

SYSTEMATIC PROBLEM SOLVING IN CAPSTONE PROJECT A CASE STUDY OF EDUCATION 5.0 THEME

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Abstract: *This paper shows the implementation of the Capstone Design Project also known as Integrated Design Project (IDP) course at Faculty of Electrical Engineering in UiTM Shah Alam with a main theme of Education 5.0. A design module from Kanazawa Institute of Technology (KIT) has been adopted to assist students develop relevant skillsets to demonstrate the workflow of the ideation skill involved. The process of the ideation skill was adapted to ensure students have better thinking process before proposing ideas as design solutions. A case study using Education 5.0 as the theme was selected in this paper. Steps involve in the ideation process includes identifying the issues related to Education 5.0, investigation of the existing current issues, current available solutions, reasons for the issues that have not been solved and finding the suitable conditions for execution. The tasks were performed by the students in a team collaborative environment. Samples are taken from the batch of 141 students in that semester, they are comprising of electronics, system, satellite and computer disciplines students. From the findings, the highest score for problem statement and customer needs selection is 89%, while the lowest score is 70%. In conclusion, the module has assisted students establish a methodical thought process.*

Keywords: *Capstone, Ideation Process, Education 5.0, Project Design Education System .*

Introduction

Online Education evolve rapidly ever since world wide web has been introduced in 1991. The distance learning has become less resilient and flexible. These empower the art of learning and appreciated by higher level students including highly complex and technical subjects. Capstone Design subject is a subject where students in final year of an engineering school requires to complete before they can graduate in most universities nowadays (Halim, Buniyamin, Imazawa, Naoe, & Ito, 2014; Isa, Mohammad, Saad, & Nigel, 2021). The course requires students to apply multiple field from subjects learnt in the program and to integrate problem-solving skill and past experiences to demonstrate a good performance in a capstone design project (Boon, Taufiq, Azilah, Hung, & Shigeo, 2017; Saparon, Ang, Maulana, Hung, & Matsumoto, 2017).

Problem solving in a design class always require systematic process that guides the students to explore a theme to bring out the specific problem that will require a new design solution. A technique that many universities have implemented in a design class is a Problem-based Learning (PBL). It has become popular for a capstone design project class specifically because it requires student to look at a specific problem given and must find the suitable design solution. This approach is appropriate since the designing and developing one focused project should be taken step by step such as using worksheets to follow through (Saparon, Ang, Maulana, Hung, & Matsumoto, 2018).

Capstone course known as Electronics System Design for Fakulti Kejuruteraan Elektrik (FKE), UiTM Shah Alam was introduced in March 2015 for final year students as required in an engineering program. The course offers students the experience and knowledge in designing electronic engineering system or product in a systematic way. At the end of the course, students via their team able to successfully design an electronic system in a systematic approached as in design thinking (Lewrick, Link, & Leifer, 2020) and they are expected to perform and complete all the essential components of electronic engineering design process and procedures which will be useful in their design endeavours later.

Main outcome of this course is to design and develop solutions for complex engineering problems which emphasizes on the activities performed comprehensively in a fourteen-week course. In addition, the design thinking will be elaborated to provide the highlights of the course, that is to expose students with new experience and knowledge in designing electronic engineering systems systematically.

Chia Pow Liew *et. al*, (2020) claimed the implementation of design complex engineering problem exclude some important design skills as well as limited characteristics of complex engineering problem solving. In addition, the absence of complex engineering activities in the design of assessment rubrics in higher education have been undertaken in a wide range of disciplines but not in the field of engineering. Hence, it is expected for engineering educators in enhancing their instructional materials for implementing complex problem solving in engineering design projects and subsequently improve the ability of the engineering graduates to solve complex problems. As for design thinking attributes play another important roles in complex engineering problem, the activities that we adopt may contribute to the absence in the assessing the rubrics.

Boon Chye *et.al* (2017) focus is to adapt the active learning process which to allow the students to practice future working environment which involve in individuals and teamwork activities. Project Design Education System (PDES) in Kanazawa Institute of Technology (KIT) curricula

is introduced to resolve the issues of risk in active learning for unplanned activities. The authors describe the tools for the active engagement that have been adopted to assist the students to become active learners, increase in peer and instructor interactions, how to understand the issues and problem solving process that take place. As for instance, the setup of capstone class by splitting students into smaller team and giving them job roles rotation assist the student to have proper engaging and coaching.

Azilah *et.al* (2017) highlights an effective module to equip students with the relevant skillsets of an engineer to be ready for the industry has been reported. The model applied for PDES benefits students to become an independent thinking engineering through collaboration with others. In the case study , methodology of teaching project design (PD) courses has been elaborated in details .

This paper aims to demonstrate how when contrasted to the conventional approach, the design thinking process has helped students establish a methodical thought process and improved the overall performance (Isa *et al.*, 2021). The methodology or work flow of the ideation skill process is described in Part II of the article, along with examples of the techniques. The results of 141 final year student samples from four different group disciplines were studied in Section III to reveal how the concepts of empathise, define, and ideate are pertinent to developing a capstone design project, followed by the findings' interpretation.

Methodology

Class Activities

This course requires students' collaborative work to demonstrate a design work that involves solution exploration considering public health, cultural, societal, and environmental. This course is considered as a pinnacle of the program since students are required to apply knowledge from the previous core courses. The sustainable development goals (SDG) and the fourth industrial revolution (IR4.0) are two examples of the multidisciplinary environment theme that is introduced for this course. The design thinking approach will be used by the students as they work in teams of three to five people. Each team needs to undergo the design thinking process such as identifying the needs and constraints, investigating the problem, finding the possible solutions and proving the concept of solutions as described in (Al Junid *et al.*, 2018).

In this section, the workflow for solving the Capstone Project for Education 5.0 Case Study is elaborated. The course covers 14 weeks' activities. Overall, the project is expected to address problem statement, survey, design selection, design costing and sizing, analysis, and evaluation on the implementation of product/conceptual design development.

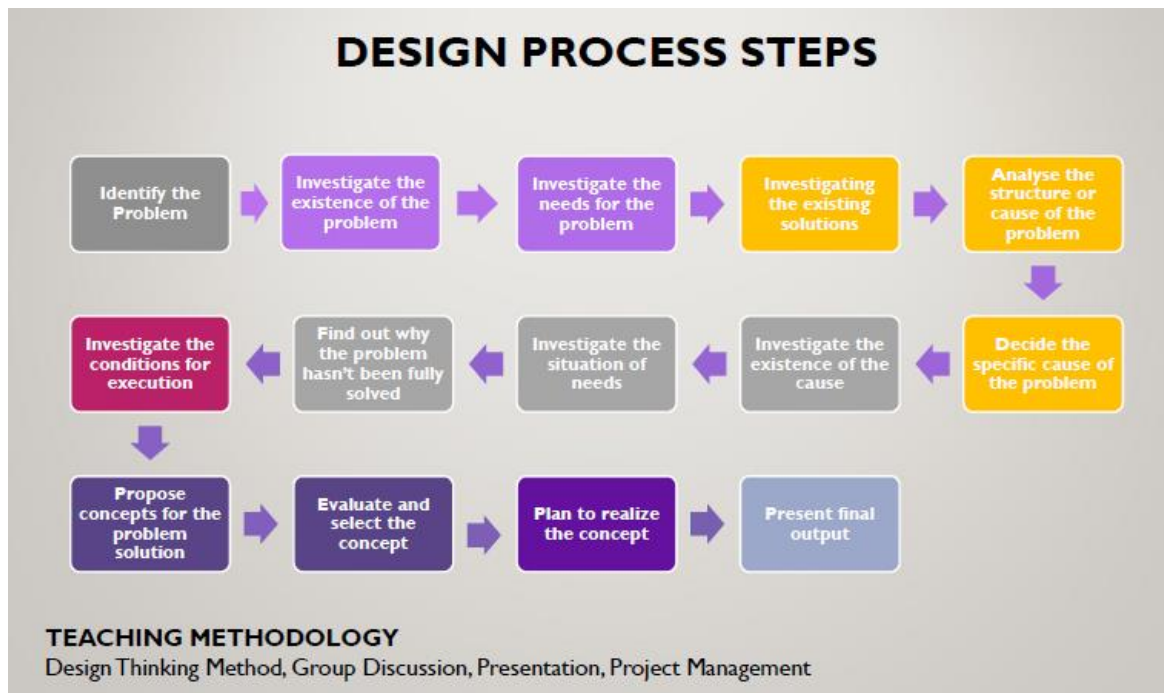


Figure 1: Overall activities for Capstone course in FKE UiTM, Shah Alam

However, the ideation skill covers for 5 weeks. The process of ideation skill involves in 5 steps, and the activities to the students related to the process involves 6 worksheets. Figure 1 refers to the overall activities for the capstone course in this case study. The ideation skills covers from week 1 until week 5. However, the activities involve the ideation skill is mapped according to the worksheet provided to the students. Each student is required to examine and perform the task as outline in the worksheet. As exhibited in Table 1, the steps are displayed to show the sequence of the process to achieve the ideation skills. Also, included in Table 1 is the lists of the specific tasks and anticipated results for the activities from Week 1 through Week 5 in detail.

Table 1: The Mapping Of The Ideation Process Step To The Task

Steps	Task
Identify the Problem	Creation of Ideas/ Problems associated with the Education 5.0 Gathering of Information and Proposal of Individual Preferred Project Themes (PTs)
Investigate the Existence of the Problem	Survey on Existing Similar Problems: Comparative investigation and Survey on Stakeholders' Opinions and Needs of the Tentative PT
Investigate the Existing Solutions	Assessment of Available Solutions
Find out why the problems has not been fully solved	Assessment of Available Solutions of the SP Problem
Investigate the conditions for execution	Survey on Specification Indicators of the SP Problem

There are 5 steps involve that each student has to execute by researching on Education 5.0. The activities start with creation of ideas where the team of 4 or 5 students requires to think about all possible problems related to the Education 5.0 theme. Each team must fill up the team member form and team member activities to assist the lecturer in charge about members of the team and organization of the team in doing activities (Saparon *et al.*, 2018). The responsibilities of the each team members is interchangeable weekly from leader, secretary, minute taker and presenter. Their task for Week 1 starts when they are required to provide three ideas or issues related to Education 5.0 using keywords or short sentences and post it to the worksheet. Subsequently, each teams will read and choose the ideas or issues from the idea pool that worth for further investigation. This task cater for Week 1 activity. Students also were informed that their activities in class will be recorded or captures via photo and videos as part of the evidence for the instructors.

For week 2 activities, once the idea or the issues has been voted and decided; each team members will make their own information gathering and propose individual preferred project theme using evaluation matrix where the process and instruction lead by the leader to lead the team's discussion and evaluation. The minute taker will write the opinions by writing the project theme proposals and the name of the authors or by each team member. Then team will think about the viewpoint/criteria for evaluation and subsequently evaluate the proposal by checking if the proposal matches the criteria *i.e.* if he or she does have enough experience or knowledge to judge the proposal, make a guess for the criteria below:

- Match, write O (2 point)
- Does not match, write X (0 point)
- Undecided (difficult to decide), write? (1 point)

Each project theme proposals are scored according to the provided score number of O – number X. The proposal that receives the highest total score is voted to be the best alternative.

Regarding the week 3 activities, each team member must go forward with the best alternative suggestion for additional research and explain how it relates to Education 5.0. Each team member will write down their thoughts, credit the sources, and include all supporting documentation. Each team member is required to keep track of the time spent gathering information and to provide a description of the specifics of the problem under investigation. Each team member will share their informational findings and discuss how they relate to Education 5.0 during the team meeting. Following the collection of responses, the Kawakita Jiro (KJ) technique and fishbone diagram are used to group all possible causes into effects, issues, and causes, respectively, and to choose and emphasize the five solvable causes for further analysis.

Week 4 activities involve the team to describe the strengths and weaknesses of the selected problem project theme Education 5.0 earlier, and based on the results of investigation the team can add some changes to select the problem of project theme Education 5.0. Each team members has to investigate and assess the existing solutions of the revised selected problem and find out why the problem has not been fully solved. There are two additional tasks for the team to complete in these activities. The first is a survey on current, comparable difficulties, where each team must examine the circumstances of current, comparable problems and compare them to those of the problem project's chosen theme, Education 5.0. Second, each team will have to determine how important and necessary it is to solve the problem being investigated by gathering

data from stakeholders such as employers, employees, users, and/or related parties. This survey will focus on stakeholders' opinions and needs of the selected problem project theme Education 5.0.

These activities can use multiple platform such as google forms, interviews or website searching and the sources for the survey must be cited to ensure the eligibility of the information gathering. The analysis of the activities is performed by assessing the available solutions of the specific point (SP) problem according to the findings from the survey of activities for the existing similar problems and stakeholders' opinions and needs of the selected problem project theme Education 5.0. To summarize, the activities of Week 1 until Week 5 details the task each team to complete for the design and develop solutions for complex engineering problems of Education 5.0 theme. The team leader will lead the team to come up with survey on existing similar problems for comparative investigation and survey on stakeholders' opinions and needs of the selected problem project theme Education 5.0.

In the subsequent activities for Week 5 that involve a deeper examination of the current conditions of the specific-point problem using numerical and/or visual data and, if possible, a comparison to the conditions of other problems that are similar. Each team will conduct a survey of all the requirements, including preconditions (prerequisites) and desired conditions, needed to solve the SP problem. Then, each team member will examine into present state of preconditions and desired conditions for the specific-point problem and offer specific indicators individually as well as provide the numerical and/or picture data. By examining the SP for Education 5.0 theme's strong points and weaknesses, the team will further analyse whether or not its contents are simple for others to understand. If necessary, a new title might be suggested to take the place of the SP Education 5.0 theme.

Assessments Analysis

Analysis of data starts with collection of 141 samples from 4 groups of classes. They are comprising of electronics, system, satellite and computer disciplines students. The assessments selected are based on ideation process as explained earlier. As display in Table 1, the definition of each activities are described and what were expected from the students to response to the activities. All these activities are arranged in sequence to facilitate the students for the flow of the ideation processes. In this case study, the data was analysed based on the expected outcomes and the activities were evaluated and assessed according to team. As shown in Figure 2, the process of data evaluation is described for this case study - Education 5.0 theme.

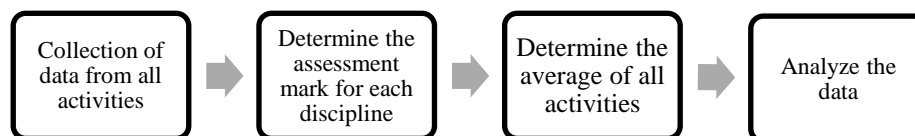


Figure 2: Display the flow of data evaluation for Education 5.0 case study.

Result And Discussion

For the purposes of this case study, we pay attention to how well students empathize, define, and generate ideas. primarily covers Week 1 through Week 5's activities. In Week 4, they will present what they have discovered or learned so far about their project (PJ) theme. The activities were measured from Week 1 through Week 5 and evaluated.

Class Activities

For the purposes of illustrating the aforementioned actions, Figure 3 provides an example issue statement for Week 1. The exercises emphasize both individual and team discussion, as shown in Figure 3.

MAIN THEME : 'EDUCATION 5.0'			
TEAM MEMBER	PROBLEM I	PROBLEM II	PROBLEM III
ZARIFAH	Level about stress about bully.	Traffic jam that causes late to the class.	Burden to bring the learning material to the class.
AINUN	Students cheat the attendance, time taken to count no. of students longer.	Hard to find the pages per chapter in the e-book.	Waste the time in finding the data of replacement during examination.
SARAH	Students cannot imagine and see clearly at the projector.	Disable students having difficulties to enter the class.	Students facing glare sensitivity because light of the screen projector.
FATIN	Students often lacks of concentration during online learning.	Students cannot imagine 2D as theoretical.	Students feel sleepy during fundamental lessons.
MUIZ	Students tend to cheat in the examination hall.	Children hard to understand without real images.	Lecturers have difficulties to bring the heavy materials in the class.

Figure 3: A sample of teamwork discussions output from Week 1 activities.

Figure 4 refers to the illustration on the groups to discuss issues with Education 5.0. Each member will suggest three different problems, and the best one will be chosen. The final problem statement is then chosen by assessing and ranking the problem's importance in accordance with the criteria. The criteria that have been investigated and measured to weigh are based on (Saparon *et al.*, 2017):

1. *Many people need the problem to be solved? (Impact on society),*
2. *We can easily interview targeted person? (stakeholders),*
3. *The problem is related to the main theme?*
4. *Prototype solution will be easy to be made?*
5. *Results of solution can be measured?*
6. *We can do mock-experience by choosing this problem?*

1. |

	Individual Preferred Project Themes	multiply_factor (1-3, if needed) → member's name ↓	measurement / criteria to weigh project themes						Total Score
			Many people need this problem solved	We can easily interview target persons	The problem is related to Main-Theme	Prototype's solution will be easy to be made	Result of solution can be measured	We can do mock-experience by choosing this problem	
Main theme: To establish " Education 5.0" in Utm.	Level of stress about bully	ZARIFAH SHARINA BINTI MOHD ZARIB	o	o	o	? Prototype takes time	o	o	11
	Students cheat the attendance, time taken to count no. of students longer.	NURAINUN AQLAH BINTI AHMAD	o	o	o	o	o	o	12
	Students facing glare sensitivity because light of the screen projector.	NUR YASARAH BINTI MOHD ROZALEE	o	? Hard to find disable person	o	o	x	o	9
	Students feel sleepy during fundamental lessons.	NUR FATIN NABLAH BT MOHD SOBRI	o	o	o	? Hard to simulate in real time	o	? Make noise that can disturb other student	10
	Children hard to understand without real images.	ABDUL MUIZ BIN ZULKILPLI	o	o	o	?	?	o	10

Figure 4: Teamwork discussions output from Week 2 activities.

The following phase in design thinking is to comprehend the current scenario; hence, a survey with collective questions from teammates regarding the issue has been distributed. In essence, the survey aims to identify similar issues that already exist and conduct a comparative analysis. The survey will also gather feedback and needs regarding the potential project theme from stakeholders. According to the responses, students cheat on attendance, and the time taken is too long, according to the evaluation, which is the issue the team has chosen to address. In other words, they become the center of the group project, as depicted in Figure 4.

The Kawakita Jiro (KJ) technique and fishbone diagram are used to group all possible causes into effects, issues, and causes, respectively, and to choose and emphasize the five solvable causes for further analysis. As shown in Figure 5, reveals that there are a few key reasons that contribute to immoral behaviour. For example, it is simple to fabricate attendance while passing around the attendance paper, and some students feel violated as a result, making the attendance paper invalid. Once all potential causes have been identified and mapped out on the fishbone diagram, it's important to analyse the results and prioritize the most likely root causes as discussed in (Yunusa-Kaltungo & Jungudo, 2023).

This can involve further research, data analysis, and collaboration with others and develop an action plan: Once the root causes have been identified and prioritized, the final step is to develop an action plan to address them. This may involve implementing process improvements.

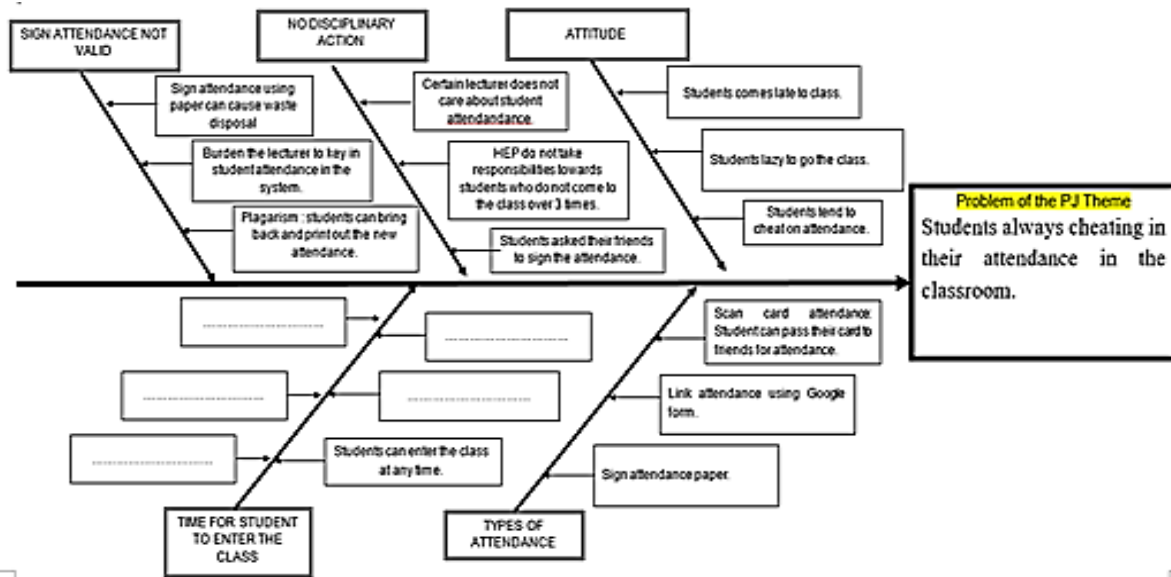


Figure 5 : Fish-bone method to look into the cause-and-effect of root causes of a problem statement.

Following the survey and analysis, the team will conduct further research into existing design project possibilities. The students have already identified several commercially available alternatives that could potentially contribute to the Education 5.0 scenario. Additionally, the team's research has revealed various concepts and technologies that could be leveraged to address the identified issue, particularly in the context of the evolving educational landscape where students are becoming smarter. To facilitate further discussions and brainstorming, students are seated in groups, as depicted in Figure 6.



Figure 6: Students are seated in groups to facilitate teamwork and open communication among team members.

Analysis of Assessment

These activities are assessed and evaluated to demonstrate how design thinking process has assisted students in developing a systematic thinking process. Table 2 is the tabulated data collected from 141 samples in 4 group classes in the semester. It depicts the performance in percentage of the activities that the team has acquired for 5 weeks. As mentioned previously, the group was divided according to specialization area - electronics (M7A), system (T7A),

satellite (S7A) and computer (C7A). The assessment reveals that in understanding on the Education 5.0 problem relevant to main theme were varied for the ideation skill covers for 5 weeks.

Finding the problem statement is the first stage in the ideation process, which is then followed by research into issues and solutions related to the Education 5.0 theme. Students are then expected to concentrate on developing design ideas that can contribute to better products from those that are currently on the market once each team has chosen its project theme. With their design assignment, students are to be urged to be innovative rather than merely creative. The survey's highest score for problem statement and customer needs selection is from group M7A with 89%. While the lowest score is 70%, which is from group S7A. The exercises consist of two worksheets that are designed to help students grasp the challenge they have chosen and to detail each team project's concept.

From the observation, students in electronic major grasp better to fulfil the detailing of problem selected in previous exercise. In contrary, S7A students are having difficulty to look for more information hence fill up the gaps of problem statement selected earlier.

Table 2: Data collection for Group Performance from Week 1 to Week5

Assessment	W1a	W1b	W2	W3	W4	W5	Average
Group							
S7A	96%	63%	57%	70%	73%	59%	70%
T7A	100%	89%	65%	79%	87%	73%	82%
M7A	92%	78%	88%	92%	91%	93%	89%
C7A	78%	70%	76%	69%	71%	64%	71%
Average	92%	75%	71%	77%	80%	72%	78%

The ideation skill process involves five steps, and as part of the exercises, students are expected to complete six worksheets. Based on the percentages displayed, the team was successfully map, examine, and complete the tasks outlined in the worksheets. However, the team was able to complete the ideation process tasks outlined in the worksheet, as evidenced by the highest percentage score for W5 activities for M7A. Figure 7 is a chart that clearly shows group M7A and T7A outperformed Group C7A and S7A. From the observations, the students can still improve their performance in organizing their thoughts and suggesting better solutions to the root cause of the problem determined during the design thinking process. As the skillset has been introduced, students are expected to practice the same to other subjects and that benefits to all other project-based subjects such as final year project, engineering in society, which will acquire a lot of design thinking process and critical analysis for selection of project and come up with a proper design solution.

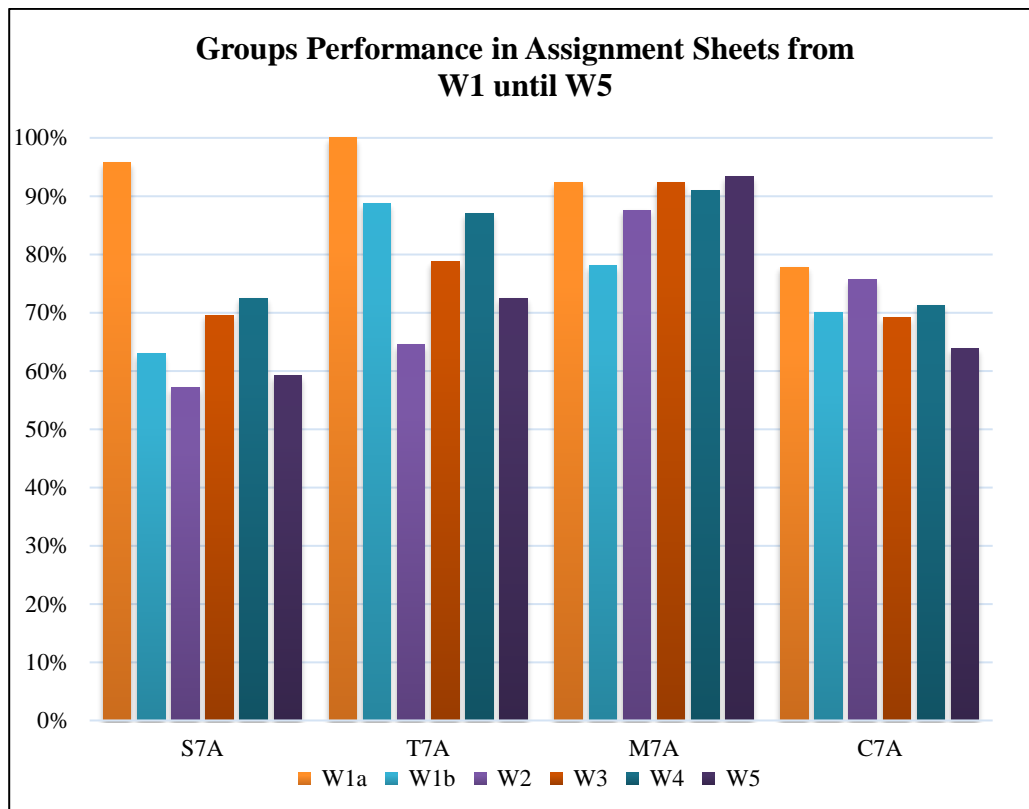


Figure 7 : Group Performance in Weekly Sheets Activities

Conclusion

The case study for theme of Education 5.0 were performed by all students of four different discipline majors in semester 7 of Bachelor of Engineering in Electronic Engineering program. They are working in team environment and are expected to fulfil the capstone design project with relevant skillsets. Samples from the 141 students were assessed from the weekly activities and results provided are average marks for each team's performance. The skillsets related in the activities are to ensure the concept of empathize, define, and ideate the ideation skills process adopted well and the teams need to come up with design solutions of the selected theme problem statement. The relevant skillsets acquired while involving with the activities enabled the students to be more effective at project task. Even though the performance of skillsets was not excellent, this is a good beginning for the students. Now, the students are introduced with new skillset and can be used for their future in working environment life especially in defining the design solutions. The students have gone through each step with clear learning objectives for weekly activities. The students also have acquired soft skills, such as communication, collaboration / teamwork, and presentation, throughout the activities.

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