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A design thinking approach to develop entrepreneurial skills in the field of Mechatronics Engineering

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Abstract— **This paper discusses the utilization of design thinking process in the entrepreneurship classes, which involves problem-solving approach, creative thinking and procedural steps to solve the problems. The entrepreneurship training classes facilitate the students to address the real-world problem through the real-world skill development activities. Entrepreneurship education leads the students to develop projects with the outcome as societal beneficial product or service. The students' expertise after attending the class will be incredibly useful for resolving the problems which need an immediate focus like Covid-19 and post pandemic situation. The case study discussed in this paper describes the growth of an engineering student into a technopreneur, who uses design thinking to solve the societal problems. This case study comprises the framework as follows: The first framework is based on Outcome Based Education (OBE) and Choice Based Credit System (CBCS) for Batch 1 and 2, and the second framework with Batch 3 on Conceive Design Implement (CDIO) and Operate framework. According to the findings, students of Batch 3 outperformed than the students of Batch 1 and 2 in applying higher order thinking abilities to turn a prototype into a working business model. As a result, the CDIO framework is ideally suited to the development of engineering abilities into the entrepreneurial opportunities.**

Keywords— CNC machine, Design thinking, Technopreneur, societal problem.

I. INTRODUCTION

THE Entrepreneurship is quickly gaining traction as a way of accomplishing large-scale commercial objectives by solving problems and bringing the proven business models from the proposed solutions. It is essential for the college students to understand entrepreneurship and its significance. The early exposure of students to entrepreneurship encourages them to think and dream big. They will gain valuable problem-solving skills by learning and mastering the course. Learning many practical terminologies such as effectuation principles, business models and marketing tactics take time after graduation, and hence gaining knowledge about these concepts at younger age is highly advantageous. Students who are introduced to the problem-solving skills through entrepreneurship courses have the best chance of being recruited by large corporations and setting up their own start-up. Primarily, design thinking is used to find solution for any type of problems. This approach aims at addressing the complex problems and finding the solutions and thereby transforming them into a business model.

Learning the human centric problem-solving ability shall be beneficial in future, especially when dealing with pandemic like COVID -19. Adequate expertise in problem-solving ability may help the learners to tackle significant problems by providing inventive solutions, which in turn provide lot of opportunities to many other people. Any Entrepreneur would view the crisis as an ocean of opportunities. Many start-ups grow during pandemic as they found solution for the problems using design thinking and other entrepreneurial tools. Entrepreneurship has been escalating for the past two decades as means of boosting a country's economy.

In the early 1970s, only a few colleges or universities offered courses in entrepreneurship but by 2005, around 1600 colleges offered this course for their students for learning and practicing. Donald F. Kuratko argued that regardless of challenges, curricular initiatives on new venture formation have been found extraordinary. Entrepreneurship is defined in a variety of ways depending on the perspective of the individual.

Scott Shane (2004) defined entrepreneurship as 'an activity that involves the discovery, evaluation and exploitation of opportunities to introduce new goods and services, ways of organizing, markets, processes, and raw materials through organizing efforts that previously had not existed'. Similarly,

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Stevenson and Jarillo (1990) stated entrepreneurship as the process by which individuals pursue opportunities without regard to resources, they currently control. According to Thomas. M. Cooney et al. (2012), critical thinking and problem solving are recognized as the vital talents for entrepreneurs but concurrently risk-taking, invention, creativity, and teamwork should also be valued more. A more hands-on approach may develop the financial abilities and project management skills. Michael H. Morris et al. (2021) in one of their research projects, highlighted that case studies, games, projects, simulations, real-life actions, internships, and other hands-on activities can be used to teach entrepreneurship skills.

Steven P. Nichols (2003), et al., argued that engineering institutions must offer both theory classes and thinker lab to encourage engineering entrepreneurs. This may train the learners to address the engineering issues in a social setting. Further, it develops the students' leadership, innovative thoughts and creativity, which are important factors that add value to the student's career. As engineers are preparing for the fourth industrial revolution, Industry 5.0 requires entrepreneurs undoubtedly to solve the societal challenges. A survey of 500 engineering students from three different institutions that provide entrepreneurship courses was undertaken. The study aims to evaluate the level of achievement of entrepreneurship course outcomes as well as the characteristics of students participating in course activities. It was found that over two-thirds of the students were willing to work for large corporations, and a matching percentage proved that this would extend their career opportunities. Also, the entrepreneurial self-efficacy was higher among students who took one or more entrepreneurship courses.

The current predicament concerns the covid-19, and the discovery and spread of the corona virus, has put several governments in a precarious position. Large swaths of society and economy have been shut down because of the lockdown. It halted the work in variety of industries, such as production industry, entertainment industry, academic institutions, sports, technology firms, markets and even the least inventive start-ups. Many innovative start-ups were threatened by the emergence of the new corona virus. The shutdown due to the spread of the corona virus had a variety of consequences in various industries having higher impact on the economy as well as the lifecycle of the human beings. According to an investigation, the lockout has harmed numerous Small and MEdium (SME) scale companies and businesses that had a high level of job maintenance.

Abu-Rumman et.al (2021) stated that the SME growth is more important for all growing countries and hence suggested to provide opportunities to all SME industries to grow further. Many people lost their jobs, and many businesses crumbled due to the pandemic. In current crisis, strong strategic thinking and entrepreneurial orientation are essential for the board of directors to help resuscitate jobs and enterprises. Design thinking, which is the problem-solving aspect of the entrepreneurship, may solve the difficulties of small-scale enterprises and other businesses.

Wei Xingjian et.al (2019) proposed that the design thinking concept is an analytic and creative process in which a person is encouraged to explore, and create prototype models, collect feedback, and rethink. This method aids not only in the resolution of real-life issues, but also enhances numerous personality traits such as creativity, imagination, and planning. It is critical for the students to understand the design thinking process to improve their problem-solving abilities.

This paper presents a case study on a team of engineering students who had finished an entrepreneurship course and uses design thinking to solve the problem of people in small-scale industries. The first chapter of this paper contains the paper's abstract and the literature survey. The methods of design thinking are illustrated in chapter 2. In chapter 3, the outcomes of the experimental case study are analyzed and the application of ANOVA to group and analyses the data of each student individually. Chapter 4 deals with the implementation of final thoughts and plans to enhance the students' involvement further in various case studies

II. Proposed Design thinking model

David Kelley, creator of first mouse of the Apple company, found the Design Thinking Process in early 1980s. This model is an interactive process, created to understand the user's problems and requirements to solve the problem. It is a helpful process as it is categorized by different stages and has clear understanding about the requirements at each stage. This process helps all the big firms that are product as well as service based. It is more like a common process which can be adopted by any business company to solve their problem.

The process consists of 5 stages that has a continuous flow to solve any problem. The 5 stages in design thinking process are:

- Empathize
- Define
- Ideate
- Prototype
- Test

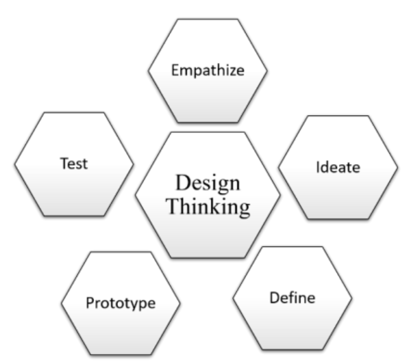


Fig 1. Overview of design thinking process

In this case study, a team of engineering students who have completed an entrepreneurship course, employs the design thinking process to solve the societal issues. As a first step, research was conducted using the questionnaire or survey to identify the various problems, its severity and urgency with which it must be resolved. Next, an empathy map was built using the answers obtained from the questionnaire. This map comprehended all the aspects of the user in one picture. In this survey, students used the google forms to collect feedbacks on the existing cutting and engraving technologies. The survey also inquired the people who are working in small-scale industries like making gifts, designing firms, shape cutting firms, paper chart cutout and so on. A survey was conducted to the people working in gift domain. The sample questions the survey are as follows: What type of business they run? what are the items they sell? and what were the machines they use?. Figure 2 and 3 show the findings obtained in the survey. The empathy map was produced using the results and after interacting with the individual stake holders and table 1 gives the comments for the ideas and the Figure 4 shows the team activity ranking in the brainstorming session conducted by the mentor.

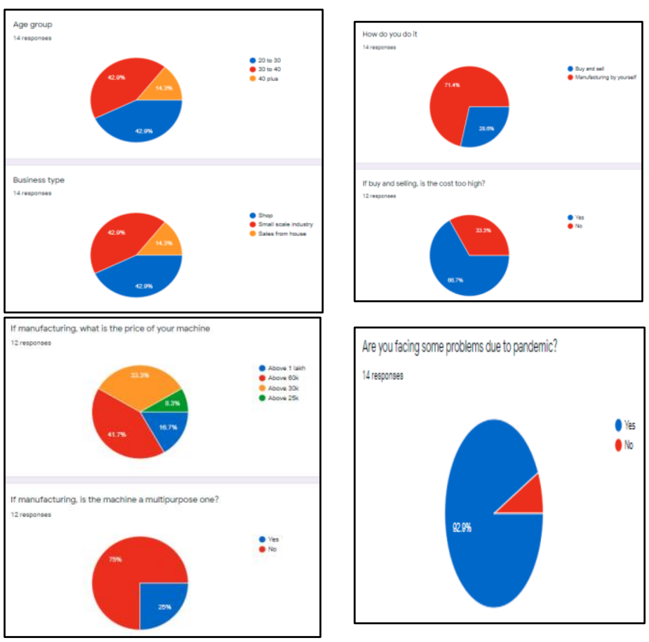


Fig 2: Empathize stake holder survey responses

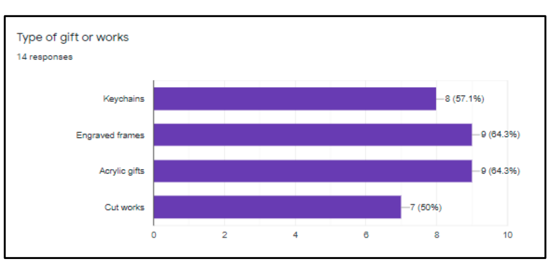


Fig 3: Stake holder survey questionnaire responses

A SWOT analysis was developed based on the survey results. SWOT analysis is a project planning tool that identifies stakeholder strengths, weaknesses, opportunities, and threats. We learnt about the stance of our stakeholders using this analysis. According to the data collected, most stakeholders expect a few adjustments to the current method and also gadgets for cutting, engraving and designing in gold smithy.

TABLE-1:
SWOT ANALYSIS FOR GOLD SMITHY BASED ON EMPATHIZE SURVEY.

SWOT ANALYSIS

STRENGTH	WEAKNESS	OPPORTUNITIES	THREATS
1.Existing business customers. 2.Availability of raw materials at low cost 3.Good machine and high production capacity	1.Lack of capital due to pandemic 2.Less number of labours for working 3.dequate supply	1.Chance of developing new business ideas 2. launching of new varieties 3. Development of new machinery and gadgets	1.Import of readymade design. 2.Due to pandemic, the business may come to a halt for a period of time. 3. Lack of designer availablity

TABLE-2
MENTOR SUGGESTIONS ON BRAIN STORMING ACTIVITY

S.NO	IDEAS	COMMENTS	RANK
1	Purchasing of articles directly from the manufacturer	It might not be possible for everyone	2
2	Be as a supplier from manufacturer to the wholesale customers	It is difficult to change of a sudden	5
3	Start manufacturing by buying second hand machines	Cost may be inappropriate and no guarantee	3
4	Do something similar using manual labours	Getting labours is tough and finishing is not good	4
5	Developing a low-cost machine which can be useful	It can be tried once but efficiency may vary	1
6	Buying high efficiency machines from foreign countries	It may be costly and deliver late due to pandemic	3

A brief investigation was conducted into the current prototypes, which were all Do it by yourself (DIY) projects. These machines were designed from the scratch to provide them as a finished product in the market. The entire setup was kept open with a tiny work area. The idea of constructing a low-cost machine received the top ranking during the brainstorming session, and so the following step was taken to obtain the final product. Any product's design is the initial need and it must have a finished design which is appealing. Hence the design must be made in such a way that it appears to be a product machine rather than a project. The prototype and product must be distinct from the other prototypes available. Design, components, assembly, workspace requirements, and so on are the things to be considered while creating a prototype.

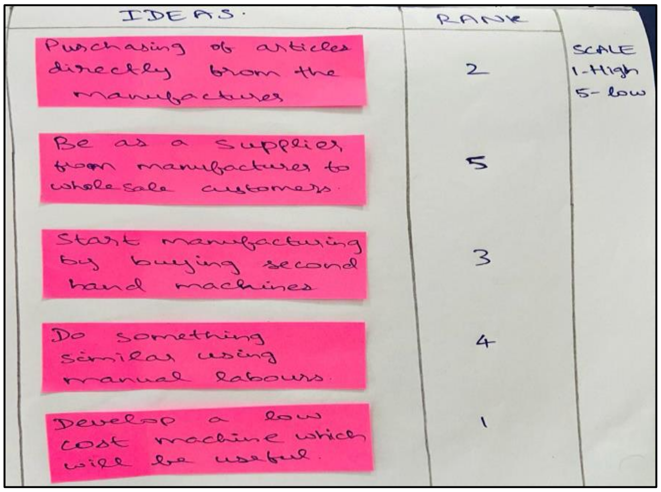


Fig 4: Brain storming team activity sticky notes ranking

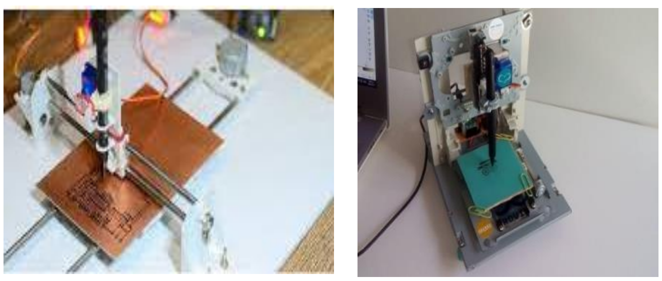


Fig 5: Models suggested in Journey map

This is an experimental stage in which the solution's model, which is a replica or visual representation of the final product, is created. While prototyping, many factors such as cost, features, design, and aesthetics must be examined. The ability to solve the challenge can be shown in the developed prototype. The final product can be developed only if the developed prototype is deemed successful after a few tests. If the prototype fails to match the stake holder expectation, a new prototype is constructed. The learners are the engineering students who are aware of the stages involved in constructing a prototype. So, with the problem statement in mind, a preliminary sketch of the working model was developed. The required components for the prototype's operation were listed as stepper motors, servo motors, an Arduino board, a CNC shield, and other miscellaneous components. The CAD model was developed with the components listed by Batch 1. In the prototype design, students proposed three models with continuous feedback received from the stake holder. The translucent 2.7mm acrylic sheet was used to create this prototype. Laser machines were often used to cut the pieces, with the CAD model as the input. The components were fitted once the chopped portions had been assembled. The Prototype model 1 is designed to draw the pattern provided by the customer.

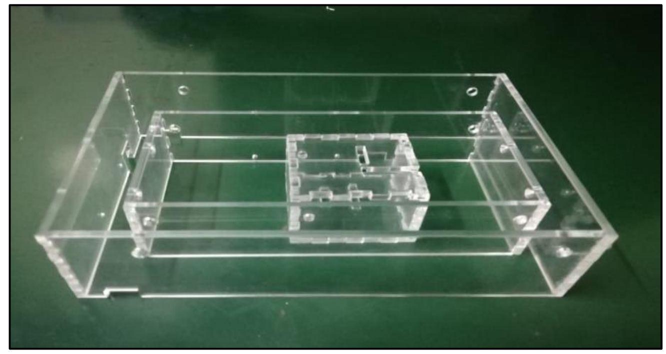


Fig 6: Assembled outer frame of prototype 1

The model's dimensions were small, and so a hardware structure is designed for plotting (drawing) small graphics. The prototype model was tested and operated with the programme. The outcome was achieved only after a first few photographs provided as input. This prototype serves as the MVP (minimum viable product) for the stakeholders to evaluate the prototype's functionality and provide feedback for the development of the final product.

As a result, after using the minimal viable product, we received the following comments from our customers:

1) Final product must be in larger dimension
2) Software must be easy to use
3) It would be better if the machine is multipurpose
4) Good aesthetics as a final product
5) Cost effective etc.

After receiving feedback from customers, the students decided to incorporate all the inputs to modify the developed prototype that would fulfill the needs of the stakeholders. Another CAD design was made, with the components significantly altered, according to the requirement of large machine. This time, the machine is designed in the shape of a T or L as shown in the Figure 7 and 8. This design was made with the aim of making the machine is designed in the shape of a T or L. This design was made with the aim of making the machine as convenient as possible.

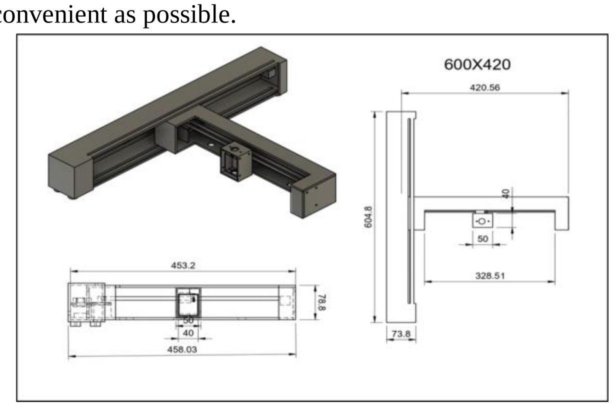


Fig 7: CAD model of the modified prototype 2

The exterior frame material for this design is 4.8mm black acrylic sheet, and it was designed to be entirely opened and assembled as needed. The plotter head is designed to be universal, allowing it to be used with any type of pens or sketches as shown in the Figure 10 developed by Batch 2. After developing the prototype's hardware structure, it was tested by connecting it to the software, and a command was issued. However, due to an incorrect interpretation of the device's operation, the machine failed to produce a desirable performance. However, the lack of support for the movement of one axis was the cause of the failure in the design.

Fig 8: Assembled structure of modified prototype 2

Also, the lack of proper guide ways resulted in unstable movement of the x axis along the y axis. This provided the design experience to the team, and a comprehensive study that paved the way for the creation of a new prototype in which the errors were fixed, as well as the feedback parameter – multipurpose machine – that has not been met in the previous prototype.

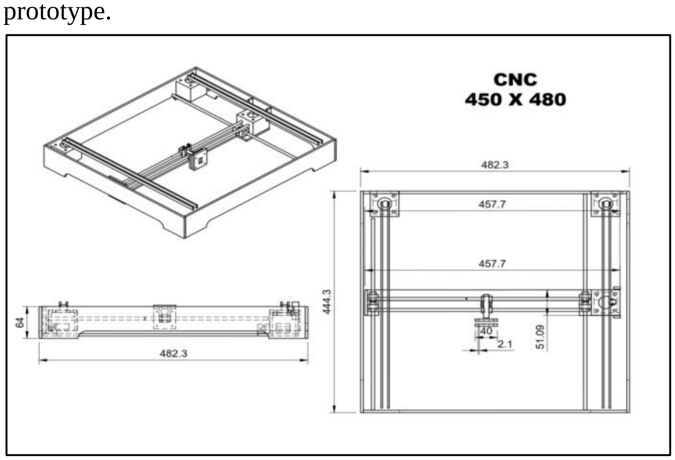


Fig 9: CAD model of final prototype

All the essential adjustments were planned to be done in the new prototype. The design for the new prototype was established after examining the previous prototype as shown in the Figure 9. Later the minimum viable product, this prototype is considered as the final product. The prototype's hardware structure was completed, and the next step is to test it. The machine was connected to the software, and a command was issued. However, due to an incorrect interpretation of the device's operation, the machine failed to produce a desirable performance. However, the lack of support for the movement of one axis was the cause for the failure in design. Also, the lack of proper guide ways resulted in unstable movement of the x axis along the y axis.

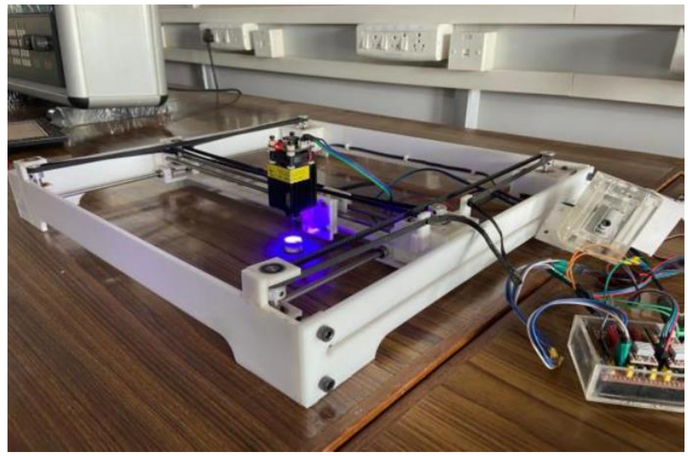


Fig 10: Assembled structure of final prototype

Fig 11: Plotted design, Wood engraved model, Wood engraved design at high precision, Acrylic engrave model, 2mm acrylic board cut model.

This provided us with design experience, and a comprehensive study that paved the way for the creation of a new prototype in which the errors were fixed, as well as the feedback parameter – multipurpose machine – that has not been met in the previous prototype. All the essential adjustments were planned to be done in the next prototype. The design for the prototype was established after examining the prior prototype. Later the minimum viable product, this prototype is considered the final product.

For smooth movement and great accuracy, the guide ways were installed with an additional stepper motor. The outer frame was made of 4.8mm white acrylic for a smooth finish. For high production, the dimensions were extended. To make the machine versatile, the machine's head must be universal, indicating that any head can be attached to or detached from the machine as needed. Therefore, on the x axis of the head, a hard plate was attached to which other heads were mounted on the z axis. Thus, this machine had two heads employed. One plotter head is used for drawing, while the other is used for engraving. Cutting is enhanced by Batch 3 due to the implementation of CDIO framework.

Existing prototypes, did not have the concept of detachable heads. It is either designed as a plotter or an engraver separately. In this designed machine, the x and y axes were the same, but the z axis can be changed or attached according to the required function. Different heads (plotter and laser) were designed so that it could be attached or detached to the machine regarding the application. After the completion of the machine structures, the inputs were tested one at a time by switching plotter and laser heads. When a laser head was employed in the machine, it showed extreme precision in engraving on wood and acrylic key chains, cutting paper, charts, acrylic (2mm) material, card boards, printing on boards, and other tasks.

III. Experimental Case Study Results and Discussion

The one-way ANOVA test is conducted for the identification of the course outcome cognitive score for all the three batch students. The ANOVA method states that, all means are equal - represents Null hypothesis, if all the means are not equal - represents Alternate hypothesis and fixing the significance level $\alpha = 0.05$. The factor information considered for the comparison is, Group 1, Group 2 and Group 3 for the course outcome 5, scores are validated as shown in the tables 3, 4, 5 and 6.

TABLE 3
ANALYSIS OF VARIANCE SCORE

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	2	18354	9177.2	55.66	0.000
Error	178	29348	164.9		
Total	180	47703			

TABLE 4
MEAN VALUE WITH POOLED STANDARD DEVIATION

Factor	N	Mean	StDev	95% CI
Group1-CO5	57	68.52	20.01	(65.16, 71.87)
Group2-CO5	64	85.366	6.445	(82.199, 88.534)
Group3-CO5	60	93.05	8.55	(89.78, 96.33)

TABLE 5
GROUPING INFORMATION USING THE TUKEY METHOD AND 95% CONFIDENCE

Factor	N	Mean	Grouping		
Group3-CO5	60	93.05	A		
Group2-CO5	64	85.366		B	
Group1-CO5	57	68.52			C

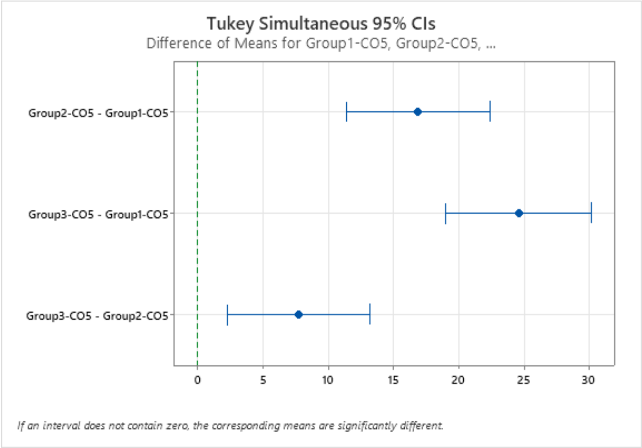


Fig 12: Anova Tukey simulation report

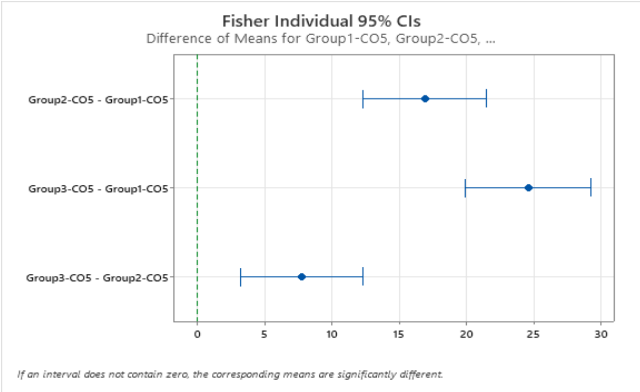


Fig 13: Anova Fisher Individual report

TABLE 6
GROUPING INFORMATION USING DUNNETT SIMULTANEOUS AND 95% CONFIDENCE

Factor	N	Mean	Grouping
Group1-CO5 (control)	57	68.52	A
Group3-CO5	60	93.05	
Group2-CO5	64	85.366	

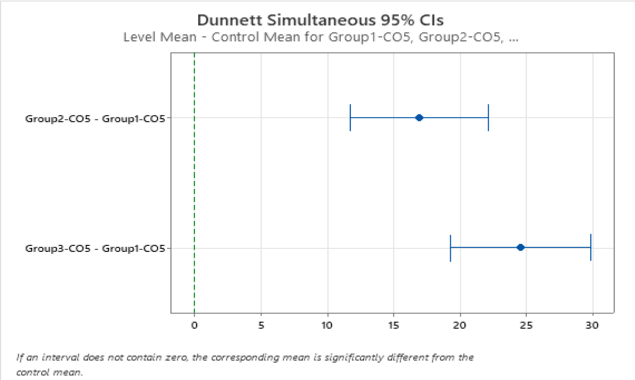


Fig 14: Anova Dunnett Individual report

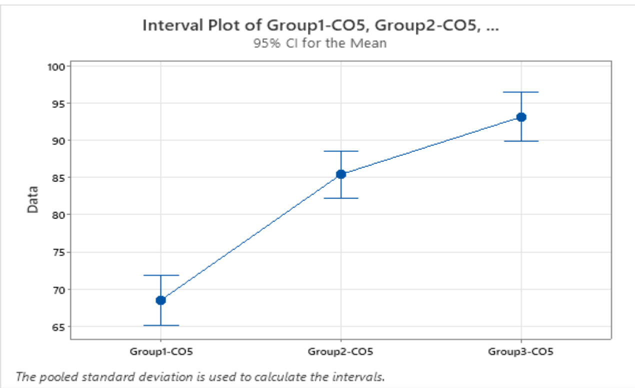


Fig 15: Interval Value plot

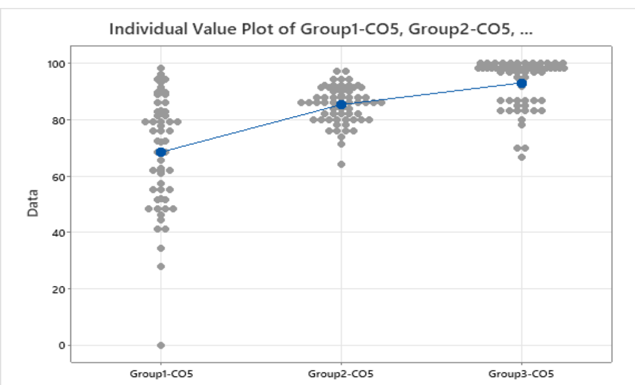


Fig 16: Individual Value plot

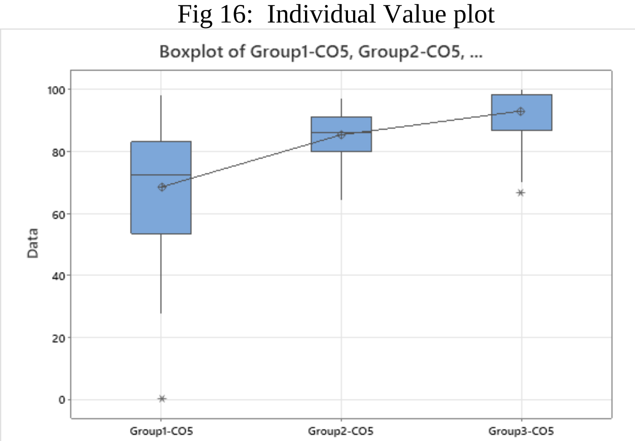


Fig 17: Box plot for the marks obtained

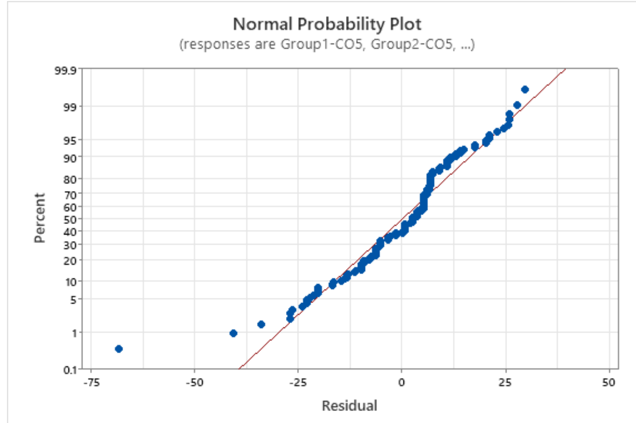
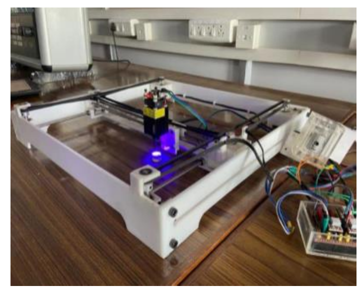


Fig 18: Box plot for the marks obtained

According to the feedback data, students in batches 3, 1 and 2 comprehended their areas of interest throughout their final year project sessions, respectively. In CNC Application, a project-based assignment method was utilized to turn a student engineer into an entrepreneur by turning a prototype model into proof of concept and finally reached business model. Table 3 shows the comparison of educational methodologies in this context with Batch 1,2,3. The average scores that students from three batches of classes received for the various CTS criteria are shown in Table 3 and 4. In order to test the hypothesis, we will choose a significance level of =0.005. Minitab 21's single-factor anova is used to test the aforementioned hypothesis against the system integration results. Tables 3,4 and 5 display the resulting anova for the Course Outcome for three groups in entrepreneurship development course. At the 5% level of significance, the null hypothesis is rejected because the probability value is less than 0.05 (P0.05). As a result, students did better on average in Group 3 than other two group. The provided tables 4, 5 and 6 clearly demonstrate that batch 3 students outperform than the students from the batches 1 and 2 in terms of coming up with solutions to industry challenges. Programs like Design thinking, Lateral thinking, Engineering Exploration, and Entrepreneurial Course approaches have improved students' capacity to gain the abilities necessary to fit themselves into Industry 4.0. The introduction of CDIO approach has aided the students in refining their design thinking, design, and construction skills, based on the information they provided in response to the feedback rubrics. To ascertain whether a prototype is suitable for industrial application, it is converted into a proof of concept and filed for patent recognition.

TABLE 7
PBA ACTIVITY ANALYSIS REPORT

PBA Activity Stages	Batch 1	Batch 2	Batch 3
Course Support	Engineering Design, Capstone Courses	Lateral Thinking, Design Thinking, System Thinking	Lateral Thinking, Design Thinking, System Thinking, Entrepreneurship Course
Problem Statement	Discussed with mentor and other students	Survey and formulate the problem statement.	Survey along with literature survey to formulate the problem statement.
Empathy Map	Nil	Develop 5'Y questions and Empathy map for problem definition	Develop 5'Y questions and Empathy map for problem definition
Brain storming	Nil	Design Brain storming map and develop the prototype.	Design Brain storming, journey map and develop the prototype.
Feedback	Prototype model was assessed and get feedback from reviewer, Students and Mentor.	Design prototype and compare with existing model and obtain feedback from stake holder, mentor.	Design Proof of concept and obtain feedback from stake holder, mentor and reviewers. Finally convert into Business model and patent it.
Prototype Model			

VI. CONCLUSION

In The case study discussed in this paper proves that the design thinking approach works well to address the social issues. With significant revenue and profit potential, the low-cost 3-axis multipurpose CNC machine has been developed and deployed as a business model. People in the society are benefitted from this product since it addresses their issues. To create key chains and photo frames of various sizes, our customers can cut and engrave designs onto acrylic, wood boards, and other materials. The design thinking solution is very successful since it satisfies all the needs of the customers. In addition to teaching young people about real-world business, the course teaches them key life skills including communication, planning, strategic thinking, time management, leadership, and teamwork. By introducing the conceptual idea, design towards intellectual property rights (IPRs), the CDIO framework batch students enhance their cognitive skills and psychomotor skills in education. According to the analysis of the data collected from this study, it is cleared that the batch 3 students outperform the other two groups of students and they have proven the concept of design thinking. Entrepreneur skill implementation calls for qualified instructors and motivated students who can focus on the current business needs of industry and the students should learn and practice abilities that are incredibly useful in the near future.

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