PROTOTYPING WITH A CONSCIOUS CONNECTION TO THE SENSES: APPLICATION OF PAPERCLAY IN PRODUCT

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ABSTRACT
The digital age has changed the way design education is taught. Current generations have developed skills that allow them to learn and experience the discipline in a different way, preferring a virtual environment and leaving behind kinaesthetic learning. This project aims to reawaken students' interest in exploring form through freehand sketching and "3D sketching," but with a more environmentally conscious approach. To this end, "paper clay" is used, a ceramic material that contains a percentage of recycled paper, enabling it to be reused as often as necessary. This aligns the teaching of design with the objectives of the Tecnologico de Monterrey's 2025 Strategic Plan, primarily considering two axes: culture, which promotes sustainable awareness; and mitigation, which seeks to reduce environmental impact in the institution's operations.
The training of designers involves the essential development of spatial thinking. This work presents the development and results of implementing a teaching methodology in which the use of the senses of touch and smell helps retain knowledge. Using paper clay, kinaesthetic learning is revisited, conducting three-dimensional exercises based on the needs of a specific user and the prior development of a design concept.
This exercise was carried out with high school students aspiring to pursue a career in design. The exercise was conducted with 3 different groups, each consisting of 30 students. It is important to note that the course on which the exercise is applied is an exploratory one, helping students choose their professional career by experimenting with techniques and materials to have an experience like that of professional exercises.

Keywords: Higher education, educational innovation, paper clay, product design, kinesthesis

1 INTRODUCTION
In creative careers, specifically in product design, it is essential to develop abstract thinking in students, which will enable them to deduce a problem, interpret it, and subsequently analyse it to arrive at a solution. Additionally, this type of thinking allows for constant iteration to propose multiple solutions based on a specific user need.
This type of thinking must be developed alongside spatial thinking, which allows students to develop various iterations from different views and types of perspective with detail. This cognitive element is known as "mental imagery" [1], where the authors mention in their paper that "Imagery is used when we reason about the appearance of an object when it is transformed, especially when we want to know about spatial relations".
For the reasons mentioned above, it is important to promote the development of translating mental imagery proposals into sketches that have all the necessary details to communicate that idea effectively. Buxton, B. mentions in his book Sketching User Experiences: Getting the Design Right and the Right Design [2], that "Sketching is about rapidly collecting existing ideas... When you capture ideas of others, you can then use those ideas as a starting point." In other words, the iterations made in sketching are a product of a set of pre-existing ideas from the student, but it allows the generation of new ideas based on previous experience.
For this paper, the definition by Pei, Campbell and Evans will be taken as a reference [3]. In their paper "A taxonomic classification of visual design representations used by industrial designers and engineering designers," they define the purpose of the idea sketch (Figure 1) as "to allow the developer

to externalise his thoughts quickly and to show how the design looks on paper." This type of sketch allows for the exploration of different ideas in the early stages of the methodology, making it natural to start with this type of sketch in design education.

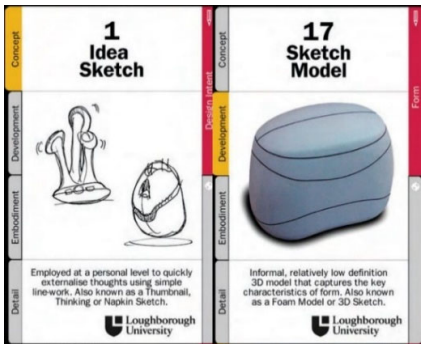

Figure 1. Idea Sketch and Sketch Model from "ID Cards A taxonomy of design representation to support communication and understanding during new product development

On the other hand, the sketching model (Figure 1), according to Evans and Pei [4], is "an informal, relatively low-definition 3D model, that captures the key characteristics of form." It should also allow for an exploration in which the student is not only aware of the form but also of the experience they are generating with it, so they need to know the textures, grip forms, weight, mechanisms, among others. In his paper, the future of design synthesis education [5], Acuña mentions, as part of his findings from the pilot study he conducted, that "teaching modeling techniques is as necessary as sketching in order to apply them in early stages of design synthesis, because Tri dimensional properties of concept models help to understand and explore design proposals better than sketching does." Therefore, teaching both is of utmost importance before using digital tools that complement the skills acquired with these fundamentals.
In Figure 2, we can observe the interrelation between the sketch and the prototype and the importance of teaching both in design.

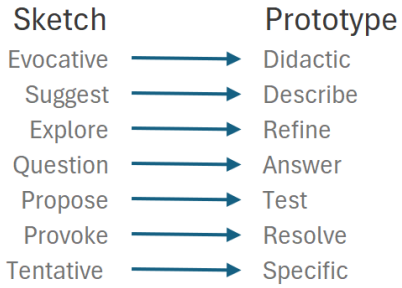

Figure 2. The sequence of sketches and prototypes based “The sketch to prototype continuum” de Buxton, 2007

2 METHODOLOGIES

The present work aims to analyse and develop a methodology in which students can develop spatial thinking by revisiting analog practices such as freehand sketching and clay model sketching. While this paper seeks to revisit previous practices such as starting design in an analog manner, it is also necessary to evaluate the environmental impact that sketching and prototyping with these characteristics can generate. Therefore, a material that can be reused as many times as necessary, if it is not fired, was chosen; we are talking about Paper clay. With this, we are contributing to two of the initiatives of the Tecnologico de Monterrey's 2025 sustainability and climate change plan:
- Culture: whose objectives are "Promote a culture of sustainability, providing knowledge and promoting behaviours in sustainable development and climate change." Tecnologico de Monterrey [6].

- Mitigation: objectives are "Reduce our carbon footprint by 50% in scope 1 and 2, water consumption by 20%, and ensure that 100% of our facilities have a sustainable waste management model." Tecnologico de Monterrey [6].

Another important reason for emphasising the use of this material, regardless of its sustainable characteristics, is that it is a material with which one can experiment with forms much more freely. Additionally, at the end, there is a final prototype that allows for real validation with the users for whom the design process was carried out.

Paper clay is a material composed of ceramic clay with a percentage of paper. The fibre contained in it, according to Bennet [8], "allows for capillary action when used in the clay body, improving the workability of the clay." During the development of this research, it has been detected that it also allows for much more efficient hydration than ceramic material without paper. The paper used is that utilised within the School of Architecture, Art, and Design building; material previously used for internal documents and sketches mainly. It has been limited to matte bond paper. The material used has the following components: 70% commercial cone 05 paste and 30% Zacatecas clay.

Of the total dry weight of this paste, 10% paper pulp with a density of 1:100 is considered. This exercise has been carried out three times in past semesters, where the number of students is between 30 and 32. On all three occasions, it has been focused on the final semester project where they have to design a liquid container. For this, they were given 2 sessions for sketching and 4 sessions for prototype production, including colour application. This exercise was carried out as an activity within the subject but not with as specific a learning purpose as in this pilot study. On those occasions, areas of opportunity were detected: In the sketch, it was the opposite; first, they were given a brief explanation of what a view or perspective drawing is, and much importance was placed on taking care of the representation system (even if it was just sketching), which made the sketches look very forced and without the possibility of exploring the form. In modeling sketching, it was important to allow students to experiment with the material before working on the final project; this point was very important as it allowed students to explore the properties of the material and discover their own manual skills.

For the pilot study, students were given more freedom to explore forms in the sketch and experiment with the material in the prototype. This resulted in self-exploration of their own skills without the fear of the possibility of error. This exercise was carried out before the final project, and I emphasised the possibility of making mistakes without repercussions on the grade. To implement the learning activity, a pilot study was conducted involving 20 high school students in a topic called Introduction to Design. This subject aims to give students interested in a creative area a better idea of what discipline encompasses to make a better decision regarding the career to choose for university. The exercise consists of three stages:

Stage 1

Students are asked to draw a product on a blank sheet of paper that they will later create in paper clay. This product must be a small container measuring 5x5x8 cm, with an additional element to choose from: handle, spout, or lid. Additionally, it must have an irregular shape. The design concept they were asked to consider was "insects." The requested drawings are: one with general views and another with a perspective view. Both must be freehand and include measurements of each part of the design, as well as specify the colours that will be used for the product's decoration. The instructions were written on the board without using digital slides. No emphasis was placed on colour, as the importance of this exercise lies in the form.

Without placing too much emphasis on iterations, the students focused on their final proposal, using their cell phones to search for different insects and existing ceramic piece shapes. At this point, the students instinctively felt compelled to seek references that would allow them to engage in a cognitive process of abstraction. Some of the results are shown in Figure 3.

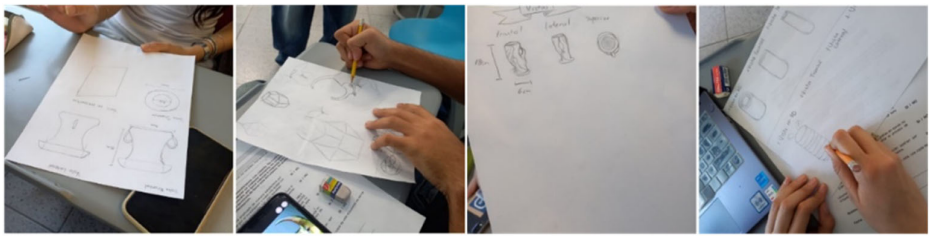

Figure 3. Stage 1. Sketching

Another important aspect to highlight is that some of the drawings are not proportionate to the paper, indicating insecurity in sketching.

Stage 2

Students enter the design workshops where they are provided with paper clay, and the challenge is to create their pieces in 3D using their sketches. At the end of the exercise, they compare the sketch with the 3D model they created. For this second stage, they were given a brief introduction to the material, explaining how to work with it to ensure the pieces come out intact from the kiln after the first firing. The exercise was carried out using coil technique. It is worth mentioning that the easiest way to explain how this technique works was by comparing it to 3D printing, something that would not have been possible in past generations. Figures 4 and 5 show examples of modeling in paper clay and results of the first clay burn.

Figures 4. and 5. Modeling in paper clay and results before the first clay burn

Stage 3

Redraw the resulting product from the model created in paper clay. The stages were carried out one per session of an hour and a half, considering the instructions at the beginning of each session, so they had an estimated one hour to complete the activity. This study aimed to compare the development of spatial intelligence before and after using paper clay. An important aspect is that the exercise was conducted in a stress-free environment where students were encouraged to overcome the fear of a blank sheet or making a bad drawing, all with the understanding that they are in a learning process. This stage was extremely important since the students were able to identify that the differences between the first sketch and the model originated from experience working with the material. This provided them with the preamble to make their design proposals for the course project with much more objectivity and feasibility.

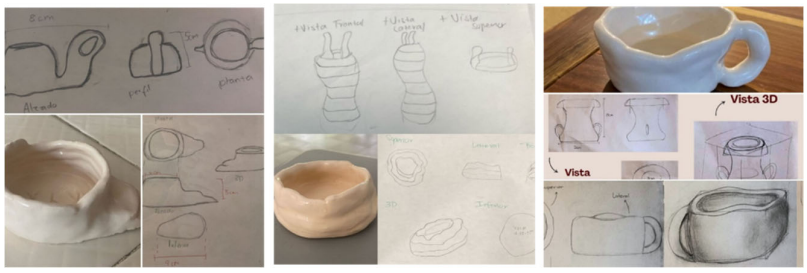

Figure 6. Pilot study results. Three stages included

3 RESULTS

In this section, two types of results will be presented: one observed by the students themselves, who answered a survey about it, and the results will be shown through graphs; the other type of results are those observed during the exercise, and some aspects can be compared with other exercises previously applied. In Figure 7, we can see the results of the questions: What academic program do you want to study? When trying to develop your idea on paper for the first time, did you have difficulties adding details? In the first question, we have a population that is 38% interested in design, but we also see a 25% interest in architecture. That is, a group with a total population of 63% interested in creative areas.

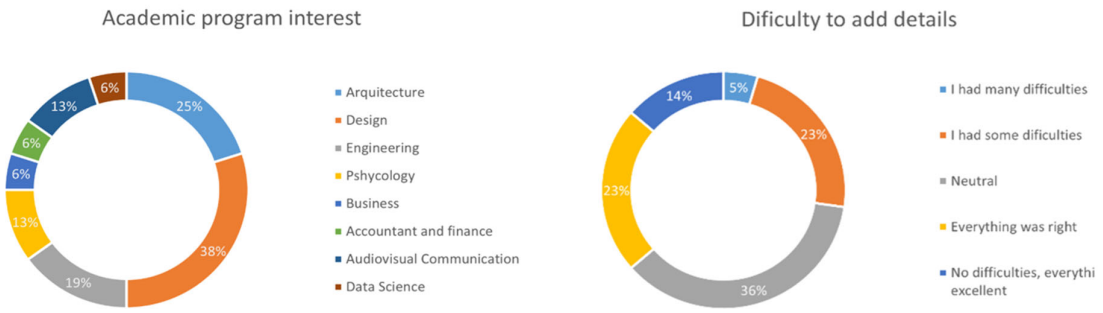

Figure 7. Answer to academic program interest questions and difficulty sketching

On the other hand, in the question about the difficulty in adding details, we see that 36% perceive it as neutral, so they cannot define the degree of difficulty of the exercise.

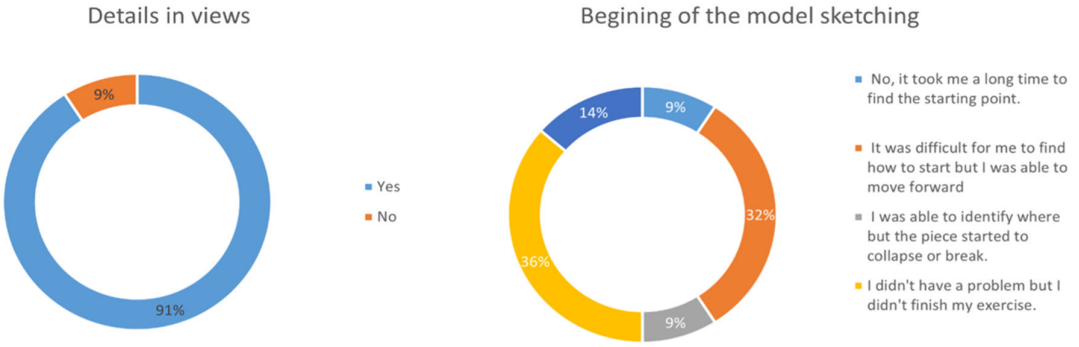

Figure 8. Answer to questions about view details and start of model sketching

In Figure 8, we see the answers to the questions: When drawing, were you able to develop the three views of your proposal in detail? When starting with the paper clay prototype, were you able to identify well where to begin? In the first question, 91% of the population perceive that the details in the views are sufficient. However, upon reviewing their sketches, it can be noted that very specific details are missing, and some of the views are not correctly represented. Nevertheless, for their first approach to a design sketch, it contains the basic elements necessary to carry out a model sketching.

In the second question, we see that 36% of the population knew how to start modeling their piece but could not finish their exercise, in this point the 62% of the students are interested in design as a major, so this works has more details than the rest. An expected situation is that 32% of the population had difficulties starting the model but were able to make progress. On the other hand, something unexpected is that only 9% of the population had no problems with their piece starting to collapse or break, which was very common in activities carried out in previous semesters.

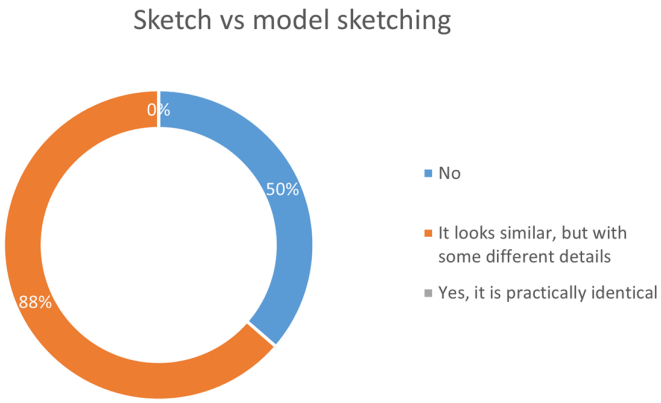

Figure 9. Answers of sketch vs model sketching

In Figure 9, we can see the students' responses to the question: Is the result obtained with the paper clay identical to your final sketch proposal? In this case, the students identified many discrepancies between the sketch and what they modelled. This result is natural since it is the first time they are experimenting with the material, but it gives them a guideline on how to work with it and its potential.
Finally, they were asked a question regarding the kinaesthetic aspects of the material, where we involved other senses for learning. The question asked was: When working with the paper clay, how did you perceive the material in terms of texture, smell, and colour? A recurring response was that they thought working with the clay would be like working with plasticine, but they found it to be a bit more complex. They also mentioned that the smell reminded them of wet soil.
The results of the exercise greatly exceeded expectations since it was done in a short time, and yet the resulting pieces were mostly 70% advanced. The resemblance to the sketches is not very close, but the idea is to give them the opportunity to experiment with the material before carrying out a more formal design exercise.

4 CONCLUSIONS

The work conducted during this paper provides a starting point for kinaesthetic teaching, revealing the relationship between sketch and model sketch and their impact on spatial intelligence for creative disciplines. Clearer guidelines for sketching with iterations that facilitate form exploration are proposed. The ceramic modeling process has improved each semester, allowing students to understand and experiment with the material for their final projects.
The fact that the implementation of the sketch focused on formal exploration rather than on the quality of the line is considered a success for the study.
By the end of this paper, only part of the methodology was reached, but the preliminary results will be analysed in the final projects of the course. It is expected to show the complete results in a future paper. It is also intended to extend the practice of modeling with paper clay in second-year courses of the degree in product design, considering longer sketching and prototyping times.

5 FUTURE WORK

For future work, an effective tool will be sought to objectively measure whether kinaesthetic teaching generates greater knowledge retention. This will require the evaluation of tools that can be complemented with other disciplines. Additionally, it will be important to conduct a pilot study with two groups to make a comparison and corroborate the validity of the hypothesis.

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