Mixed Activities to Materialize Ideas in the Teaching-Learning Process

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***Abstract*—The present research consists of the implementation of Computer-Aided Design (CAD) and Computer Aided Manufacturing (CAM) software as a didactic support resource in the "Model and Prototypes 1 Workshop" of the Industrial Design degree, in which students learn and practice different representation techniques three-dimensional, to be able to occupy them later in the generation of models or prototypes of the designs made in the subjects of projects and the professional practice. However, it is necessary to familiarize yourself with the techniques and tools most frequently used in professional practice that provide more remarkable or excellent performance when the combination of specialized software and manual processes generates a better understanding of the manufacturing process and accelerates learning. The process was implemented in a total of 42 students, divided into two groups, one in 2017 and another in 2018.**

***Keywords*—industrial design, prototyping, CAD-CAM, higher education, educational innovation**

I. Introduction

In the last two decades, technology implementation in architecture, art, and design teaching is proliferated [1–3], and visualization technologies are more relevant in the last years. This paper will focus on the design discipline, where students must have an essential visual education, manual skills, technical knowledge, and various technological tools at their disposal. Furthermore, design education has more components, including regional or territorial aspects. College education in developing countries, such as Mexico, is beginning to move towards competency-based education, and technology plays an essential role in any discipline education [4]. Technology is a synonym for 21st-century skills [5], and design education is profoundly related.

In recent years, the design practice has taken a decisive role in many disciplines that require divergent solutions. Design is a powerful catalyst to create opportunities to generate links between industry and academia [6]. The evidence is that design, as a discipline and approach, is a differentiator in industry and academia. Design thinking is an example of how academia and industry can work together. Design thinking became a popular tool, and this has been introduced in several aspects of design education. In current conditions, we can find an example of how it works in Massive Open Online Courses, where the implementation shows good results [7]. Although, these methodologies and the relationship with the industry awake a debate among many design professionals, where some prefer the design as an artistic expression (creativity) more than technological and not conventional solutions. Nevertheless, the technology and design processes demonstrated how help is to create a better design process and reach proactive solutions through creative ideation, sketches, prototypes, and more [8]. Under a processes perspective that involves technological tools, this research paper seeks to reveal that using a particular technology became a support tool for teaching fundamental principles to designer students.

Creativity is not cut off by using technology. Design education must seek its strength in technologies exploring creative interaction elements. In this case, our paper focus on the relevance of the vision. In practice, visual technology supports creativity for problem-solving [9]. Although technology has changed the discipline, it is a relevant factor in its transformation, like the same paradigm shift in design practice [10].

Even within this whole technological argument of changes in design education, there are still practices that must be considered in the curricula of design students. The prototypes or three-dimensional representation development are relevant in Mexican Design Education. Handmade or craft is a historical activity in many regions of Mexico. Nowadays, students are interested in elaborating representations using traditional techniques, and universities adapt this to their curricula. The prototype is something relevant to professional design activities. Prototypes are approximate product representations in one or more dimensions [11]. Conventionally, the prototype is a preliminary three-dimensional representation used in creating a new product, service, or system necessary to understand its materiality [12]. Historically, this practice has been made manually or handmade. Nevertheless, in the last decades, technology has replaced the handcrafted approach, became it even faster and improved. Here, technology replaces one activity and becomes numb in another, resulting in technological tools that displace

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fundamental activities to design and understand fundamentals.

Computer-Aided Design (CAD) is one of the technologies that is used preferentially in the activity of prototyping. CAD has presented significant advances in design education, especially in the modeling facility from create to print or manufactured in three dimensions; This process is known as CAM: Computer Aided Manufacturing [13]. In several areas, CAD technology became a tool for the design process, which helps in precision, productivity, and facilitation of higher-quality outcomes [14].

CAD knowledge application in architecture, art, and design areas has shown positive results in education [15]. The influence of the traditional use of CAD impacts the behavior and performance of design and art students, emphasizing the importance of solutions and modeling (productions of forms) of non-existent objects [16]. Experts believe that the success of CAD in these disciplines is due to the relevance of elements visualization created by the software. Visualizing 3D elements supports the experience and learning of designers, not only industrial designers but also architects and interior designers [17]. Then, CAD education for design problems is seen clearly, and effectively for students' creativity support at the moment or need to design process [18].

Séquin [19] mentions that CAD became a conducive tool for aesthetics teaching in any area that requires it. So, in industrial design, visual work became a relevant factor in creating a high-quality attribute for solutions [20]. As mentioned above, the technologies to help to create a prototype are suitable for design education. Other studies reveal that novice designers gain experience through prototype creation in order to get problem resolutions [21].

Finally, this paper will show how CAD and handmade activities can coexist in order to improve the prototyping activity. The work aims to describe a model project implementation that allows students to create a high-quality prototype. The project uses technology to enhance a handmade and visualization process created by plane construction. Also, this plane construction is a technique used to improve the representation in drawing, allowing students to think orthogonally. This technique provides a clear sense of the materiality of an object [22].

II. Educational Challenge

The challenge presented in this model project consists of using CAD and CAM software as didactic tools for creating prototypes by handmade techniques. As mentioned above, the serial plane or stereotomy technique [23] and its current reformulation with the "balloon frame" is frequently used for elements construction [24]. This technique became the aim of the model project presented in the topic of Models and Prototypes Workshop 1 of the Industrial Design degree of the Tecnológico de Monterrey. The manufacturing of prototypes by manual techniques is entirely justified when the object presents dimensions that cannot be handled by popular methods such as 3D printing or high creation costs [13]. An analogy was made with the popular stereotomy technique to create volumes from manageable pieces to create a piece of large sizes. The project demanded assembling an internal skeleton and filling the cavities with filler material to seal and resurface the imperfections to achieve a uniform surface. Finally, the piece was painted to create a professional appearance.

The serial planes technique is frequently used for prototype creation in product design disciplines. However, the handmade prototyping technique is customary to reproduce existing objects. This creates a limitation in students learning since they cannot develop skills beyond representation through prototyping. The challenge as professors is to teach this technique as a tool that complements a creative process or creation of non-existent objects. The object materialization that does not exist is a component that the design student must handle. The complexity of forms plays an essential role in understanding the design's fundamental principles. A poor understanding of principles affects students' learning since they omit the mental elaboration of ideas, their two-dimensional representation (drawing on paper), and their three-dimensional representation. This situation leads to an opportunity to implement a series of activities that seek to improve student learning. The primary purpose of this model project is to detonate a series of skills to create and represent forms that do not exist and link them with problem solutions and design objects [25]. In our case, these tools introduce a more realistic approximation of an object to students; virtual representation makes it possible to understand and evaluate an object that does not exist and interact with it. However, the easy use of the software does not guarantee to learn; a methodology must be designed to focus on the needs presented above.

III. Methodology

The model project methodology was designed in three fundamental stages. 1) The instruction guided by the teacher or professor, 2) activities between teacher and students, and finally, 3) the exclusive activities of the student. This model project impacted a total of 42 students, one group of 20 students for the second course of 2017 and another 22 students in the first course of 2018 of the course Modelling and Prototype Workshop 1. The complete process is described in Fig. 1.

To start, preliminary exercises were introduced to the students to understand the dynamics to perform for the modeling and creation of serial planes of a piece. The preparatory activities were guided by Inventor® software by Autodesk®, which allows for a model of pieces with specific parameters for later manufacture. The instructions were given to the professor to create an object with different specifications, which presented a level of complexity according to the dynamics of the course. Once the preliminary exercises were done, the students started with the model project. For this education proposal, the model project was a cylindrical object with three spherical cavities in different parts. The general measures were 12 cm in diameter and 40 cm in height. The purpose of the proposed specifications was to practice with depth the techniques used in the course for the details of the prototype. In Fig. 2, the object modeled by the professor can be observed. This was the model project given to the students. During the first stage of the methodology, the students attended the modeling process; after, students must reproduce the figure with high fidelity. One of the elements contemplated in this methodology is the benefits of software support for object visualization (marked in blue in Fig. 2), which allows for rotation at 360° on the X-axis and the Y-axis, moving the object closer.

During the process of replicating the object of a piece, the different views and the possibility of free rotation promote the effect mentioned by Camba *et al.* [17] to generate a spatial/three-dimensional compression of the geometry and the expected result of the course project. This methodology introduces the student to understanding materialization practically supported by technology. After the geometric interaction, the Inventor® software also allows generating the blueprints with all the measurements, as seen in Fig. 3. This possibility familiarizes the students with another critical aspect of the products' manufacturing process, such as the generation of technical drawings or blueprints.

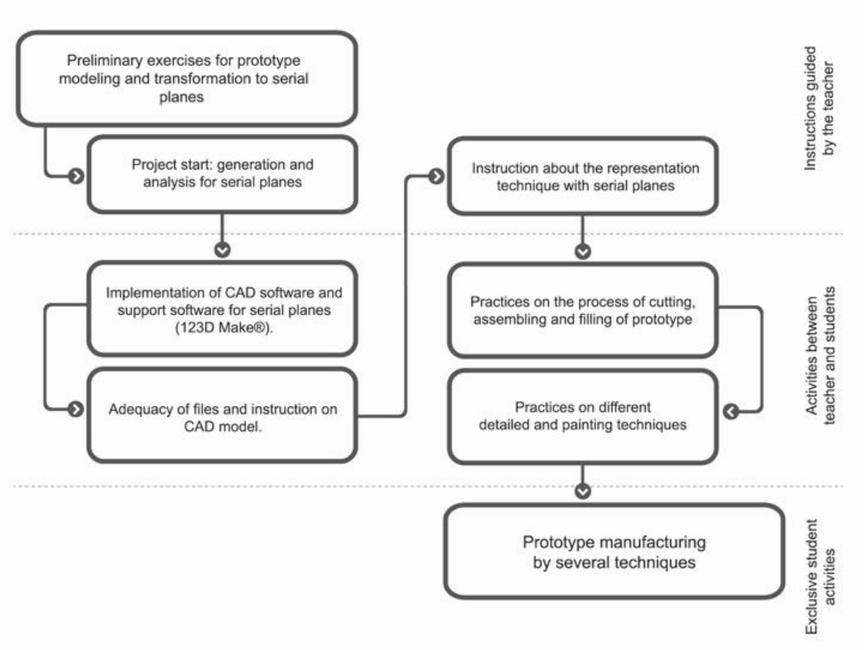

Figure 1. Diagram of the model project methodology.

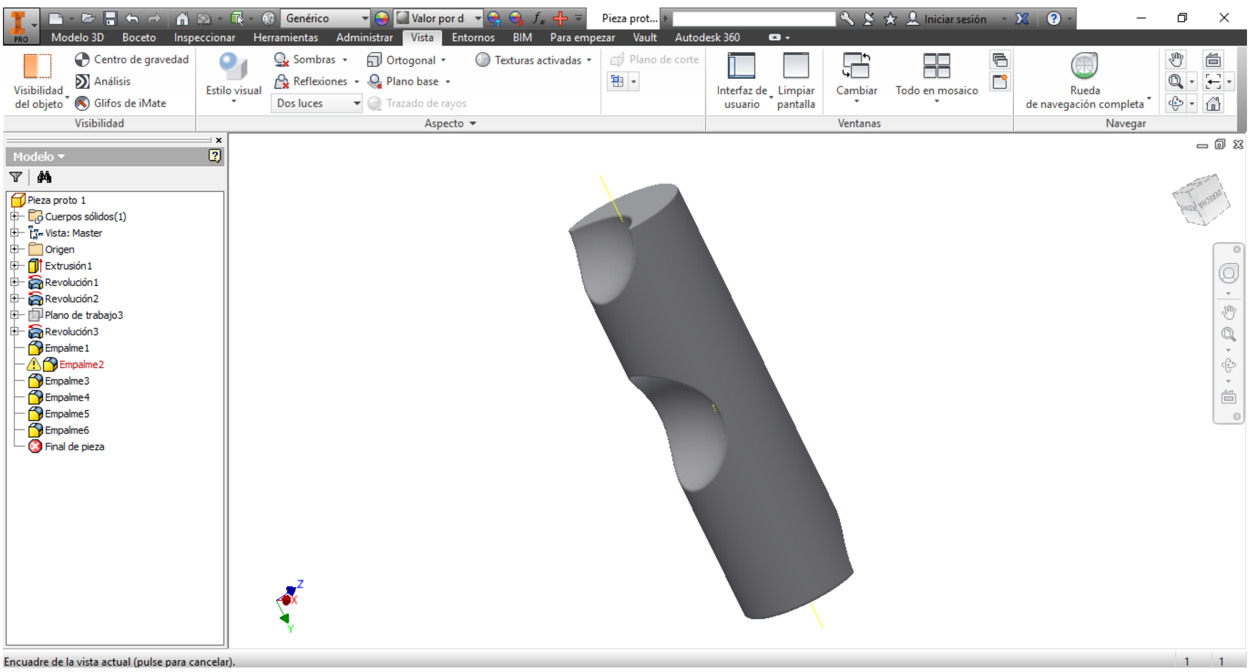

Figure 2. Image captured from the computer screen showing the software and the piece modeled by the professor.

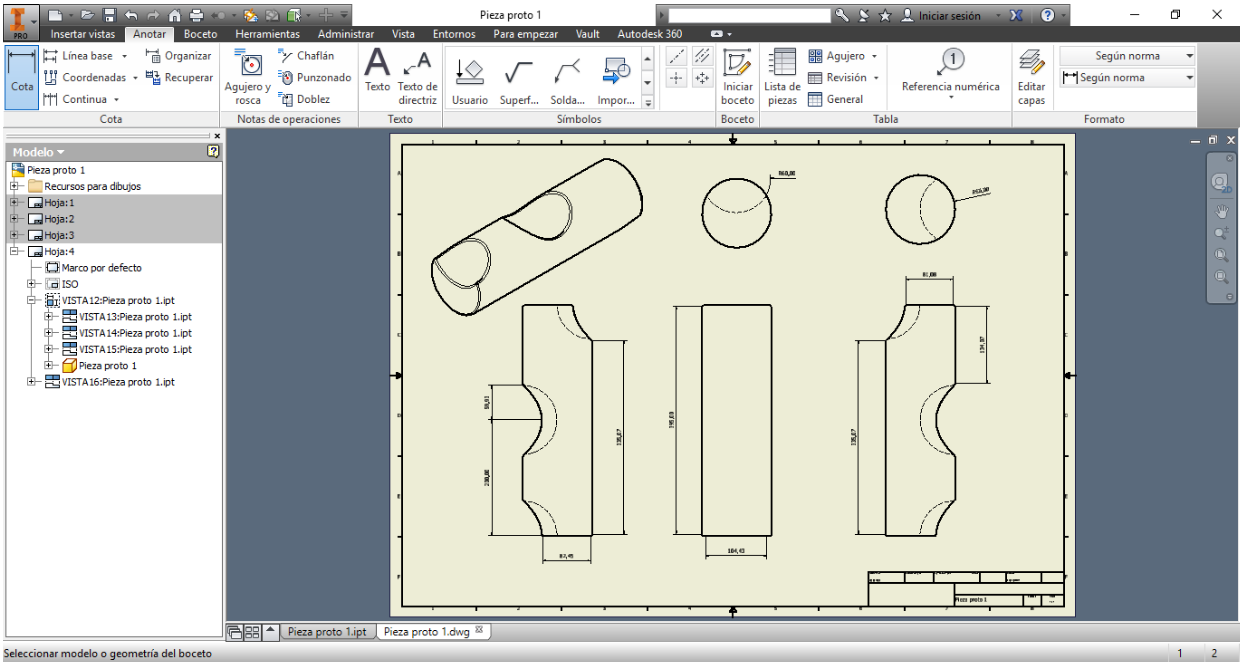

Figure 3. Image captured from de computer screen showing a blueprint with all measurements of the piece.

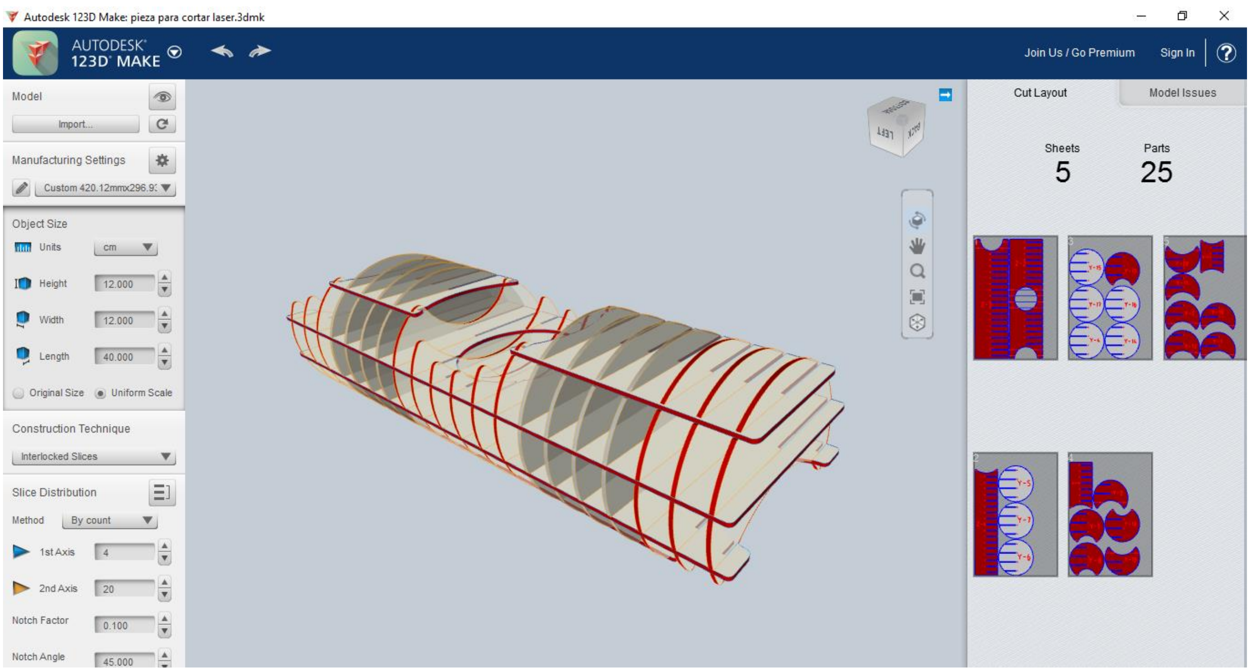

Figure 4. Image captured from the computer screen showing a complete process of 123D Make software.

In the project's second stage, after all the dimensional details have been defined and clarified, the piece is exported to the support software; the one chosen for practical use was 123D Make® of the same company Autodesk®. This program transforms solid pieces modeled into structures generated from serial planes. An example of the software implementation is shown in Fig. 4. Once the technical drawings were identified, another rapid prototyping technique known as laser cutting was applied. This technique made the pieces extracted from the software much faster than if you had to make the cuts manually to create the base structure of the piece to be built and to detail it as the final prototype. On the other hand, the laser cutting application represents and complements rapid prototyping techniques in which the last piece can be obtained once drawn in the software.

Still in the second stage, after the planes were cut, students assembled the cardboard pieces to generate what can be considered the skeleton of the object. A volumetric structure was developed where students filled with rigid foam of medium density extruded polystyrene known commercially as Styrofoam®. Then, the students covered the piece with different materials until reaching the indicated geometry of the object or prototype, as seen in Fig. 5. The piece development involves relevant handmade training for the students; the visualization of the piece, its construction process, and the covered process reach all the activities in the prototype in the curriculum.

Figure 5. Piece example development by the professor.

Finally, at the end of the second stage and last part, after the piece has been completely covered with the repaired paste, the pieces must be sanded at different times, but gradually increasing in the grammage of the sandpaper. The students started with sandpaper No.120 to 180, 220, and 280 until the students reached the desired texture. However, the students used repaired paste and sandpaper depending on the imperfections to get the texture. The following process was the color painting chosen by the student. This process is part of the course dynamics, where the student must apply fixative and, subsequently, a type of automotive paint used from a can or paint gun.

IV. RESULTS

The completed pieces from the 42 students demonstrated two essential aspects of handmade and technology implications. 1) a piece created from zero to its materialization could follow the model project methodology. 2) All students followed a methodology process that generated a positive learning experience.

The step-by-step process of prototyping was demonstrated, and the minimum quality conditions required were covered. The students could represent the digital model in all the pieces, respecting the measurements and general details. The only differences were the quality of more information; however, that is a factor determined by the same student. It was also possible to improve the time of development of the pieces since the students could visualize an intermediate stage of the manufacture before beginning the construction (stage of structure in serialized plan). One of the most relevant results is how students developed the pieces using spatial and materialization knowledge through CAD and CAM applications focused on a handmade activity. In Fig. 6, the students recreate a bit with a reference, only with the 2D plane's information. This opens the possibility of continuing to deepen in creating a more rigorous methodology with a more detailed follow-up of the learning experience.

Another significant result was the grades scored obtained by the students. 9.5% achieved an excellent grade (between 95 and 100 points, on a scale of 0 to 100), 38% received a good grade (between 85 and 94 points), 50% reached a regular grade (between 70 and 84 points), and only 2.5% failed the exercise (less than 70 points).

Figure 6. Students make the piece material and match the imperfections or repair the piece.

V. CONCLUSION

Applying and combining different techniques and methods significantly increase the professional experience in the industrial design curriculum. In a cultural environment such as Mexico, the handmade can coexist with several industrial tools. Prototype manufacturing from serial drawings is a consolidated technique [22], where industrial designer students must handle the CAD and CAM software. Additionally, our experience with CAD and CAM software implementation with handmade activities leads to students' total approach to prototyping with a fair investment of time. Also, this model project methodology offers the possibility to evaluate under the same conditions students' skills using materials and tools. Fig. 7 shows an example of the students' results.

Figure 7. Images of the pieces made by students versus the amount generated in the software inventor.

A vital aspect of this model project methodology was the systematization of the handmade process and identifying relevant stages in the interaction with the professor and students. Also, this experience revelated the student's aptitudes for workshop labor and the exploration of skills like assembly, filling, and painting. In future jobs, the correlation between students' grades and the experience process must be analyzed.

Finally, this paper represents the beginning of opportunities to continue exploring aspects of design education. The experience of using technology as a didactical tool can have a positive impact on students learning. The cultural context can be acceptable in global professional practices and finding the correct project exercises for the design students.

Conflict of Interest

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

All authors have contributed to the manuscript as follows: JCM developed the background research, designed the process, participated in the implementation with the students, and contributed to the article's writing; J-CR contributed process design, performed data analysis, wrote results and conclusions, and edited the final document; all authors approved the last version.

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