



J. Atit Shah, I. Lim, A. Molina-Cristobal, Christian, V. Dale and F. Mei, "Learner's Experience About Freehand Sketching Vs CAD For Concept Ideation Process During Product Design Development," 2021 IEEE International Conference on Engineering, Technology & Education (TALE), 2021, pp. 188-195, doi: 10.1109/TALE52509.2021.9678862.

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Learner's Experience About Freehand Sketching Vs CAD For Concept Ideation Process During Product Design Development

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Abstract—During the engineering product development cycle, while going through the concept ideation stage, it is very important to accelerate the thinking process and to represent concept ideas in front of colleagues to brainstorm and refine for faster product design and its development. Availability and use of different computer-aided design (CAD) tools in the market made this concept generation process longer and time-consuming due to its limitation on detailing and editing. As an alternative, freehand sketching is very quick and easily editable which focuses on quantity rather than quality which allows healthy discussion and quick adjustment towards a valid and relevant design proposal. To explore learner's (students') experiences of concept ideation while studying product design and development, different freehand sketching tools were introduced like the use of some software instead of just traditional pen and paper kind of freehand sketching during the start of the trimester to quickly represent their ideas amongst their peers. During the later part of detail design, they used CAD tools. In this paper, a few examples are provided to show students' freehand sketching skills during concept ideation and the use of CAD tools for detailed design drawing. The effectiveness of this approach is measured through a survey conducted for students at the end of the trimester and it has been evaluated based on the survey results. They were asked to give responses based on their experience during the trimester. The results suggest that it is very important to emphasize the use of freehand sketching during concept ideation and the utility of CAD tools at the detail design stage of the product design development to achieve the learning outcomes of the module of Design and Manufacture 1 at the University of Glasgow, Singapore (UGS).

Keywords— *freehand sketching, concept ideation, CAD tool, product design, and development.*

I. INTRODUCTION

While going through the product design and development cycle, concept generation and development are the most important steps which help the product to turn out to be an innovative design outcome. Ideally, concept idea generation and development stages would provide opportunities to explore a variety of different, creative ideas [1] which would serve as the foundation for synthesizing the final solution. Traditionally, freehand sketching performs the aforementioned functions simultaneously and was considered a tool for strong communication for engineers to develop new

ideas and concepts. But as we are in the digital era when we talk about augmented reality, virtual reality, mixed reality, and extended reality, CAD tools took over the place of freehand sketching, even for concept generation. As a result, when ideation is taught, it is commonly through techniques like brainstorming, which can lack structure and may not provide specific ways to guide concept generation and its development [2].

As it is said that a picture is worth 1000 words, very often the quickest and easiest method to develop and communicate a concept or idea in form of a picture is by using freehand sketching. The expression of the freehand sketches includes a mainly pictorial and textual representation of features. These freehand sketches help to create the feeling of the finished product in minds which is still not physically ready, but it is still under the concept mode. Uziak and Fang [3] recognized the value of freehand sketching as low cost, fast, sense-making, indispensable, and a flexible tool for communicating engineering concepts. It is the fact that freehand sketching is neglected, and more focus is given to the teaching of CAD tools in most engineering programs. It became normal practice in the last few decades in engineering education, for CAD tools are to be taught to engineering students without introducing first the basis of freehand sketching during the early years of engineering studies [4]. Traditional teaching methods in which students used to take notes in a lecture, draw diagrams in the lab session, plot the graph after a practical were enough to learn and practice freehand sketching employing pen and paper become obsolete and have been replaced by smart lecturing techniques where most of the material is explained with the help of PowerPoint slides or with the help of some impressive YouTube videos during a physical lecture [4]. Even in the last two years, the Covid 19 situation made Zoom lecturing very popular in which students even can watch the recording when they wish to and can revise the lecture in their comfort zone which allows them zero usage of pen and paper.

Studies have shown that sketching by hand allows a designer to capture an idea quickly; it concentrates on the essentials rather than on 'bells and whistles' [5]. On the other hand, some people believe that CAD is the tool to focus on detail design and not on its concept [6]. This proves that CAD drawings give the impression that ideas are firmly fixed and it

becomes difficult to change the design at that stage or the design work is almost finished and ready to go for manufacture.

A study presented by educators and researchers [7] suggests that every engineering college must emphasize the value and use of freehand sketching for future engineers “not only in the standard drafting skills but additionally in the ability to represent concepts that are more abstract and best represented as sketches”. Authors demonstrated the power of sketching for young designers and reported that “students who received advanced sketching instructions such as the strategic use of sketching and 2D layout models were better able to generate and communicate designs to their teammates. Sketching can provide a bridge between conceptual thoughts and graphical design expressions” [8]. It is mentioned that in Science, Technology, Engineering, and Mathematics (STEM) disciplines, hand sketching brings many benefits in students’ learning [9]. In 2018 Hilton and colleagues explained the importance of going back to the basic concept, considering the importance of freehand sketching and its advantages over CAD tools during the design thinking process, mainly in mechanical engineering [10]. Some disadvantages we can count for freehand sketches are, for the large design we need big space to draw out, more time required to redraw also storage is one of the major problems.

Our study aims to examine learners’ experiences and preferences on the use of freehand sketching over CAD tools while going through the concept ideation stage. We proposed to introduce different tools of freehand sketching such as pen, pencil, drawing tablets (Deco 01 v2), use of some free software such as Sketchbook to students for concept ideation, and later to continue with the same until they reach the stage of detail design, where they will be using CAD tools. At the end of the trimester, we obtain students’ feedback through structured questionnaires to identify their perceptions of freehand sketching on its importance, level of acceptance, learners’ preferences, and feedback on freehand sketching over CAD tools for concept ideation from their own experiences. We presented findings from a preliminary questionnaire’s dataset considering the aforementioned criteria which are best received through freehand sketching with a view to further research aimed at measuring the impact of freehand sketching over CAD tools for concept ideation.

The rest of the paper is arranged in the following manner. Section II presents the power of freehand sketching in the engineering design ideation process. Section III discusses the methodology adopted for this research work in detail. Section IV focuses on the result and analysis of students’ survey on their experience and perception of freehand sketching over CAD tools for design concept ideation. In Section V, recommendations are presented which are drawn from the students’ survey results and analysis. Finally, the paper is concluded in Section VI.

II. POWER OF THE FREEHAND SKETCHING IN ENGINEERING DESIGN IDEATION PROCESS

There are around more than a hundred techniques available to use for the design ideation stage according to the field in which it is used. They are mainly classified based on whether it is problem-based, concept-based, user-based, or product-based. These four main techniques are described in detail by Gharib [11]. Out of all these techniques, freehand sketching is the most popular one due to its uniqueness and as

it is the most powerful to develop and represent innovative concept ideas during the concept ideation stage of product design [12]. Freehand sketching makes students worry less about their mistakes and it makes students focus on representing their creative and innovative skills in design ideation [13]. Freehand sketching performs multiple functions simultaneously and it is considered the most effective communication language for a designer and a facilitator for engineers to develop new, innovative, and creative concepts [14]. It is the first step that allows more fruitful discussion and immediate adjustment towards a quick embodiment of valid proposals [15].

When mechanical engineers are working on new product development or product improvement, the most important purpose of concept idea generation is to get a quantity instead of judging the quality of ideas and so freehand sketching is very important while going through this stage of designing a product [16]. Freehand sketches are the first elaborations of a possible solution between co-designers of a team for a given problem statement [15]. It accelerates the process of brainstorming of engineering designers for improving spatial visualization skills to concept generation [17]. While using freehand sketching, as mentioned above, engineers are not worried about its dimensions, and this informal way of expressing concept ideas makes them comfortable to revise the design quickly compared to CAD where the detailed description and exact dimensions are required to represent the idea [18].

III. METHODOLOGY

the fact that CAT tools took over the place of freehand sketching even for concept generation, despite the latter’s value for concept ideation, motivated us to study the importance of freehand sketching over CAD during the design ideation process while going through the product development cycle from the learner’s perspective, and experience. At the UGS, we have module MEC2131, Design and Manufacture 1; it is a 5 credit module and runs during the second year of the engineering course for 13 weeks. During the last academic session, we introduced freehand sketching tools during the lab session and instructed students to use those for the design ideation process. At the later part of the design cycle when students are going through detailed design, they are expected to use CAD tools for the final design. At the end of the trimester, we conducted a survey comprising qualitative and some quantitative questions to understand students’ preference for freehand sketching over CAD tools during the stage of design ideation.

A. Details of the Module MEC 2131

This module consists of lectures, case studies, lab sessions, projects, and CAD modeling/visualization. It aims to introduce the systematic industrial design process, which includes defining the customer needs, concept design generation and selection, embodiment design, and detailed design, etc. Students learn how to create/sketch out product/engineering ideas and product engineering drawings to effectively communicate design ideas and solutions using freehand sketching which ensures that students can effectively communicate design concept ideas and solutions, where the CAD tool doesn’t do that. During project work, students will be exposed to the working of team dynamics, the engineering design process, report writing, oral presentation, and project management.

The main learning outcomes for this module are for students to be able to:-

- Apply the engineering design process in a collaborative engineering environment.
- Sketch out product/engineering ideas and produce engineering drawings creatively to effectively communicate design ideas and solutions; and
- Present the design concepts and final design technically through reports and oral presentations.

B. Module structure

The lectures cover the theory and methods used in engineering product design, the development of concept generation and methodology, and the examination of case studies. They also cover the design, analysis, and simulation for manufacture alongside 3D printing and tooling concerns. The lab sessions involve the development of creative thinking and problem-solving skills and work on a small group design project that links these to engineering requirements. The student selects a project from a short-list; each project aims to allow the students to apply their acquired creative thinking and problem-solving skills to develop a conceptual design for a product that extends the application of an existing product into new markets and/or develops the design to expand sales in existing markets and reduce manufacturing costs. The lab session work also involves the detailed design/modeling and analysis of a component or small assembly for high-volume manufacture. This will be achieved via a small group design project that exercises the application of knowledge gained through the lectures and the creative thinking and problem-solving skills practiced in the first year of engineering studies. The project provides a challenging technical problem to which the student can develop and present workable and manufacturable solutions at various levels of automation.

Below are the projects selected for students to work on during four hours of lab sessions per week over 13 weeks.

- Daily Living Aid for the Elderly
- Optimization of Patient Hoist
- Portable (Lavender) Diffuser
- Coffee shop hot beverage “tabao” (takeaway) tools

To improve the structured approach for developing project management skills and to explain and implement freehand sketching in design ideation and CAD tool during detail design, five steps are used in this project-based lab session for the design process. These include the problem statement, design specifications, concept design (design ideation), concept selection, and detail design [19]. During the lab session, students must work in their group to complete the project selected by the group from the above four options. After their market research, they picked up the project of their choice and started surveying users. Later they worked on the given design problem.

Initially, each student must do independent design ideation to showcase their ability of design thinking. This allows students to think independently and creatively and later they will go ahead with concept selection and concept evaluation as a group activity that narrows down their different ideas based on technical aspects. Students were given the flexibility to use pen and paper or a drawing tablet for freehand sketching during design ideation but later we realized that students were not comfortable using drawing tablets, as this requires proper eye and hand coordination for drawing. As demonstrated [20], students were found to be motivated and hold a positive

attitude about using an iPad in their learning, and its effectiveness is supported in the literature [21]-[23]. Considering this, we allowed students to use the software on their laptop or iPad with an Apple pencil which has a good performance on drawings and note-taking, which is frictionless, intuitive, and precise with imperceptible lag, pixel-perfect precision, tilt, pressure sensitivity. At the end of the trimester, we designed a survey for students to capture their experiences and preference for freehand sketching over CAD tools, which were used during detail design.

C. Ideation sketching during concept generation and CAD drawings at detail design

1) Personal Mobility Aid (PMA) (TRI-OHM Futuristic PMA)

Singapore is a small country with a large population; this may result in crowding in certain places, for example, supermarkets or public transport. The government here is acting to achieve a seamless public transport system including older-aged cohorts [24]. Despite the advancements in different areas of PMA, there is one area it still lacks, its maneuverability. When the elderly travel around in a PMA, they often will have to board public transport to get to their destination. However, with the current turning radius of the available PMAs, it is still difficult to turn around especially when in tight spaces such as crowded public buses. An example would be having the elderly get into the right position to put on the seatbelt allocated for them. This would be very difficult with the limited space they have to adjust their position. Thus, if there are improvements made in maneuverability, it will be easier for them to travel in confined and crowded places. This project focus on the design of such type of PMA to improve maneuverability. Fig. 1 to Fig 5 shows the initial concepts generated during the ideation stage by students using different tools as mentioned for freehand sketching.

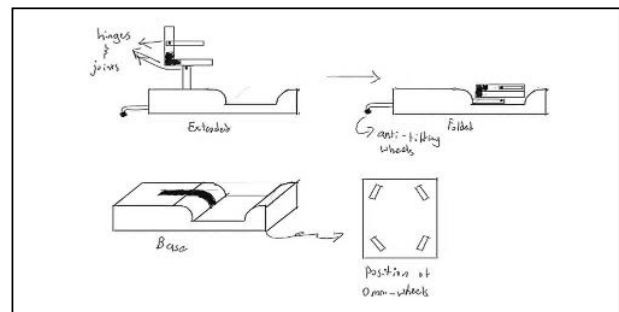


Fig. 1 Concept -1 for project TRI-OHM Futuristic PMA

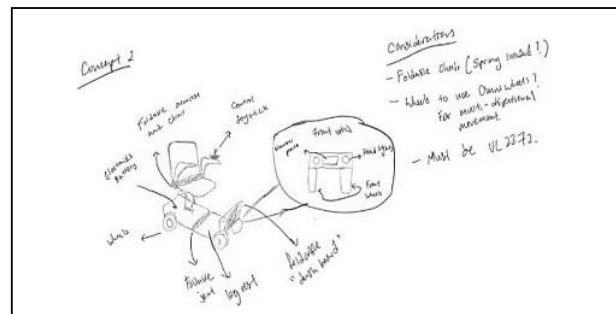


Fig. 2 Concept -2 for project TRI-OHM Futuristic PMA.

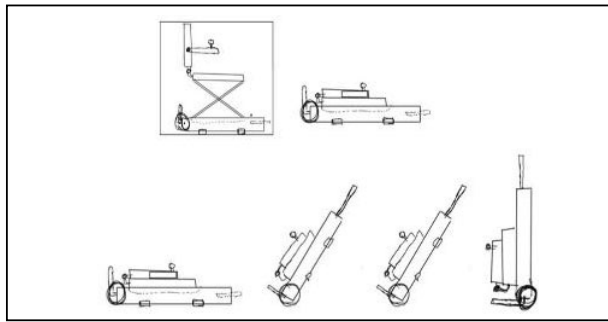


Fig. 3 Concept -3 for project TRI-OHM Futuristic PMA

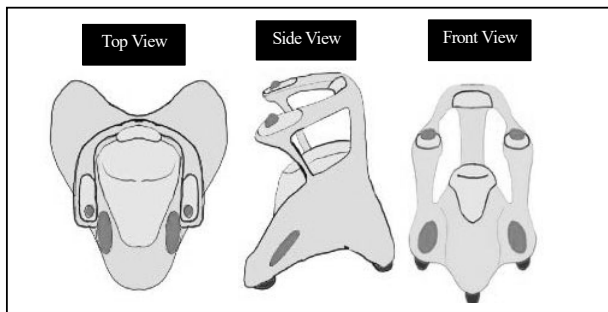


Fig. 4 Concept -4 for project TRI-OHM Futuristic PMA

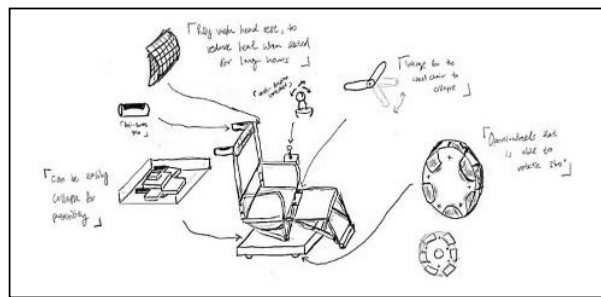


Fig. 5 Concept -5 for project TRI-OHM Futuristic PMA

Fig. 6 shows an assembly drawing for the detailed design of the project called TRI-OHM Futuristic PMA, as instructed the students used the CAD tool to create the final design. This is the result of synthesizing all the concepts created in the previous step of concept generation.

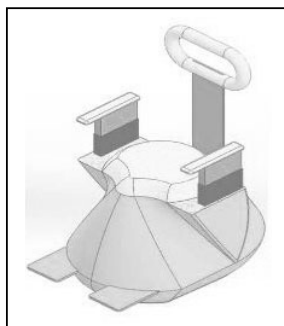


Fig. 6 Assembly drawing for project TRI-OHM Futuristic PMA using CAD.

2) Coffee shop hot beverage “tabao” (takeaway) tools (Coffee To Go)

People who work at food service chains are at higher risk

of burning themselves when handling hot beverage takeaways [25]. Subsequently, there is also the risk to the customer who purchased hot beverage takeaways, especially if the lid is not sealed properly. With that, the focus is to design an assistive product to help aid the coffee maker in the capping of the takeaway cup. Fig. 7 to Fig 11 shows the initial concepts generated during the ideation stage by students using different tools as mentioned for freehand sketching.

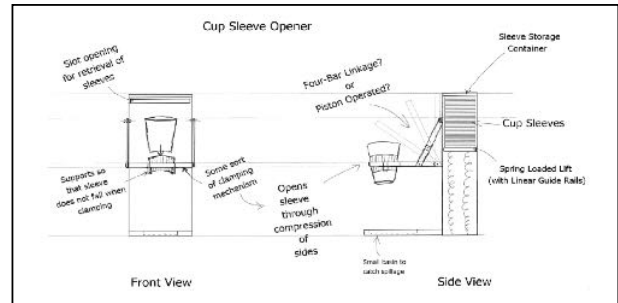


Fig. 7 Concept-1 for project Coffee to Go.

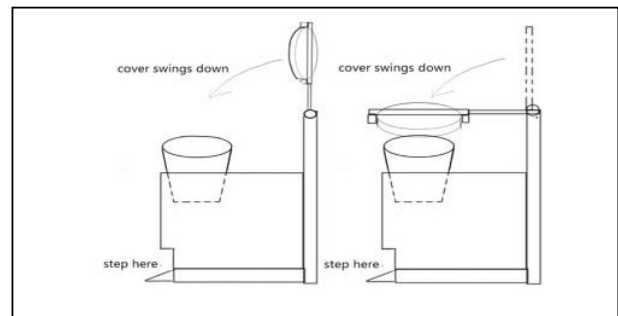


Fig. 8 Concept-2 for project Coffee to Go.

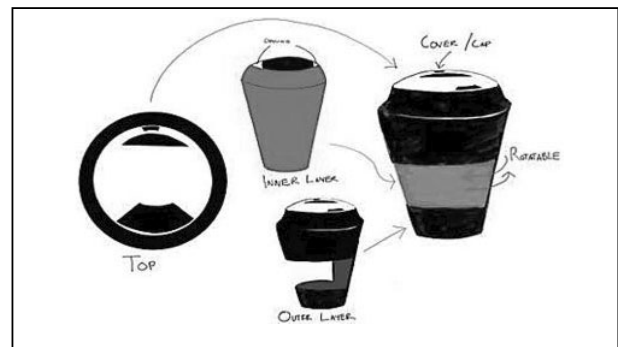


Fig. 9 Concept-3 for project Coffee to Go.

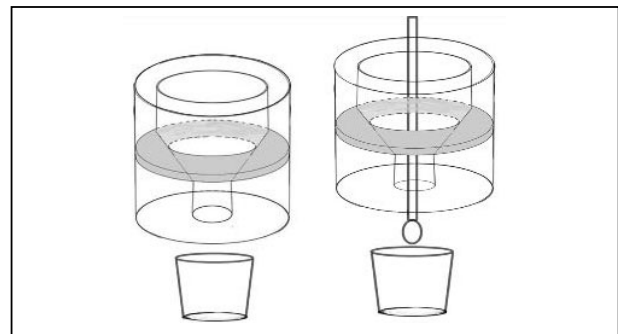


Fig. 10 Concept-4 for project Coffee to Go

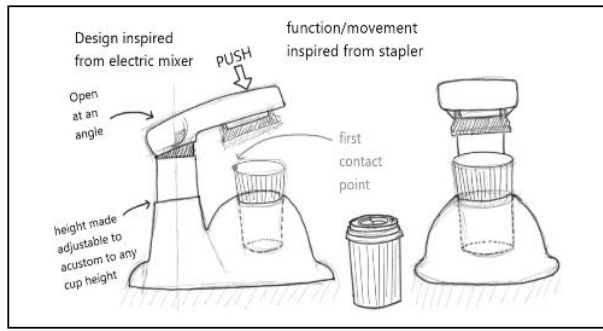


Fig. 11 Concept-5 for project Coffee to Go.

Fig. 12 shows an assembly drawing for the project called Coffee to Go, as instructed the students used the CAD tool to create the final detail design. This is the result of synthesizing all the concepts created in the previous step of concept generation.

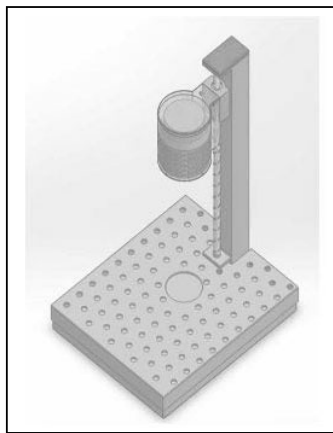


Fig. 12 Assembly drawing for project Coffee to Go using CAD.

IV. RESULTS AND DISCUSSION

The online survey to get students feedback and reflection on their experience using freehand sketching for design ideation over CAD was released at the end of the trimester and was prepared using Google Forms considering its many advantages such as lesser cost in administrating questionnaires, ability to reach out to a large population, geographical and temporal advantages, reaching unique population easily and other benefits [26].

All second-year Mechanical students registered for this module at the UGS were invited for an online survey. A total of 50 students provided their feedback which makes a response rate of 85% which is considered, a very good and high level of motivation [27].

The survey design comprised some quantitative questions and some qualitative open-ended questions to compile information on each student's perceptions and experiences on the usage of freehand sketching during the concept ideation stage of product design. The result highlight when to put attention to the use of freehand sketching and CAD tool while going through the product design cycle.

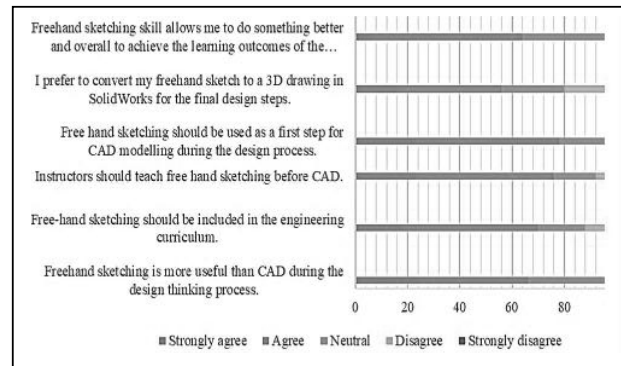
A. Learner's perception of freehand sketching on its importance on quantitative questions

The students were asked to provide their feedback on the following questions regarding the usefulness of freehand

sketching over CAD during design ideation: freehand sketching should be included in the curriculum or not, if yes then when should the instructor teach this freehand sketching?; freehand sketching should be the first step for any CAD modeling during product design; student's preference to convert freehand sketching to 3D drawing; students will do better and achieve their learning outcome goal using freehand sketching during design ideation; using 5-point Likert scale (strongly agree, agree, neutral, disagree and strongly disagree).

1. Freehand sketching is more useful than CAD during the design thinking process.
2. Free-hand sketching should be included in the engineering curriculum.
3. Instructors should teach freehand sketching before CAD.
4. Freehand sketching should be used as a first step for CAD modeling during the design process.
5. I prefer to convert my freehand sketch to a 3D drawing in Solidworks for the final design steps.
6. Freehand sketching skill allows me to do something better and overall achieve the learning outcomes of the course.

Results on learners' perception of freehand sketching on its importance on Questions listed above A1-A6 are



illustrated using an excel clustered data chart in Fig. 13.

Fig. 13 Learners' perception of freehand sketching on its importance on quantitative questions A1-A6

Students' response shown in Fig. 13 gives a clear indication that students found freehand sketching more useful during the design ideation stage while product design over CAD tool as more than 60% of students' perceptions is either agree or strongly agree. More than 65% of students want to introduce freehand sketching into the mechanical engineering curriculum at UGS and gave their preference to teach Freehand sketching before the teaching of any CAD tool. Seventy-five percent of the respondents prefer to use freehand sketching during the design ideation stage and then for the detail design stage they prefer to use CAD tool as it gives a detailed description of an engineering system of a design, with exact dimensions [6]. Sixty-two percent of students indicated that after using freehand sketching during the ideation stage and CAD tool during the detail design phase in their selected projects, they can achieve the learning outcome of the module named Design and Manufacture 1.

B. Learner's level of acceptance on quantitative and qualitative questions

To understand students' level of acceptance to adopt freehand sketching by using different media available (pencil and paper, drawing tablet, or iPad), they were encouraged to

try them during the project work and the following questions were designed. The first two questions were quantitative questions using a 5-point Likert scale (Extremely comfortable, very comfortable, comfortable, slightly uncomfortable, not at all comfortable).

1. Rate your comfort level for freehand sketching using a drawing tablet after completing the module on Design and Manufacturing 1.
2. Rate your comfort level for freehand sketching using an iPad after completing the module on Design and Manufacturing 1.

Results on learners' level of acceptance of freehand sketching on Questions B1 and B2 listed above are illustrated in Fig. 14.

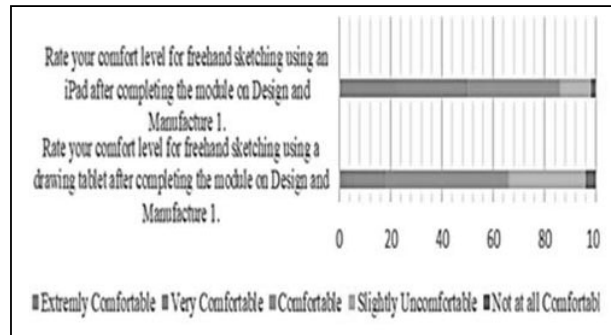


Fig. 14 Learners' level of acceptance on quantitative questions B1, B2.

Students' responses in Fig. 14 gives a clear indication that students found the use of drawing tablet and iPad to be comfortable during the design ideation stage of product design as 62% of students are comfortable or more comfortable to use the drawing tablet. Over and above this, around 84% of students are more comfortable using iPad for freehand sketching.

The third question was designed as an open-ended qualitative question on suggestions and feedback.

3. Which one is the best suitable option to start and end with, for any designing process?
 - Traditional design methods using paper, pencil, and some geometry tools.
 - Designing using freehand sketching software such as Sketchbook using a drawing tablet or iPad.
 - Designing using CAD software such as Solidworks 2018.
 - Start using freehand sketching software for the design concept such as Sketchbook and then move onto CAD software for detailed design.
 - Traditional pen and paper and then move towards CAD tools like Solid work.

Results on learners' level of acceptance of freehand sketching on Questions B3 are illustrated using an excel clustered data chart in Fig. 15.

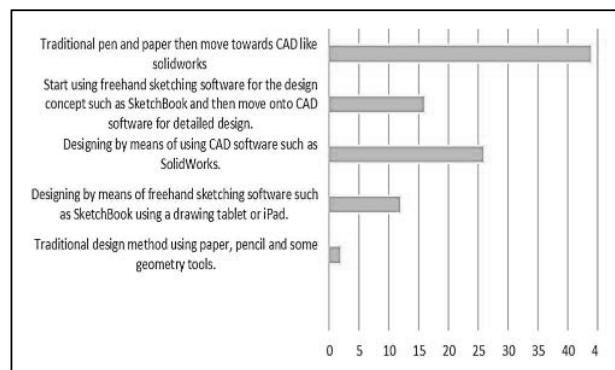


Fig. 15 Learners' level of acceptance on quantitative question B3

The above analysis shows that every user has a different ability and choice to represent their design work and their comfort level also differs from one method to another method. Forty-three percent of students indicated their response to use pencil and paper for freehand sketching at design ideation stage and later for detail design they are more comfortable to use CAD tool.

The fourth question was designed as an open-ended qualitative question on suggestions and feedback.

4. Suggestions, feedback, or ideas I would like to share with faculty who will be teaching freehand sketching in the future.

In response to open-ended question 4, some feedback is stated below,

"Instead of the drawing pad, maybe issue an iPad as it is more convenient to students to translate the ideas through freehand sketches using iPad instead of the drawing pad issued during the design and manufacture 1".

"Maybe instead of using tablet and connect it to computer to draw, can just draw on an external device like iPad where the drawing can be seen immediately, requires no coordination. Also, allow sketching on paper as well in the event the student was unable to bring any devices on that day to avoid missing out on the learning experience".

"More exposure will be good as this digital freehand sketching is a really useful skill".

"Firstly, start a lesson drawing on paper. Then slowly shift onto drawing pads".

"Having Tablets/iPads helps with sketching, otherwise pencil and paper are fine".

C. Learners' feedback on qualitative open-ended questions.

Some open-ended qualitative questions were also added to the survey to capture the advantages and disadvantages of freehand sketching during design ideation and to get suggestions and feedback from students. The questions along with the responses are listed below.

Que: What are the advantages of freehand sketching during the design thinking process?

Most of the responses to this question matched with what was mentioned in the section on the power of freehand sketching in the engineering design ideation process. Many students mentioned flexibility, ease to start, ease to edit, very quick, timesaving, ease to communicate, fast translation of ideas from mind to paper and so many similar advantages of

freehand sketching of design ideas during the design thinking process. A few more responses from students are listed below:

“Allows you to quickly get a visual view of the ideas that you've generated.”

“Not limited to computer skills can illustrate without concern of constraints”.

“Freehand sketches allow for easy communication between the ideation process as freehand sketches are straightforward and fast”.

“Fast. Ideation is more of idea creation, regardless of good or not”.

“It is quick and easy; notes can be written at the side as a reference as well”.

“You can easily produce ideas and alter as you go without the need of specific dimensioning”.

“It helps the user to visualize their concept better, to be able to test the feasibility of the concept by seeing it with the possible movements on paper. it also helps me to explain the concept better to my teammates and classmates, they have a brief understanding of it through words, but with aided sketches and designs, they can understand it better”.

“Easier to express our ideas which may take time to draw using CAD software”.

“Ideas are drawn on the go without losing any momentum or chain of thinking process”.

Que: What are the disadvantages of freehand sketching during the design thinking process?

Responses to this question have revealed unsupportive freehand sketching in terms of the ability of highlighted acute issues of using freehand sketching such as difficulty to visualize, not being very precise, not to scale, could be very messy, difficult to transfer to 3D drawing, need to be artistic for good sketch, need time to be confident on sketching skill. A few more responses from students are listed below,

“Not as precise as CAD”.

“Might not show all the function”.

“If the person isn't particularly good at drawing, he/she will find it difficult to properly sketch out their ideas”.

“Sketches might not be clear if the artists aren't very skilled at drawing or presenting their ideas”.

“Some people can't portray or visualize the idea they had in mind. Which might be difficult to draw”.

“It can also be quite difficult for those who aren't inclined towards art; in the way that they can visualize the concept in their head, but they can't seem to draw out the part because it's complicated to them to draw the minute details”.

“Some ppl might not be confident in sketching abilities. Without a digital device, I have a problem of misplacing the sketch”.

Que: Suggestions, feedback, or ideas I would like to share with faculty who will be teaching freehand sketching in the future.

This question was designed to get feedback from students as learners and users of freehand sketching during design ideation for product design. Also, to capture future possible improvement for instructors while teaching freehand

sketching to students if the university plans to go ahead with the use of freehand sketching during design ideation.

Suggestions received from students were very fruitful and focused on future improvement. They mentioned the need for more encouragement, time, and practice to use freehand sketching. They proposed more emphasis on the drawing methods adopted by many designers elsewhere or in the industry would be good. A few more responses from students are listed below:

“Hand-drawn sketches are the fastest and easiest method to translate our ideas”.

“Teach the importance of engineering hand drawing like the details instead of a proportionally drawn sketch”.

“Teach how to draw, not like an art and craft lesson but, how to draw for designing purposely”.

“Firstly, start a lesson drawing on paper. Then slowly shift onto drawing pads”.

“Probably teach some perspective sketch as well”.

“Give students practice session where they are needed to freehand sketch to tackle small problems”.

“I think it'll be better to teach them how to draw joints and locking in 3D view and advise them to always draw details and label them and their functionality”.

“Make it a workshop instead of a graded module”.

“Don't make sketching a graded component as drawing abilities vary a lot between people even after some training and this will be very biased towards those with more artistic talent”.

D. Recommendation

Considering the responses provided by students on a qualitative and quantitative set of questions, the following recommendations are presented:

1. Introduce freehand sketching to students while teaching module on Design and Manufacture 1 during the second year of mechanical engineering or in any other suitable module in year one, at UGS. Also, students should continue using freehand sketching while doing subsequent project-based modules for design concept ideation.
2. Provide useful learning and training platforms to students to make them comfortable for the use of freehand sketching as part of the curriculum to sketch out product/engineering ideas and produce engineering drawings creatively to effectively communicate design ideas and solutions.
3. Introduce freehand sketching before introducing CAD tools to students.
4. Give sufficient time to the students for practicing freehand sketching by providing small and simple design problems to make them comfortable before launching some innovative design projects.
5. Provide effective and efficient digital devices with proper hand-eye coordination to students for fast and easily storable freehand sketching.
6. Considering concept ideation required more human-centric work where freehand sketching is better while detail design required more precise and intricate detail

work with dimension, CAD tools are more efficient at this later to improve the effectiveness of product design and development cycle.

7. Convert freehand sketching into workshop practice rather than as a graded component. If not possible then do not grade students' project work on the quality of freehand sketching, emphasis should be put on quantitative work, not qualitative work as drawing abilities varies a lot between people even after some training and practice sessions.

We can confidently say that these recommendations will not only improve the ability to sketch but it will be a source of sustainable, innovative, and quick mechanical design in this competitive market.

V. CONCLUSION

In this study, we sought to explore students' (learners') experience of using freehand sketching over CAD tools for concept ideation while studying product design and development. The effectiveness of this approach was measured through a survey conducted with students at the end of the trimester and it has been evaluated based on the survey results presented in results and discussion. From that, we can conclude that removing 'freehand sketching tools' from the syllabus would hinder the learning outcomes of design courses. Particularly in terms of developing their ability to conceptualize, communicate design ideas, and navigate through the design process. Traditional freehand sketching is here to stay along with mechanical engineers. A proper blend of freehand sketching at the design ideation stage and the use of CAD tools at the detail design stage during product design development will elongate the product life cycle. So, engineering universities such as UGS need to introduce freehand sketching in the curriculum along with CAD tools.

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