Fostering Students to be Interpreters for Enhancing Creativity in the Engineering Course

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INTRODUCTION

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This study references Conceive-Design-Implement-Operate (CDIO) [1, 2] approach. Creativity practicing and innovative methods such as Design-driven innovation (DDI) [3] are added to the courses. A group of interpreters is formed to try and achieve DDI through constantly listening to design discourse as well as interpreting and addressing the process of design discourse. Creativity and design concepts were added to an Electronic Circuitry class. The students, teachers, Teaching Assistants (TAs), researchers, and experts from the course were put together as a group of interpreters. Aside from the teacher offering electronic circuitry related experience and experiments, design thinking activities and lectures were added to the course. This gives students many methods to interpret and address their design discourse. Students need to complete group objectives in activities using the three phases conceive, design, and implement. Aside from practical design and actual creating, students also need to learn how to address their design discourse which helps foster students into interpreters, and also strengthens the students' creativity in their projects.

This study uses peer evaluation as well as course teacher, TAs, industry/education experts offering final creativity evaluations. This helps understand the results of strengthening creativity through fostering students to become interpreters. This also compares the differences of projects from different semesters that have and have not used design-driven innovation strategy. On the other hand, class teacher and TAs can observe as well record the performances of students in order to evaluate them. The study results show that through the use of the new DDI strategy in fostering students in this course to become interpreters can strengthen the creativity of their school projects and variety of the topics chosen. In order to achieve their goals, each group of students would work together to design a goal, constantly discuss, fix problem, implementation, evaluation, and exhibition. The results show that the creativity and design abilities of engineering students have indeed strengthened which also results in a better learning experience and efficiency.

1 BACKGROUND

As the Internet grows, industries are looking to require talents who possess both digital and design skills. The methods to integrating design and creativity into engineering education and thereby allowing students to learn in these fields is the goal of this study. It has been discovered in previous studies that good education environments can help inspire and foster student creativity [4, 5, 6, 7, 8, 9]. The planning and design of education content is also one of the key deciding factors of this. Therefore, the highly regulated traditional education flow in the current education system needs to be changed and be properly designed as well as planned to help create a creativity education system [10]. Bordogna and other authors have said that in an education system's elements, multiple courses, practical design, teamwork, and problem discovering/solving can all be used as a basis core for course design and thereby creating a course for fostering creativity [10]. After creative thought has been created, practical assignments and projects can be used to assess the students' creative outcome [11, 12]. Under the standard of CDIO [1, 2], it can be realized that to create an engineer, besides needing "Introductory Course" and "Integrated Curriculum", adding "Design-Implement Experience" and industry related information is necessary. To more adapt to industry needs, engineering education need courses which foster thoughts of creativity in students. Examples of creativity being fostered can be seen in many successful companies. The strategy they used is a form of radical innovation which is called DDI [3]. As a part of this, the design discourse is often used by a group of cross-disciplinary interpreters to achieve DDI through constantly listening to design discourse as well as interpreting and addressing the process of design discourse.

Therefore, the aim of this study means to use methods/tactics CDIO, Brain storming and DDI to engineering courses in order to foster students to become interpreters which in turn strengthen their creativity.

1.1 Conceive-Design-Implement-Operate (CDIO)

In current cases of engineering education reformation, the CDIO engineering education framework is one of the most influential reformations in Europe in recent years. The design inspiration for the CDIO engineering education comes from the four phases (conceive, design, implement, and operate) of system and products and acts as the whole background for its life cycle. With the CDIO outline and standard acting as the basis and an emphasis on integration style course design, students can have a firm grasp of basic and professional engineering knowledge. Through active learning, problem-solving guided learning, and teamwork, they can acquire skills needed for engineers through innovative and practical training [1]. Conceive means to use methods like questionnaires, brainstorming, and the blue ocean strategy to analyse the needs of the client as well as consider needed skills, business strategies in order to develop a conceptual business plan. Design means to uses methods like Auto CAD and MATLAB to describe product design with a detailed amount of information, or design product blueprints. Implement means to use tools like 3D printers, CNC, and RP to transform design thoughts into products or systems, which include software/hardware development, system integration and testing. Operate means to improve designed products and tend to a product's sales, logistics, customer service, management, recycling, and improvement [2]. This study's course structure uses a product's life cycle starting from its development to its operation as its background, and mainly advocates changes in the course design and implementation environments. Through the use of the CDIO talent growth philosophies and experiences, the course structure for electronic circuitry classes can be redefined to allow for students to be able to grasp basic and professional engineering knowledge. Also through active learning and problem-based learning methods, students can develop abilities including teamwork and design thoughts.

1.2 Brainstorming

There are many ways to turn imagination into creativity and different methods have different suitable times and places as well as pros and cons. The most famous is Osborne's brainstorming method which involves the participants brewing creativity face-to-face [13]. The basic rules are told before the session starts to lessen peer pressure of those involved and to inspire creativity and design as well as strengthening the overall creative potential of everyone. To inspire creativity and design, visually guiding the team in brainstorming is one of the most common methods [14, 15]. Sibbet proposed that when visually guided, the team displayed three experiences: Participation, Big Picture Thinking, and Group Memory [16]. When people in the discussion see their thoughts being recorded, they will feel listened to and acknowledged because the amount of thought they put into the discussion was granted involvement. Then as the group begins to think using a big picture, they can more easily remember discussions visually through use of message comparison, discovery, and collaborated blueprints.

1.3 Design Driven Innovation (DDI)

It can be seen from many successful examples in businesses that to successfully create a competitive and publically loved product, not only is a beautiful appearance and adhere to market appeal needed, but looking for innovations in product design is also needed. In recent years many corporations have begun advocating use of the Innovation Management Scholar Roberto Verganti's proposed DDI [3].

DDI isn't working behind closed doors. It's done through a network of interpreters who understand the situations from the lives of users. Only through many different encounters through different angles can one learn how to think of out the box. In the flow of DDI, interpreters will take part in design explanations, and through direct or veiled methods, they will use methods such as works, prototypes, lectures, products, discussions, or proposals to continue communications and conversations. These are mainly composed of listening, interpreting, and addressing and continue without stopping.

2 ENHANCE CREATIVITY IN ENGINEERING EDUCATION COURSES

Although normal universities have complete learning maps, but there is a lack of experience in innovative design after basic knowledge is learned and professional skill is practiced. The CDIO engineering education framework mainly fosters skills in four measures including basic engineering knowledge, personal abilities, interpersonal/team abilities, and engineering system abilities. Based on the CDIO, we focus on how to redesign engineering courses to allow students to strengthen their own and the group's creativity in addition to learning professional knowledge.

2.1 Engineering Education Courses Design

This study's test subjects are 2nd year university students taking an Electronic Circuitry class. Starting from the 102nd academic year, this class started to require compilations of information of the final projects of students. Two different course changing methods were used in the 103rd and 104th academic year respectively to try and foster the students' creativity and innovation in engineering education. The 102nd academic year's course was used as this study's control group. The course content only focused on engineering experiments and practical tasks. In the 103rd academic year's course, we used extracurricular times to host after-class clubs which invited experts and scholars to share knowledge regarding new tech with its members. Also there were creative thinking training exercises which fostered creative thinking abilities in the club members [2]. In the 104th academic year we redesigned the course structure to include CDIO. Students can use a course structure filled with theories, DDI tactics, brainstorming activities, and experimental learning to increase abilities regarding active learning and group-based creative thinking.

Based on CDIO's design flow, we can break down the course into the phases of conceive, design, implement, and operate. From regular experiment classes to creative thinking activities to final projects, we let the learning methods of students follow a similar pattern to an engineering product's cycle of starting from conception, product blueprinting, developing and then improving the final product. The gradual method of learning can help students more firmly grasp the key points of each phase. The semester syllabus can be seen in *Table 1*. The normal device controller practice will act as practice for the practical phase which helps students to better understand how to use and integrate skills. As for the creative thinking activity course design, it is mainly designed to foster design thinking, proposal abilities, and student confidence.

After experiencing enough training, the activities will be extended to fostering prototype design skills which can let students more completely express their used scenarios and design concepts. After many more practices, the results will be reflected on the students' end-of-semester final projects. Through the uses of the CDIO flow and the DDI tactics, the students will have been able to strengthen their project's narrative and expression of concept.

Table 1 104th Academic Year Electronic Circuitry Experiment Class Syllabus

week	Syllabus	Brainstorming
1-4	Class introduction, Arduino, Digital I/O, Analog input	
5	Analog output	Creative Paper Lamp Project
6-7	Power supply, relays	
8	Tangible User Interface	Interactive Rag Doll
9	Mid Semester Project Progress Report	
10-11	Introducing other digital sensors, internet of things introduction + computer internet knowledge	
12	Weather Watching Station, Internet Frontend Interface	Interactive Room
13	Internet Controlled Motor Turning	
14	Internet controlled relays	
15	Arduino asynchronous operation	
16	End of Semester Project Proposal Report and Recommendations	
17	Prototype	
18	End of Semester Project Progress Report	

For the final project, students are free to use the knowledge they learned about engineering and scenario thinking abilities they learned from brainstorming to conceptualize a creative project. Before creating the project, students will create a presentation explaining their thoughts, structure design, and applied scenarios. Before beginning development, teachers and TAs will also give feedback to help students make new discoveries or improvements. During development, students will also interact with one another regarding similar structures or parts due to knowing each other's projects. They will also discuss amongst themselves or with teachers and TAs which will in turn increase learning efficiency. On the day of the exhibition, students will use presentations, videos, and live showcases to explain their project prototype. The teachers would give these prototypes new meaning and language as well as give feedback to the student. The students would fix or add to their project based on this feedback. The teaching team would also change the course material for next time's design explanation.

2.2 Applying Brainstorming to Conceive Stage

After each class, students will be asked to create a practical example of what was taught that class in order to booster learning effectiveness. Through the practice of professional knowledge during this class, we hope that it can spark an interest in students and allow them to design new works through the process of learning and thinking. After students have finished phase based knowledge learning, we plant in differently themed brainstorming activities into the course with 5-7 students in a group. Each group will have a host who hosts the discussion and records the process [17]. This achieves the purpose of creative thinking training through solving different problems and also strengthens the students' abilities to design prototypes, propose projects and work as a team.

The first brainstorming event has creative paper lamps as its theme. First the teachers would lead the students in thinking of scenarios and how light can be used to further the design of a lamp. After a diverse amount of thought, students will start to refine each idea and put them into groups. They will then discuss their thoughts on the idea and how to potentially integrate them. Finally during the proposal, each group will go on stage to present their drawn blueprint prototype and explain what their idea is.

The second brainstorming event has interactive rag dolls as its theme. During the conceiving phase, we would give each doll a random living environment and allow students to discuss what possible traits and personalities each doll would have under its own environment. In the design phase, students would have to further add the knowledge they have learned into their thoughts. Then the backstory of the dolls would be explained and a prototype could be made. The teacher and TAs would help students create the functions they want based on what electronic parts were available. Finally, they would go on stage to report on their concepts and practical prototype. This allows everyone to use the knowledge they have learned to breathe new life into older objects.

The third brainstorming event has interactive rooms as its topic. First, every student was asked to take a picture of a space in their own home. Students were asked to design an environment based on random story scenarios. Every group would then pick the most creative and start designing a prototype. In the design phase, students can think from the perspective of the IOT's functions on how to set up interactive devices based on the room's used scenario. Finally, students will explain their room's design concepts to everyone and explain how this space can be renovated.

2.3 Enhancing Students Creativity through Design-Driven Innovation (DDI)

After setting the course in accordance with the CDIO, this study will focus on adding the tactics of DDI into the course to foster students to become interpreters and strengthening their creativity. During the class, there were three brainstorming activities, one academic expert lecture, and one industry expert lecture. Based on the methods of DDI, this class can be viewed as the whole hierarchy of a design department. Every single student, TA, teacher, academic expert and industry expert who is a member in this class is also a member of the design discussion, also known as interpreters.

In the course preparation phase, teachers and TAs will discuss and edit their course material many times in order to ensure that the course content is rich and well-paced. Academic experts will also be invited to join in discussions. The teacher will also invite experts in related fields to give lectures based on the content of the course and industry needs. During the execution of the class, teachers will teach students basic knowledge regarding engineering and circuitry practice. The TAs will also help students solve logical problems. Students, teachers, and TAs will also use the internet and social groups to discuss advanced knowledge and solve problems outside of class. Regarding related lectures in the class, experts will first discuss with the teachers and TAs what needs to be prepared beforehand and during the lecture itself, they will discuss industry knowledge with the students, teachers, and TAs.

Through the interaction in this class, interpreters can have many methods to listen and interpret each other, explain their surroundings, and give new meaning as well as langue to the outside world. Students can use regular classes, TAs can help create presentations, and experts can use their gathered industry knowledge and experience to enter the listening phase. Interpreters can also find new discoveries and meanings from listening to each other explain their design. For example, besides learning about professional knowledge and industry applications during class, students will also interact with teachers, TAs, and experts. Teachers and TAs can fix and teach parts of the course where the student is confused and experts can get a different kind of feedback from students. In the interpreting phase, students will use the knowledge that they learned from the experts during design explaining and add new thoughts into their production. Teachers and TAs will adjust the course content and course presentations according to the students' learning situation. Experts will also add knowledge that they deduce students may need through interacting with them. At the end of the course, students can explain how they used knowledge through showing their prototypes. Teachers and TAs will showcase their adjust course content. Experts will collect the students' feedback and use it in other lectures. The feedback after the explaining will affect the interpreters and in the next listening session the whole cycle will start again.

During brainstorming activities, DDI tactics and pacing can also be implemented. After the teacher and TAs start the session, students will first try thinking and go on stage to express their thoughts for all of the interpreters (Students, TAs, teachers, and Experts) to listen to and gain more knowledge. After entering the interpreting phase, students will propose their thoughts and organize the statements made before to conceptualize scenarios and products related to the theme. In the final explaining phase, each group will go on stage to share and explain their philosophy through their drawn prototype and express their vision to the interpreters.

2.4 Assessment of Student Creativity

Creativity can be presented through many ways such as appearance, function, and structure. Based off of traits of the DDI interpreters, CIDO engineering education ability fostering measures, and course goals, we defined the following assessment items to act as the grading standard for the students' final project. In DDI, the organization of the interpreter's knowledge can show their skill's depth. The concept competition amount and development completion amount can be reflected off of the interpreter's explaining abilities. Originality and story elements can be reflected off of the interpreter's brand new thoughts and abilities to give new meaning.

1) Skill Depth: The use and organization of skill
2) Concept Completion: The completion amount of the project
3) Development Completion: The technical completion amount of the project
4) Live Expression Ability: The expressive abilities of the present interpreters
5) Originality: The originality of the design concept

Creativity has multiple layers, such as a new machine's design, skill, programming structure, or methods. Another example is a new internet service's style, hardware/software integration or applications. This study reestablishes its creativity assessment after analyzing creative assessment theories. The four items of the original Torrance Test [18] were added to Abbreviated Torrance Test for Adults [19] to assess student creativity. Its items are as follows:

1) Fluency: The ability to create a large amount of idea related to the topic
2) Fluency: The ability to use different methods to process information and items regarding the project.
3) Originality: The ability to create unusual, brand new, or special ideas.
4) Elaboration: The amount of detail in the project. No extra marks are awarded for repeated details.
5) Topic: The ability to specifically name and describe items as well as the use of words and how complicated the content is.

3 DISCUSSION

In this section, this study will compare the results of the final projects and creative performance of the Electronic Circuitry class from the 102nd and 104th academic year respectively. The 102nd academic year's course will be the control group. Its course content focuses only on engineering content and practical tasks. In the 104th academic year's class however, we implanted creative thinking into the class which allowed for the students to use their professional knowledge creatively while at the same time learning engineering content. The assessment items for this study are divided into three items :(1) Teacher Final Assessment, (2) Peer Assessment, and (3) Design Expert Creative Assessment.

1) Teacher Final Assessment

The final projects by students from each academic year are evaluated based on presentation and display, and overall advice and possible fixes are given.

2) Peer Assessment

Every group of students would go on stage to explain their projects and each group of students would grade each other based on the use and integration of skill as well as showcase of creative and design abilities.

3) Design Expert Creative Assessment

The experts would evaluate the final student projects of different academic years from the same class based on creativity presentation and overall advice and possible fixes is given.

3.1 TEACHER FINAL ASSESSMENT

In the final project presentation event, students will use presentations, videos, and live showcases to present their project to the other interpreters. The interpreters include teachers, experts, TAs, and students of other groups.

In terms of skill depth and development completion, the teachers think that when comparing the 102nd academic year and the 104th academic year, the two classes have been taught nearly identical skills. In terms of skill difficulty, the difficulty of the two years' course material was similar, but in terms of the depth of applying the skills, the students from the 104th academic year were able to more easily combine different parts as well as being bolder in their project development and design concepts. Their development completion was also higher than those of the 102nd academic year.

In terms of live expression abilities, results show that the 102nd academic year students were more focused on completing the engineering end of things and the 104th academic year students decided based on what scenarios the users may find themselves what parts they would use and could see the user scenarios for every part in their final project. This is due to them having participated in the course's brainstorming practices. In general, when comparing the projects from the two academic years, the ones from the 104th academic year had more meaning and could be applied to daily life. ◦

The project types from the students of the 102nd and 104th academic year can be seen in *Fig*. 1, and after the teacher discussed with the TAs, their consensus was as follows:

1) The 104th academic year's students chose a more diverse range of topics and covered more different ones overall.
2) In the development process, students of the 104th academic year actively asked the TAs questions and asked them what the creative realization viability was for their projects.
3) In the execution process, the teachers think that besides having better creativity, the students of the 104th academic year were braver in facing problems that challenged their creativity during execution.

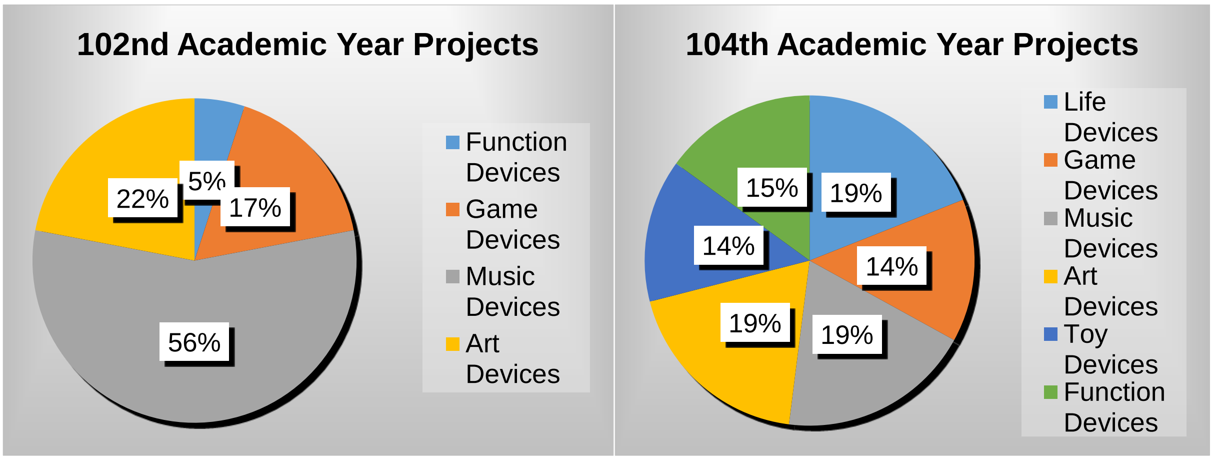

Fig. 1. Comparisons and Differences between the Project Types of the 102nd and 104th Academic Year Projects

3.2 PEER ASSESSMENT

The 104th academic year's class has 42 students attending it with it divided into 21 groups consisting of two students each. When the final projects are being presented and explained by each group of students, other groups of students will grade the group who is on stage at the time based on use of skill, integration, and assessment of design and creativity. In the 21 groups of students, their projects can be divided into categories of life, game, music, art, toy and function. As for the overall assessments, the toy devices were overall graded the highest and the function devices were graded lower in comparison. Life and music devices had a very large difference in its grades, and the game and art devices achieved normal grades.

The students from the 104th academic year generally expressed that when they were thinking about their projects, they would think in many different ways and that past experiences would affect the results of their thought (For example students who played guitars would use guitars as their creative direction). In the conception phase, students would go onto the Internet to look up related creations or examples. They would also watch related videos for inspiration. In the design phase, they would deduce and rehearse possibilities for execution and also propose some possibilities for execution as well. In the actual operation phase, they would spend extra effort experimenting parts that they thought were difficult. Finally, as a result of understanding each other's projects, the students would challenge themselves to look up software or hardware that the class did not teach in order to strengthen their own project's originality.

3.3 DESIGN EXPERT CREATIVE ASSESSMENT

This study invited five design field experts to assess the creativity of each academic year's student's final projects and videos. The assessment items include Torrance's creative measures: Fluency, Flexibility, Originality, Elaboration, and Topic. The results are seen in *Fig.* 2. In the assessment results, the 104th academic year was graded higher than the 102nd academic year.

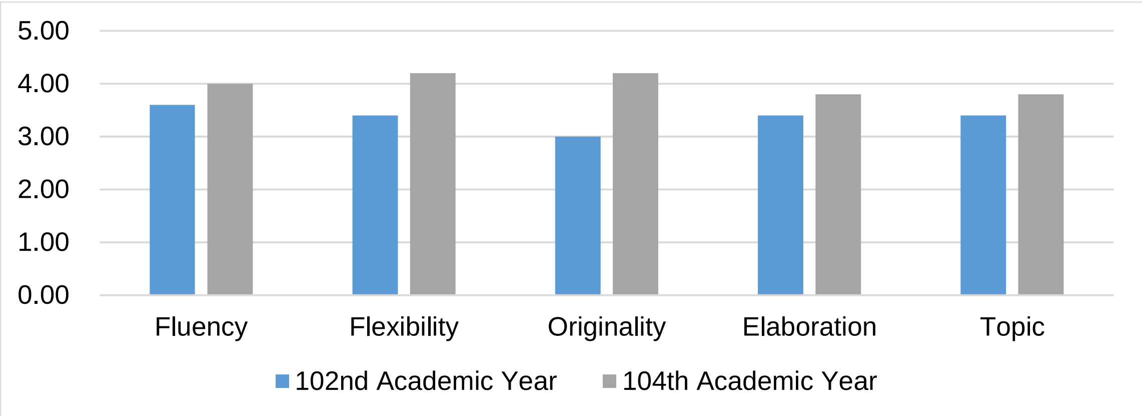

Fig. 2. Design Expert Creative Assessments

The consensus of the judges was as follows:

1. Whether it was in creativity or completion amount, the 104th academic year's students showed improvement, which shows that the CDIO helps in fostering creativity, inspiring conceptual creativity and motivates students to finish their actual project. Their average performance was an improvement the 102nd academic year students.

2. In conceptual design, the 104th academic year's students were more creative due to the appearance of new structures.

3. Judges recommend that theme conceptualizing and design can be started early, and also motivate the integration of hardware and software.

4. In terms of originality, the judges think that in terms of themes, the 104th academic year's students were able to more obviously conceptualize brand new or original ideas. As for flexibility, the judges think that the 104th academic year's students were

able to more obviously display abilities to use different methods to organize information and objects.

4 SUMMARY

This study uses teacher assessment, peer assessment, and design expert creative assessments to understand the effectiveness of fostering students to become interpreters to strengthen their creativity. The final projects of semesters with and without CDIO tactics are also compared. After the interviews and assessments during discussion, it was found that the same 18 weeks long course was able to allow students learn more skills and thinking abilities in the 104^{th} academic year which had applied brainstorming to its course and added IOT to the professional knowledge. This strengthens the learning effectiveness of the students. From the results it is shown that the projects of the 104^{th} academic year's students had more useful scenarios which creates the project more valuable, has meaning, and is a usable product. Due to DDI emphasizing giving products new meaning and boldly proposing idea to the public, the students in the class were able to bravely integrate what they learned into their project's meaning. This fits the proposal of this study of fostering students to become interpreters in order to strengthen creativity.

The study results show that through use of DDI tactics, the teachers can lead students in brainstorming activities which will create a design filled environment in the engineering class which will foster students to become interpreters. This will strengthen the creativity and diversity of themes of students in their final projects. Each group engaged in repeated discussions, adjustments, executions, assessments, and presentations in order to achieve their shared design goals. The results show that the creativity and design abilities of engineering students have indeed strengthened which also results in a better learning experience and efficiency.

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