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Perception over the use of traditional and digital mediums within the design process: A questionnaire study on design students

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Abstract

The purpose of this study was to explore design student's perceptions over traditional and digital mediums within the design process. In this research, a convenient sample of design students was selected from two universities between Latin America and North America to respond a questionnaire which inquired for the design steps and the type of tools they used. The importance of traditional medium in the design process has been widely researched (e.g. Goldschmidt, 1991; Suwa et al., 1998; Tang & Gero, 2002). In a similar manner, digital medium has evolved in the design practice and researchers have looked at how the use of digital tools affect the design process (Salman, et al.2014). Multiple studies have argued that some stages of this process cannot be supported by digital medium tools (e.g. Bilda & Demirkan, 2003; Kwon, et al., 2005; Meniru, et al., 2003; Stones & Cassidy, 2007). In contrast, digital medium stimulates the occurrence of design patterns and epistemic actions (Yu, et al. 2015: Chandrasekera, 2014). Digital medium will require the development of new knowledge which may affect the designer's role and the education practices of new designers. The outcomes of this study will help design educators to understand design students' preferences in using digital tools and develop curriculums accordingly. In addition, it will aid software developers to better understand, cater to design students' needs and take advantage in the growing shift from traditional to digital medium.

Key Words

design process, design pedagogy, design method, design medium, digital tools, sketching

Introduction

Research on how the design process can be explained and documented began with Archer (1963) moving forward into multiple studies to better understand how designers think, develop their ideas and generate design solutions (e.g. Darke, 1979; Cross, 1982; Goldschmidt, 1991; Suwa, et al., 1998; Tang & Gero, 2002). However, better understanding how the design process unfolds and how multiple design mediums affect this process remains an ongoing area of exploration. Design mediums are defined by the type of design tools that are used in the design process. This study focused on two design mediums. First, the *traditional medium* constituted of non-digital design tools, such as pen and paper, sculpting and modeling materials, etc., and second, *digital medium* structured by digital tools such as vectorial software, modelling software, photo editing software, etc.

The importance and relevance of both design mediums within the design process has been acknowledged in previous research. For Rittel and Weber (1973), the design process is a

solution testing method which tackles wicked problems. Such problems will never have a final solution and must be revisited over and over again. When facing wicked problems designers analyze the problem re-examining ideas (Cross, 1990). In this re-examination process, traditional media has been found crucial for idea's reinterpretation and evolution (Goldschmidt, 1991; Suwa, et al., 1998; Tang & Gero, 2002). One of the main reinterpretation attributes in traditional media is *emergence* (Oxman. 2002). In contrast, digital media has been found restrictive to generate and support such attribute (Purcell & Gero, 1998; Oxman, 2002). Nonetheless, digital media can enhance the design process differently. In the study conducted by Yu, et al. (2015), digital tools evidenced the occurrence of *design patterns*. Design patterns are defined as core solutions to problems which can be repeated over and over again, always generating different outcomes. Furthermore, digital media permits the manifestation of *epistemic actions*. Epistemic actions are defined by Kirsh and Maglio (1994) as actions which free cognitive load through physical manipulation of the problem while looking for a solution, instead of, thinking on the solution prior to the manipulation process (pragmatic action). These attributes of digital media deliver a more efficient design process and liberate cognitive load.

This study collected data using a questionnaire from second year design students from multiple design majors in two universities between Latin America and North America. This questionnaire intended to better understand their preferences in design mediums as related to different design stages of the design process.

Literature Review

According to Gericke and Blessing (2011), there is no definitive design methodology ranging in different proposals between different models. Nonetheless, multiple shared stages in those models have been demarcated within them (Gericke & Blessing, 2011). These stages are subdivisions of the design process often defined as design phases. Three main stages were identifiable as the most common according to Gericke and Blessing (2011): a *problem definition stage*, a *conceptual design stage* and a *detail design stage*. The type of design mediums used in each stage varies according to the needs of the designer as well as specific stage's properties (Ibrahim & Rahimian, 2010). Since traditional media rouses idea reinterpretation and emergence, this study estimated that, such media was more frequently used in the problem definition and conceptual stages. In contrast, due to attributes of efficiency and repetitiveness, digital media was expected more frequent in the detail design stage.

Design Mediums: Between Traditional and Digital

Design mediums can be divided in traditional media and digital media. Traditional media is typically used through the direct manipulation of pen and paper or by the generation of tridimensional models (Cross, 1990; Ibrahim & Rahimian, 2010; Shih, et al., 2017). Moreover, the relevance of making and iterative reflection to enhance cognitive processes in the creative process has been addressed in the past. Traditional media has been frequently used to conceptualize ideas which can be later revisited by designers. In contrast, digital media has been more frequently used to focus on details and obtain realistic results (Ibrahim & Rahimian, 2010; Shih et al., 2017). According to the designer's intrinsic skills and interests, each medium has its own characteristic and properties which can help attain the desired results.

According to Oxman (2006), there are four levels of medium interactivity ranging from paper based representation (traditional drawings) found in basic levels to completely digital

environments in the highest levels. In this categorization, the first level involves physical interaction between the designer and the environment or representation, while the remaining three levels require an increase in digital interactions in non-physical environments, as well as a more developed designers' skillset**.** Within the first level, traditional medium tools are most commonly used to move the design process forward, more specifically, drawing regularly refereed as *sketching*. In contrast, digital mediums are most commonly used in the remaining three levels. The importance and relevance of sketching for the design process has been amply researched. For Cross (1990) sketches can be found all throughout the design process in various levels of complexity according to the designer's needs. He understood sketching not only as a communication tool, enhanced with models or tangible supports for designers to express their thoughts, but also as the way designers manage their thought processes, represent their early ideas and further evolve the ideas into final proposals or solutions. In summary, sketching was seen not only as a traditional medium tool used by designers to represent an idealized world, but rather as an ideation tool to develop their own design process. Through a series of protocol studies, Goldschmidt (1991) was able to expose the important relationship of creativity and sketching by evidencing through it the reflection process between ideas. Through the action of sketching and its observation, designers reflect discovering new attributes which move the design process forward. This iterative action *between seeing as* and *seeing that* was definite to propose an interpretative dialectic which enhanced creativity within the design process (Goldschmidt, 1991). In addition, Purcell and Gero (1998) stated that in order to be able to reinterpret sketches, attributes of ambiguity and density were crucial. To do so, the image or drawing in hand must be decomposed and recomposed into a new image which will give origin to creative moments within that process. Furthermore, according to Purcell and Gero (1998), these attributes are missing in digital mediums. Design students perceive and value sketching as a necessary skill, however, they find this type of traditional medium time consuming, expensive, lacking in detail and less efficient to achieve more realistic results (Ibrahim & Rahimian, 2010; Jonson, 2005).

In higher levels of medium interactivity, digital design has been emerging as a new practice of design. The impact of such is still divided and researchers have approached how digital mediums affect the design process (Salman et al., 2014). Multiple studies have argued that tools in this digital medium are still incapable of supporting idea development in conceptual stages (e.g. Bilda & Demirkan, 2003; Kwon et al., 2005; Meniru et al., 2003; Stones & Cassidy, 2007). The issue is that digital medium tools evolve rapidly. According to Yu, et al., (2013) the usage of digital medium tools in the design industry has changed. Sketching or drafting software which used bi-dimensional platforms, has been replaced by more diverse and elaborated tools which permit deeper thought processes positively affecting the design process (Hernandez, 2006). In addition, designer's need for more elaboration and less ambiguity in traditional medium has opened the opportunity for digital mediums to evolve and become more intuitive to satisfy this need. This evolution is currently permitting digital tools to be present in the design process from the beginning to the end (Shih et al., 2017).

Table 1. Challenges and benefits of traditional medium and digital medium.

Challenges and Benefits of Mediums		
	Benefits	**Challenges**
Traditional design medium	1. Physical interaction. (e. g. pen and paper)	1. Less capability to zoom in or zoom out
	2. Intuitive to use	2. Difficult to alter design proposals
	3. Simple supplies required	3. Fewer visualization details
	4. Easy to propose multiple design alternatives	4. Low efficiency in the process
	5. Attributes of ambiguity and density	5. Low detail and accuracy possibilities
	6. Multiple idea iterations	6. Tool specificity according to the design stage
Digital design medium	1. Liberates cognitive load	1. Complicated skillset required to use
	2. Design manipulation through zooming, omitting elements, panning, rotating, etc.	2. Lack of ambiguity and density
	3. Uses design patterns	3. Facilitate idea iteration
	4. Possibility to undo actions	
	5. Better visualization with more detailed and realistic results	

The study conducted by Jonson (2005) challenged dominant views in literature in which sketching was seen as the most important ideation tool in contrast to digital tools which were more used for representation, modeling and detailing. Verbalization was found to be vital within the design process generating more *A-ha* moments mediating between traditional and digital tools (Jonson, 2005). In an experimental setup, Jonson (2005) combined traditional and digital mediums to conclude that the combination of these mediums, intermediated by verbalization, generated more interactions which positively affected creative thinking. Such finding may suggest that ideation thrives under dynamic setups rather than under organized conditions.

This study does not intend to discern between traditional or digital mediums to see which one is better than the other. In contrast, the advantages of mixed medium environments in enhancing creativity has been supported (Salman et al., 2014; Shih et al., 2017). Table 1, summarizes and contrasts the benefits and challenges of traditional design media versus digital design media. Each design media has its own advantages and disadvantages and each can be enhanced by switching actions to compensate for weaknesses. Hence, mixed mediums are currently preferred by designers since they stimulate creativity by switching actions between them (Shih et al., 2017). Nevertheless, neither traditional nor digital mediums are solely used to currently handle the complete design process. Striving to fill the transition gap between the two mediums, integration mechanisms have been proposed to facilitate this between them, such as the Digital Sketch Modelling method proposed by Ranscombe, et al. (2017). In addition,

shifting between multiple digital tools can replace the apparent dynamism of traditional media (Jonson, 2005; Salman et al., 2014; Shih et al., 2017). In conclusion, new digital medium usage will require the development of new knowledge which may affect the education of new designers as well as the designer's role. Also due to the relevance that personal attitudes have towards the process of learning (McLaren & Stables, 2008), design student's preferences should be considered to adjust the instruction of design knowledge to effectively satisfy their needs and maintain the expected design outcomes. It became important for this study to better understand the perception and usage preferences of diverse mediums in current design students.

> *RQ1. What types of design mediums are more frequently used by design students in diverse stages of the design process?*
>
> *RQ2. What is the perception of design students over traditional and digital design medium?*

Method

A questionnaire was conducted to a convenient sample of 54 participants consisting of junior year undergraduate design students. For this study two universities were selected, one located in Colombia, Latin America, and the other in the Midwest of the United States, North America. In both locations, mandatory design studio courses for students above junior level were selected to conduct the questionnaire, hence the gender conformation of the sample was completely random according to each undergraduate program characteristics. The questionnaire consisted of two sections, the first section constituted demographics and the second a combination of open ended questions and multiple choice questions using Likert scales to measure several levels of response. In this section, the multiple stages of the design process and the students' perception on the two design mediums were explored. Design students were required to arrange the steps of their own design process, manifest which kind of tools they used for both medium and evaluate the importance and benefits of both mediums in relation to the steps. The statistical package/software SPSS version 24 was used for statistical analysis.

Analysis and Discussion

The total sample of 54 participants presented an age mean score in years of 21.81 (*SD = 1.65*) distributed according to geographical location for each university in 57.4% for Latin America and 42.6% for North America. For the complete sample size, 37% were design students in Junior level while the remaining 63% were design students from senior level. A total of 79.6% were female with the remaining 20.4% of male. For the female group 48.8% were based in the Latin America university and 51.2% were in the North America university. For the male group, 90.9% were in the Latin America university and 9.1% in the North America university. Table 2, displays general descriptive statistics of the sample. In relation to the fields of design activity, 59.2% of participants manifested activities in interior design, 57.4% product development, 25.9% graphic design, 5.5% architecture, 1.8% apparel design and 14.8% manifested activity in other types of design, such as experience design, furniture, and packaging.

Table 2. Sample's descriptive statistics.

Sample General Descriptive				
		Gender		Total
		Male	Female	
Latin America University	Count	10	21	31
	% within University	32.3%	67.7%	100.0%
	% within Gender	90.9%	48.8%	57.4%
	% of Total	18.5%	38.9%	57.4%
North America University	Count	1	22	23
	% within University	4.3%	95.7%	100.0%
	% within Gender	9.1%	51.2%	42.6%
	% of Total	1.9%	40.7%	42.6%
Total	Count	11	43	54
	% within Universities	20.4%	79.6%	100.0%

The questionnaire required seven defined design steps of the design process to be arranged in chronological order according to each respondent's perception. The defined design steps arranged in order of importance according to the respondents' answers were: *research, analysis, conceptualization, ideation, sketching, modeling* and *representing*. Of the total sample, 11% proposed new design steps: v*erification, observation* and *prototyping, verification* being the most common with a 66.7% share of 11% total. For the purpose of this study and in relation to the design method stages of the design process proposed by Gericke and Blessing (2011), *research* and *analysis* were linked to the problem definition stage, *conceptualization, ideation* and *sketching* to the conceptual design stage and *modeling* and *representing* to the detail design stage. Each design step was evaluated according to the level of importance given by the participants in a seven point Likert scale. The design steps which had the higher scores were *research* with a mean score of 6.69 (*SD = 0.61*), followed by *modeling* with a mean score of 6.29 (*SD = 0.88*) and *analysis* with a mean score of 6.26 (*SD = 0.82*). In contrast, the only design step that had a mean score below 6.0 was *sketching* with a mean score of 5.39 (*SD = 1.204*). A one sample t-test with an alpha level of .05 was conducted between the total sample mean score for all steps 6.14 (*SD = 0.52*) and the mean score of *sketching* which displayed statistical significance (t(53) = -4.621). This finding displays that *sketching* is perceived as the less important step of the design process. This does not necessarily suggest that students perceived sketching as not important in the design process. In addition, it is relevant to keep in mind that this step had the highest standard deviation of the mean scores for all steps. Therefore, we may infer that the perception of participants about the importance of sketching is the most diverse between subjects. In relation to the three stages of the design method, the highest score was for the *problem definition stage* with a mean score of 6.47 (*SD = 0.62*), followed by the *detail design stage* with a mean score of 6.16 (*SD = 0.75*) and in last place the *conceptual design stage* with a mean score of 5.93 (*SD = 0.70*). An omnibus ANOVA was conducted between the three stages with statistical significance (*F(2,96) = 12.454*). In post hoc analysis using a Bonferroni adjustment, the pairwise comparisons displayed statistical significance between the *problem definition* stage and the remaining two stages. From this we concluded that for participants the problem definition stage was the one of higher importance. Research has demonstrated that problem framing is a very important stage in the design process (e.g. Rittel & Webber, 1984; Dorst, 1996; Lawson, 2004). Problem definition defines the required approach to solve the

design problem and prepares the mindset to use the required tools to accomplish that solution. Table 3, shows information regarding the design steps evaluation and the type of medium used.

Table 3. Design steps evaluation and type of medium.

Design Stages and Steps					
		Steps Grading		Medium used %	
Design Stages	**Design Steps**	**Mean**	**SD**	**Traditional**	**Digital**
Problem Definition	Research	6.69	0.609	88.9%	55.5%
	Analysis	6.26	0.828	61.1%	68.5%
Total stage		6.47	0.625		
Conceptual Design	Conceptualization	6.09	0.925	70.4%	72.2%
	Ideation	6.24	0.799	42.6%	77.8%
	Sketching	5.39	1.204	35.2%	92.6%
Total stage		5.93	0.704		
Detail Design	Modeling	6.26	0.880	98.2%	20.4%
	Representing	6.10	1.063	92.6%	46.3%
Total stage		6.16	0.752		
Total of All Stages		**6.14**	**0.525**		

The use of traditional and digital mediums was also contrasted with the seven design steps previously discussed. The steps which had the higher usage of digital mediums were *modeling* with 98.1% of the total sample size followed by *representing* with 92.6% and *research* with 88.9%. In contrast, traditional mediums had higher usage in *sketching* with 98.1% of the total sample size followed by *ideation* with 77.8% and *analysis* with 68.5%. Furthermore, 94.4% of the total sample size believed that digital media is more beneficial than traditional media in the design steps overall. Open ended questions were asked to better understand why digital mediums were believed to be more beneficial. Answers varied between participants, but the most frequent reasons related to efficiency and realistic results. Supporting previous research (Ibrahim & Rahimian, 2010), apparently speed and efficiency in the process are very important to design students and such is better achieved through the use of digital mediums. Some of the answers were:

> *"I can be more creative with my pencil, but sometimes making it with a program is faster"*
>
> *"Digital media speed up the process and provides realistic results"*
>
> *"You can show a client what the space will look like and with VR design they can actually walk through it at a human scale"*
>
> *"Better idea representation permitting the client to better understand the idea, its benefits and innovation"*

Additionally, all participants were asked if they use sketching in the design process with a 90.7% of them answering yes. Furthermore, when they were asked if they used digital tools, the total of 100% of the sample answered yes. We were expecting to find that all participants used sketching in the design method in accordance to previous research which has demonstrated

the importance of sketching. For the participants who responded that they used digital tools in the design process, which in this case was the total of the sample size, we asked what kind of digital tools they most frequently used. The most frequently used digital tools were modelling tools with a 96% of the total sample, followed by photo editing tools with 68% and vectorial drawing tools with 62%. In contrast, digital tools used for sketching were only used by 14.8% of the total sample. Since most of participants use sketching in the design process and all of them use digital tools, this finding opens the possibility for future research to address sketching through new digital tools which may positively contribute to the ideation process.

Finally, a five point Likert scale to measure the level of agreement or disagreement of participants in various attributes for traditional and digital mediums was applied. Table 4, exhibits the level of agreement evaluation between digital and traditional mediums for each attribute.

Table 4. Level of agreement between digital and traditional mediums.

Agreement Evaluation Between Medium				
	Traditional		Digital	
	Mean	SD	Mean	SD
Helps to organize ideas	3.70	0.952	4.17	0.717
Helps visualize final idea	3.30	1.160	4.85	0.408
Appealing to clients	3.12	1.166	4.94	0.235

The scale ranged from *strongly agree* (5) to *strongly disagree* (1). For the attribute *helping to organize ideas*, digital medium obtained a mean score of 4.17 (*SD = 0.717*) in contrast to traditional medium which obtained a mean score of 3.70 (*SD = 0.952*). A dependent t-test was run with statistical significance (*t(52) = 3.165*) displaying that digital media help to better organize ideas. For the attribute *helps visualizing the final idea*, digital medium obtained a mean score of 4.85 (*SD = 0.408*) in contrast to traditional media with a mean score of 3.30 (*SD = 0.160*). A dependent t-test was run with a statistical significance (*t(53) = 1.881*) displaying that digital media helps to better visualize the final product. For the attribute *appealing to clients*, digital media obtain a mean score of 4.94 (*SD = 0.235*) in contrast to traditional media with a mean score of 3.12 (*SD = 1.166*). A dependent t-test was conducted with a statistical significance (*t(51) = 10.832*) displaying that digital media is perceived to have more appeal to the viewer. Participants containing missing data were not considered for the dependent t-test evaluations. Effect size was measured for the three dependent t-tests with a moderate effect of 0.43 standard deviations for the attribute *helping to organize ideas* and high effect for attributes *helps visualizing the final idea* and *appealing to clients* with 1.30 and 1.50 standard deviations respectively as by Cohen. Power was measured for all three dependent t-tests, being the lowest of the three *helping to organize ideas* which displayed a high level of power () with a probability of 7.9% Type II error. This information supports that participants' perception over digital media is that digital media is more beneficial in helping designers organize ideas, better visualize the final product and make ideas more appealing to clients.

Conclusions

The findings on this study reveal the importance digital mediums currently have in the design method according to design students' perception. Of three proposed stages for the design method, stages in which there was higher influence of digital media were more relevant. The

full sample manifested the importance of digital medium within the design process. Traditional medium is considered very important in the design process, nonetheless, for current design students the application of such media may seem of lesser value than that of digital medium. Digital medium offers attributes of effectivity, time efficiency and realistic results, which can be adapted to strengthen traditional medium as well. While traditional medium tools such as sketching continues to be of relevance in the design process, digital medium still has not found the way to make digital tools efficient and practical to satisfy the user's sketching needs.

As initially stated, was not to suggest which medium is better than the other. The main purpose was to expand in the better understanding of design students' preferences and perceptions on using these mediums. Findings suggest that digital medium is overcoming traditional medium and it is currently being used along the complete design process. In addition, the advantages of mixing mediums could be further explored in design academia. Students are aware of the relevance of sketching in the design process. New medium and tool shifting practices, more dynamic setups and increased group interaction to augment verbal communication may enhance creative moments. Design educators must find new ways into how to adapt these digital media tools to reinforce stages of the design process, such as the conceptual design stage. Curricular approaches and methodologies in design studio courses which traditionally used pen and paper are required to incorporate digital medium tools. Future research is needed into how more intuitive and dynamic digital tools may positively affect problem definition and conceptual stages of the design process. Finally, the findings suggest that traditional medium will be completely replaced by digital medium. Design educators must prepare for that change.

Limitations and Future Directions

With the imminent increase of the use of digital media, and its fascinating and compelling use throughout the complete design process, this study provided a baseline to better understand current students' preferences of design mediums. Future studies should address how the design process may be enhanced by using these tools. Moreover, design educators must keep this in mind to better adjust their pedagogical practices to grasp the students' attention and satisfy their needs.

The study was limited by the number of participants. Future studies will be conducted by increasing the sample size. Only two universities mainly focused on industrial design, interior design and apparel design were included in this study. This might have generated some bias in the type of design processes carried out by the participants. Future studies will diversify in the number of institutions and the kind of design programs to select the sample. All data was collected after IRB approval.

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