verbal and non-verbal communication	**Case Study** • Interview (Affective) • Video (Affective) • Report (Cognitive)	20

CO2: Demonstrate managerial and entrepreneurial skills in identifying technology-based business opportunity	**New Product Development 1** • Group & Individual Presentation (Affective) **New Product Development 2** • Report (Cognitive) • Prototyping (Psychomotor)	20 20
CO3: Demonstrate information retrieval and management skills in preparing technology venture blue print	**Blue Print** • Report (Cognitive) **ENT Day** • Poster Presentation (Affective)	20 20

3.3 Coefficient of Variation

The coefficient of variation (CV) is a measure of relative variability. It is the ratio of the standard deviation to the mean (average). For example, the expression "The standard deviation is 15% of the mean" is a CV. The CV is particularly useful in this study, where comparison of results was made from two different groups that have different measures or values. The formula for the coefficient of variation is: Coefficient of Variation = (Standard Deviation / Mean) * 100. (SPSS Inc., 2004)

4. RESULTS ANALYSIS AND DISCUSSION

4.1 Students' Performance Assessed based on Design Thinking Approach

Figure 4.1 shows the percentage distribution of marks attained by the students who applied DT approach, which is integrated with CDIO concept. This DT group consist of 30 students taking ENT600 in Semester September 2017. The assessment tools used were case study, new product development 1, new product development 2, blueprint (report) and ENT day (oral and poster presentation).

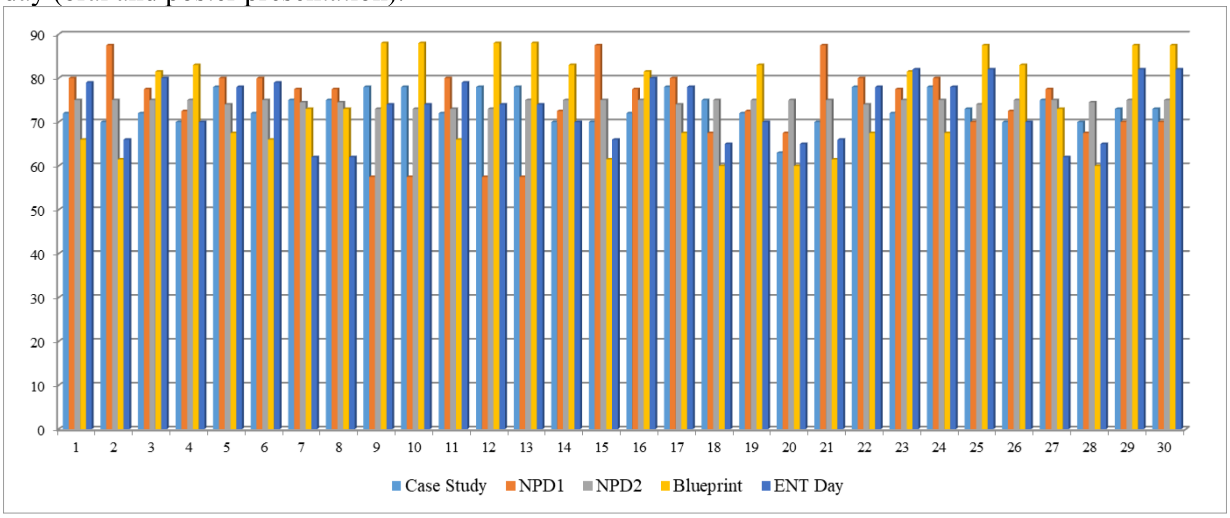

Figure 4.1: Percentage Distribution of Marks for DT Group

There are 11 students attained more than 80% of marks for blueprint report and for NPD1, 9 students attained 80% and greater of marks, while 6 students attained 80% and more of marks for ENT day presentation.

4.2 Students' Performance assessed based on traditional OBE approach

Figure 4.2 shows the percentage distribution of marks attained by the students using traditional OBE. The assessment tool namely; case study, new product development 1, new product development 2, blueprint and ENT day for the control group consists of 30 students undertook ENT600 in Semester March 2017.

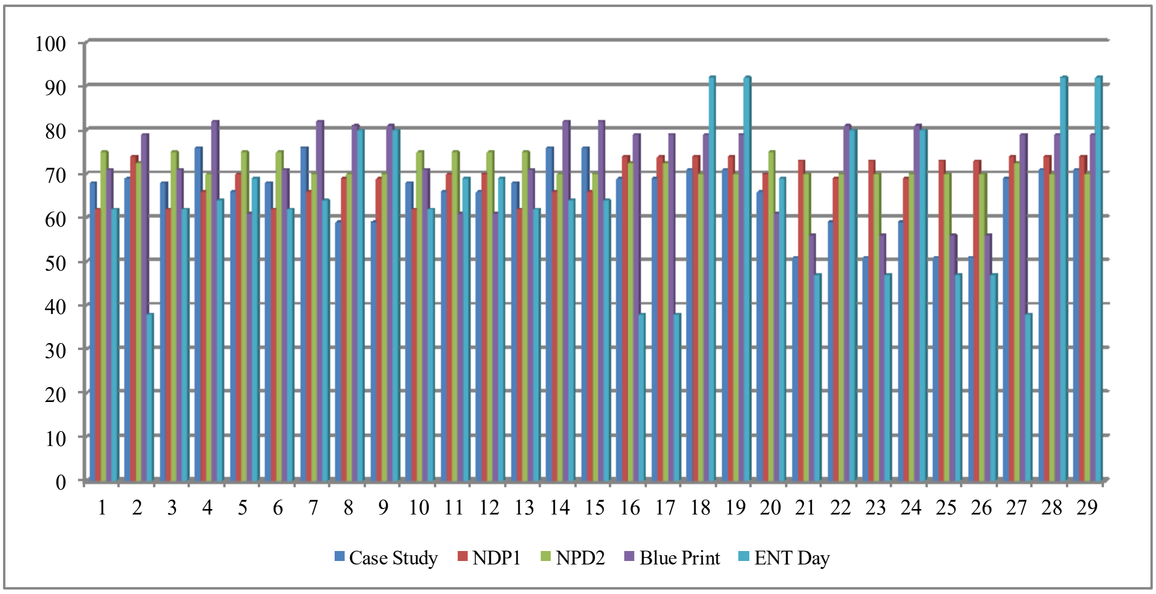

Figure 4.2: Percentage Distribution of Marks for Control Group

Using the traditional approach, 8 students attained more than 80% of marks for blue print report, while 4 students attained more than 80% of marks during ENT day presentation.

Figure 4.2 shows a comparison between the average marks for both groups of students. Higher marks of more than 70% were obtained by 27 students (90%) in the DT groups as compared to only 10 students (35%) in the control group who obtained less than 70%.

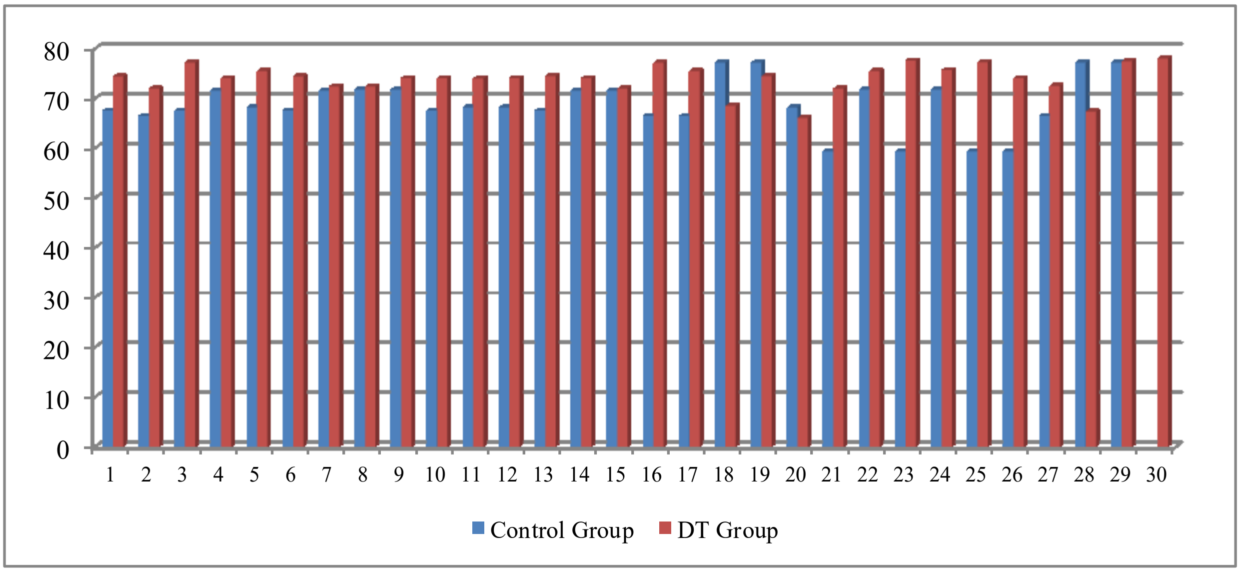

Figure 4.2: Percentage Distribution of Average Marks between the Control and DT Groups

4.3 Coefficient of Variation between Two Samples

In order to differentiate the students' attainment, coefficient of variation for both groups is determined as shown in Table 4.1.

Table 4.1: Statistics for Both Groups based on Mean, Standard Deviation and Coefficient of Variation

	DT Group	Control Group
Number of Students	30	29
Mean (M)	73.9	68.9
Standard of Deviation (SD)	2.85	5.12
Coefficient of Variation (CV)	3.85	7.43

In this study, comparison was made from two groups having different learning mechanisms; DT Group was exposed and measured through DT approach while the Control Group was not exposed to DT approach. However, both groups are measured using the same assessment tools. The mean value for DT Group is about 5% greater than the control group. In terms of coefficient of variation (CV), the DT Group has a CV of 3.85% and Control Group has a CV of 7.43%. Thus, Control Group has larger variation, relative to its mean as shown in Table 4.1. Therefore, it can be concluded that assessment of students using DT tool has less variation, relative to its mean. It indicates that consistency of assessment using DT tool was evident in attaining the direct and explicit measurement of outcomes. These findings in this study suggest that design thinking can be a relevant methodology for supporting course (re)design efforts in engineering education, but that these efforts may be impaired by individual participant knowledge and mindset (Fila et al., 2018).

5. CONCLUSIONS AND RECOMMENDATIONS

An implementation of DT integrated with CDIO approach is a simple but effective way to nurture a new generation of instinctive lateral thinkers and problem solvers like engineering students. From the literature and limited study conducted, several conclusions can be drawn. First, design thinking (DT) through five (5) processes can be utilized to develop innovative ideas among the civil engineering students to solve complex engineering problems. The DT - CDIO integrated method can be used to develop personal and inter-personal skills of engineering students. The five (5) criteria of DT can be mapped with the traditional OBE assessment tool for direct and explicit measurement of the course and programmed outcomes. The performance criteria to assess students that exposed to the integrated DT-CDIO concept to solve problem given were developed to ensure consistency and fairness by minimizing variations throughout the assessment process. Finally, it was deduced that teaching delivery together with assessment tools for students engaging DT-CDIO approach could be implemented for engineering students in general to fulfill and complement the EAC requirements simultaneously. It is recommended that a modification on assessment methods based on DT approach is used as an accompanying method to evaluate the students' outcomes that contributed to the designated outcome of this ENT course. It is recommended for future study to explore methods to support an effective adaptation of design thinking in engineering course design contexts and to thoroughly understand the nature of engineering course design and the role design thinking can and should play in such efforts.

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