A Content Analysis on Poetic and Artistic Qualities of Digital Fabrication in Architecture

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New production techniques and digital design tools allow new possibilities in architecture and digital fabrication laboratories provide an environment for these new opportunities. In addition to its potential in terms of science and technology, digital fabrication creates many opportunities for artistic aspects of architecture. Therefore, we aimed to make a theoretical discussion and present a new perspective for artistic and poetic aspects of digital fabrication. From this perspective, to clarify the artistic aspects of architecture in the context of digital fabrication technologies and to understand how the subject is covered in the literature clearly, a comprehensive literature review has been made. Initially, the literature review was limited to the themes of digital fabrication and architecture to extract from out-of-context articles and 197 peer review journals written in the last 10 years were examined. Then, a pre-coding schema was prepared from two authors and extended after a detail literature review. The extended coding schema was grouped in terms of their semantic distance and these groups were used to make an assumption about papers. The software MAXQDA, which is commonly used in the social science, assist us to identify the semantic codes related to the research context without any omission. Articles were investigated with the keywords created after precoding. Content analysis was used to investigate the remaining 51 articles on the field of Architecture through these codes. Our aim is not to prove if there is sufficient paper that discuss the artistic aspects of digital fabrication. However, this methodology helps us to understand the focus of the papers and the tendencies as an approach in this context. In general, the subject of digital fabrication in architecture is studied more about materials, structures, processes, technology and how to use digital fabrication tools instead of why it was examined in the literature. From perspective of artistic dimension, the reviewed papers mainly emphasize 'characteristic, identity, variety, style, concept, customization, subjective, subjectivity, formal, composition, tectonic, geometry, form'. On the other hand, 'aesthetic, beauty, expression, art, stereotomy, craft, artifact, are less discusses codes. Words directly related to art and craft are not discussed in the articles and there is less discussion on the aesthetic values of digital fabrication. 'Sense, experience, perception, intuition' are also less discussed codes even if these are strong relationship with architectural context. Although not included in the academic literature, the issue of digital fabrication has begun to be discussed in the context of experience, through art installations in 1:1 scale produced by digital fabrication tools. In a nutshell, the issue of art is at least as valuable as the most frequently asked question of how in digital fabrication, and this aspect should be given more place in scientific research.

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Mimarlıkta Dijital Fabrikasyonun Sanatsal ve Şiirsel Boyutu Üzerine Bir İçerik Analizi

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Mimaride yeni olasılıklara izin veren güncel üretim teknikleri ve dijital tasarım araçları sayesinde dijital fabrikasyon laboratuvarları birçok yönden öncü bir ortam olarak görülmektedir. Dijital fabrikasyon laboratuvarlarının sadece bilim ve teknoloji açısından değil aynı zamanda sanat açısından da önemli bir potansiyel olduğu düşünülmektedir. Buna rağmen son on yılda bu alanda yapılan çalışmalarda mimaride dijital fabrikasyonun sanatsal ve şiirsel yönüne olan vurgunun eksikliği dikkat çekmektedir. Bu nedenle bu olgunun literatürde sanatsal ve şiirsel açıdan nasıl ele alındığına dair nitel bir araştırma yapılarak kuramsal bir tartışma yürütülmüş, mimarlığın sanatsal ve şiirsel yönlerini dijital fabrikasyon teknolojileri bağlamında ortaya çıkarmak ve konunun nasıl ele alındığını anlamak için kapsamlı bir literatür taraması ve içerik analizi yapılmıştır. Analiz MAXQDA yazılımı ile dijital fabrikasyon ve mimarlık temalarını içeren son on yılda basılmış 197 hakemli dergi makalesini içermektedir. Araştırmanın amacı dijital fabrikasyonun sanatsal yönden yeterince tartışılmadığını kanıtlamak değildir ancak bu metodoloji, makalelerin odağını ve eğilimlerini anlamamıza yardımcı olmaktadır. Genel olarak mimaride dijital fabrikasyon konusu literatürde "neden" sorusundan çok malzeme, strüktür, süreç, teknoloji ve dijital fabrikasyon araçlarının nasıl kullanılacağı ile ilgili olarak incelenmektedir. Yapılan literatür analizi sonuçlarına göre; karakteristik, kimlik, stil, çeşitlilik, konsept, form, kompozisyon, tektonik ve geometri gibi kavramlar sıklıkla kullanılmış olup, estetik, güzellik, sanat, zanaat gibi kelimeler daha az kullanılmıştır. Üstelik duygu, deneyim, algı, sezgi gibi mimarlık disiplini ile oldukça ilişkili olan kavramlar da çok az yer almaktadır. Özetle dijital fabrikasyon ve mimarlık ekseninde yapılan çalışmaların neden yapıldığı ve sanatla olan ilişkisi bu konuda sıklıkla sorulan nasıl sorusu kadar değerlidir ve bu bağlamda yapılacak bilimsel araştırmalarda daha fazla yer almalıdır.

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Anahtar Kelimeler: Dijital Fabrikasyon, Sanat, Mimarlık, Şiirsel

1. INTRODUCTION

'Paradigm shift' is a term that relies on Kuhn's most influential book 'The Structure of Scientific Revolutions'. (Khun, 1996) used the term 'Paradigm' referring to the 'particular coherent traditions of scientific research, an accepted model or pattern' and 'shift' for the emergence of scientific theories and changes. The paradigm shift includes changes in theory and application together according to (Khun, 1996). He says that these changes, which he describes as disruptive, occur when the number of unresolved problems in a discipline increases and these unresolved problems are focused on by some key figures in the field (Hairston, 1982). Khun's paradigm shift concept is discussed in every field such as sociology, education, and economy. It is so essential to understand the types of production in society.

The change in mode of production affects the architectural paradigms inevitably. Architecture and its production tools were also affected by the transformation from Fordism based on mass production and standardization of the same product to post-Fordism including a more flexible production process and customization. While the Fordism, which is an industrial paradigm, involves mass production and standardisation of products to reduce the costs and make the products more affordable (Dunham-Jones, 1997), the modernist paradigm for architecture also involves the same characteristics. However, the standardised body measurements and simplicity, which were characteristic of the modernist paradigm, lead an assumption on users as; not a unique person, but anonymous. Today the following paradigm in industry 'post-fordism' and the post-modernist paradigm involves emphasis on customization. Mass customization discussions have been growing in literature since the late 1980s (Fogliattoa, Silveira, & Borenstein, 2012) (Lau, 1995) and argued as a new industrial revolution (Yao & Lin, 2016).

The characteristics of existing paradigms affect architectural pedagogy of that time. For example, the approach of the Bauhaus, the most influential art school of the 20th century, was associated with the Modernist paradigm. The Bauhaus saw itself as a part of the cultural modernity movement and made a lot of effort under the

name of "modernism" to re-establish the unity between artistic and technical production areas, again separated by industrial production (Michael & Lutz, 2009). Standardization, one of the most important features of the modernist paradigm, can be seen in the book of Neufert, one of the first students of this school. Neufert, educated by Walter Gropius, focused on standardized building arrangements and pre-planned items at all scales in his famous book (Meister, 2020). Unlike the standardization in the modernist era, the new digital era includes digital design and fabrication tools that enabled customization and opened up new possibilities in architecture.

Digital fabrication, which is a new form of production in architecture, has been discussed frequently in the literature in the last 10 years. The issue of digital fabrication was more discussed over the perspective of how to use it. In the literature, questions such as how to use new technologies and materials are discussed in digital fabrication. The question of why is as important as the question of how. One of the answers to the question of why lies in the relationship between art and digital fabrication. Therefore, the question “how important is art in digital fabrication in architecture” is crucial to highlight the artistic aspects of digital fabrication in architecture. To answer the research question, the article explains the components of the art and then proposes a comprehensive analysis of the literature.

2. DIGITAL FABRICATION LABORATORIES

Developments in manufacturing are assisting paradigm shifts today as they did in the 20th century (Terzidis, 2004) (Bell et. al., 2010). Actually, the introduction of the digital design and fabrication tools is not new. Between 1980-1990 it was associated with the first CNC machine usage (Wiedenbeck & Parsons, 2010) even though the tool was introduced a long time ago. CNC technologies were identified as subtractive manufacturing tools after the first 3D printing machine emerged in 1986 (Bhatia & Sharma, 2014), which was identified as one of the additive manufacturing tools. However, the reason for maker movement is not the introduction of these tools, but accessibility of them. Hybrid manufacturing processes (subtractive and additive together) can be used by architectural researchers in most of the university laboratories owing to the robotic

manufacturing. These are known as “digital fabrication laboratories'' today and they are assisting a milestone for architecture as in Bauhaus.

Digital fabrication term is used for the production process of digitally designed and materialized products (Savastano, Bellini, D'Ascenzo, & Scornavacca, 2017) and it is categorized into three types; “subtractive, additive and formative” (Paio et al., 2012). These manufacturing techniques and digital design tools are together assisting new possibilities in architecture in digital fabrication laboratories. These tools provide us freedom in terms of form and complexity in terms of architectonic. The freedom has been interoperated a promise for more customized architectural entities from researchers (Oxman R. E., 2010) (Kolarevic, 2001) (Johnson & Vermillion, 2016). Architects are not just researching the formal opportunities but also reconsider the materialization options and re-examined the natural resources in digital fabrication laboratories (Beorkrem, 2017), (Kolarevic & Klinger, 2013), (Oxman N. , 2010), (Sass & Oxman, 2006). The frequently used terms “customization” and “personal fabrication” although the construction process still uses mass customized architectural elements.

The material emphasis and formal studies are the dominant character of digital fabrication laboratories. On the other hand, today, art is not in the list, but engineering, biology, material science in digital fabrication laboratories. The fact is that digital fabrication technologies provide us artistic, poetic and aesthetic possibilities whether we do or do not collaborate with art. Here, the question is how we consider the artistic value of it?

3. POETIC AND ARTISTIC QUALITIES

The researches in digital fabrication were especially focused on formal and structural properties of architecture. Statics, functions, scripts and simulations, which are related to how question, were used in a descriptive way of the process. We also need to track the why question as we do for the how question. The why question in the architecture field is related with the architectural phenomenology that emphasize its poetic, artistic and ethic dimensions. Pallasmaa (2012) also highlights the necessity of spatial sense, experience and

the poetry of space and critics “the blind belief in technology” (Amundsen, 2020).

Husserl (2001) who is the founder of phenomenology, Heidegger (2001) and Merleau-Ponty (2010) associate art and aesthetics with experience and sensory perception. Therefore, the aesthetic value of architecture could be discussed from the perspective of phenomenology which determines this value through experience. However, Heidegger emphasises the limiting capacity of technology (Heidegger M. , 1982), (Alawa, 2013), (Corsini & Moultrie, 2018), digital fabrication tools that emerge with technology have the potential to exceed this limit by enabling experience.

Poetic and artistic aspects of architecture are more examined in architectural pavilions and spatial art installations which are significant 1/1 scale architectural element manufactured through digital fabrication tools. These temporary research pavilions make it possible to reconsider the human experience while researching formal and structural relations. One of the studies that will exemplify this issue is an ASMR-focused fabrication production. The Autonomous Sensory Meridian Response (ASMR) is a sensory phenomenon that has not been previously studied and has been growing interest by people who can experience it. People react to certain triggering sounds and visual stimuli on the scalp, back of the neck, or other areas of the individual, such as tingling or feeling a sensation [7]. This concept, which is generally subject to psychology, has started to be discussed in the field of architecture. The museum exhibition was designed in 2020 by ETER, a partnership of architects, researchers, and educators (Eeter, 2021). This exhibition, titled "Weird sensation feels good", is devoted to these feelings and to the field of creativity that is thought to result from these emotions. Products like hands produced by 3d printing, 1 km long pillow which resembles the inner body tissue, the brain curves, vocal cords and irregular waveforms were custom-crafted objects and produced in the Northern Baltics. Especially for the pillow, 1 to 1 research models were made for a better understanding the texture of the fabric (Arterritory, 2022).

With this exhibition, Architects aimed to relax both body and mind for individuals by experiencing tangible and audio-visual stimuli

(Arterritory, 2022). The theme of the exhibition is that digital will bring people together physically and emotionally and how this can be used as a tool (Arterritory, 2022) to share this experience in a public space (Archdaily, 2021). The design of the installation provides an environment that allows visitors to experience a sensory environment visually, audibly and tactilely (Figure 1) (Arterritory, 2022).

Figure 1: Sensation, human body and technology (Archdaily, 2021).

Therefore, we investigated the traces of the artistic dimensions of space in the context of digital fabrication from the scholarly journals of the last ten years in this paper by using semantic data.

4. CONTENT ANALYSIS

To clarify the understanding of artistic aspects in studies related to digital fabrication in the field of architecture, a systematic literature review was made with the selected keywords and the criteria determined below.

- Keywords: “digital fabrication” and “architecture” in order to find journals in architectural fields and associated with the main topic ‘digital fabrication’
- Database for the literature search: ProQuest which provides access to large scholarly journals from various databases.
- Selection criteria for journals: Only peer-reviewed scholarly journal articles written in English were selected
- Publication Date: 10-year period between 2012 and 2021

To evaluate the artistic aspect of digital fabrication in architecture, 197 articles were found as a result of the above-mentioned criteria with the selected keywords. By checking the contents of these articles, their relationship with architecture has been examined. The topics of these articles were classified and those outside the field of architecture were excluded. The remaining 51 articles on the field of

Architecture were examined in more detail to extract those related to art (Table 1).

Journals	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Advances in Civil Engineering								2		
Architectural Science Review									1	
Arquiteturarevista	1									
Assembly Automation	1									
Buildings									1	1
Education Sciences			1							
Energies									1	
Int. J. of Comp. Methods and Experimental Measurements						3				
Int. J. of Design									1	
Int. J. of Design & Nature and Ecodynamics						1				
Int. J. of Tech. and Design Education									2	
ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences					1	1				
J. of Edu. for Library and Information Science						1				
J. of Pre-College Engineering Education Research				1						
Materials								1	1	
Nexus Netw. J.						1	12	2	1	1
Polymers									1	
Rapid Prototyping J.				1		1				
Scientific Reports (Nature Publisher Group)									2	
Sensors								1		
Sustainability									3	2
TechTrends										1

Table 1: Selected articles by journal and year order.

The aesthetic aspects of an architectural form, unique experience promises, the style and the subjectivity of design, creativity and formal language were discussed in the paper while doing qualitative data analysis in MAXQDA software (Maxqda, 2022). A pre-coding schema is prepared from two authors and extended while doing a detailed reading. 37 Art-related keywords were decided by scanning the selected 51 articles and looking at their meanings in the text. Then, classification was done through semantic relations between the meaning of keywords (codes) with similar meaning logically and grouped; aesthetic, art, creativity, craft, freeform, sensory, formal (Table 2). The software which is commonly used in the social science, assist us to identify the semantic codes related to the research context without any omission. Then the papers were analyzed

through these codes. Our aim is not to prove if there is sufficient paper that discuss the artistic aspects of digital fabrication. However, this methodology helps us to understand the focus of the papers and the tendencies as an approach in this context.

Acknowledgements and references were excluded from the text data. Authors' affiliations and irrational word overlaps like 'National Gallery of Art', 'state of the art' were excluded manually while coding. Text data of the eliminated papers were analysed.

Table 2: Codes and sample text of coded segments.

Groups	Code	sample texts of coded segments
1	aesthetic	"a formal and aesthetic language", "architecture expression", "beauty of structures" (Tibuzzi, 2018)
	beauty	
	expression	
2	art	"design principles of stereotomy", "artistic expression", "art of stereotomic stone" (Boddeti, 2020) (Diles, 2018)
	stereotomy	
	artistic	
3	characteristic	"customization of the products ", "maker style learning ", "different conceptual aspiration" (Gamerro, Bocquet, & Weinand, 2020)
	identity	
	variety	
	style	
	concept	
	customization	
	subjective	
	subjectivity	
4	creativity	"unique product designs" (Gamerro, Bocquet, & Weinand, 2020)
	create	
	creative	
	unique	
5	craft	"hand crafted", "craftsmen", "artifacts of artistic interest" (Fallacara & Barberio, 2018)
	artifact	
	artefact	
6	freeform	"freeform thrust surfaces", "freedom of shape", "organic structural morphology" (Fallacara & Barberio, 2018)
	complex	
	freedom	
	organic	
	irregular	
7	sensory	"the perception that the shell is floating", " the sensory experience of a space" (Bosqué, 2015).
	intuition	
	intuitive	
	feel	
	perception	
	experience	
8	Form(al)	"formal language", "tectonic qualities", "geometrical configuration" (Chilton & Chuang, 2017)
	composition	
	tectonic	
	geometry	
	form	

The contents of the groups resulting from the classification and the context of the phrases within the text to explain the structure of review are explained in detail below:

Group 1: Considering the artistic aspects of digital fabrication in architecture, the aesthetic value of the product that emerges is one of the first concepts that come to mind. In addition to the function or material of the product resulting from digital fabrication, its aesthetic value is worth discussing. The word “aesthetic” is associated with beauty and art (oxford dictionary) and the aesthetic values of the design strengthen the feelings or ideas of the designers, namely their expressions. Therefore, the issue of aesthetics must be considered during the digital fabrication process. "a formal and aesthetic language", "architecture expression", "beauty of structures" are the sample text of these categories from the selected journals.

Group 2: Although the artistic and poetic aspects are seen as a main keyword and backbone for the entire study, it has been analysed as a normal word in the literature analysis within the other art related words. All words of group two in the above table are directly or indirectly related to art, but “stereotomy”, which is accepted as a form of art, and word of “artistic” coming from the same root grammatically have been put under this group. Stereotomy is discussed in selected articles in the context of design principles and its relationship with art. "design principles of stereotomy", "artistic expression", "art of stereotomic stone" are the sample text of these categories from the selected journals.

Group 3: Artistic works have a character so architecture may have been mentioned through that aspect while the author discusses. The word ‘character’ and other related words were coded in that segment in order to track and visualise the frequency. The issue of digital fabrication is defined as a process that enables customization that has a semiotic link with the other codes in this group. "Customization of the products ", "maker style learning ", "different conceptual aspiration" are the sample text of these category from the selected journals.

Group 4: Creativity, which is seen as one of the basic components of art, constitutes the content of this group but analysed in a separate

group. Creativity is a term that means; producing a unique and novel entity. However the code 'novel' search provides no meaningful result for these documents. "unique product designs" "in a creative way", "create hyperboloid modules" are the sample text of these categories from the selected journals.

Group 5: Craft, which is defined as a job or activity that is related to art but requires skill and experience unlike it, is another important topic. It is related to Bauhaus and also digital fabrication in that context and may be a frequently used code of this issue. "Artifact" and "artifact", which have the same meanings but different spellings, are coded associated with crafts. "hand crafted", "craftsmen", "artifacts of artistic interest" are the sample text of these categories from the selected journals.

Group 6: The word free-form simply means not having or following a particular style or structure (Cambridge dictionary). It is a frequently associated term related to digital paradigms in the architecture field. It is used in order to discuss the freeing potential of new technologies in terms of complex, organic or irregular forms and structures. "free-form thrust surfaces", "freedom of shape", "organic structural morphology" are the sample text of these categories from the selected journals.

Group 7: Experience, sense and perception which are the frequently associated words in order to emphasise the artistic aspects of the architecture field as we have discussed the previous chapters in detail. Sensory is an etymologically justifiable word with sense that is associated with physical touch, smell, taste, hearing, and sight (Oxford dictionary). Intuition and intuitive also considered under this segment because it is used as a capacity for understanding something depending on feelings instead of evidence. "compromises the perception that the shell is floating", " the sensory experience of a space" are the sample text of these categories from the selected journals.

Group 8: Form, meaning the shape or appearance of something (Cambridge dictionary), is closely related to art. Tectonic, composition and geometry are grouped under the formal codes and explored from the documents separately. "formal language", "tectonic qualities",

"geometrical configuration" are the sample text of these categories from the selected journals.

5. KEY RESULTS

Selected articles were analysed with the determined codes (Table 1). Text data analysis with word count and frequency of them is chosen to make an interpretation about the weight of the why question. The column headers show id no of the publications (D1-D51) and raw headers shows the coded words **(Figure 2).** From the visual density of the matrix, it is clear that the codes in groups 3, 4 and 8 are most frequently used codes and used at least 1 time in all papers. It can also be seen that the 'stereotomy' is a specific topic that is not used in all papers but on the other hand whose amount is also noteworthy. The code 'concept' and relatively the code 'variety' are frequently used words in the literary, on the other hand the total group has no significant usage but formal codes have.

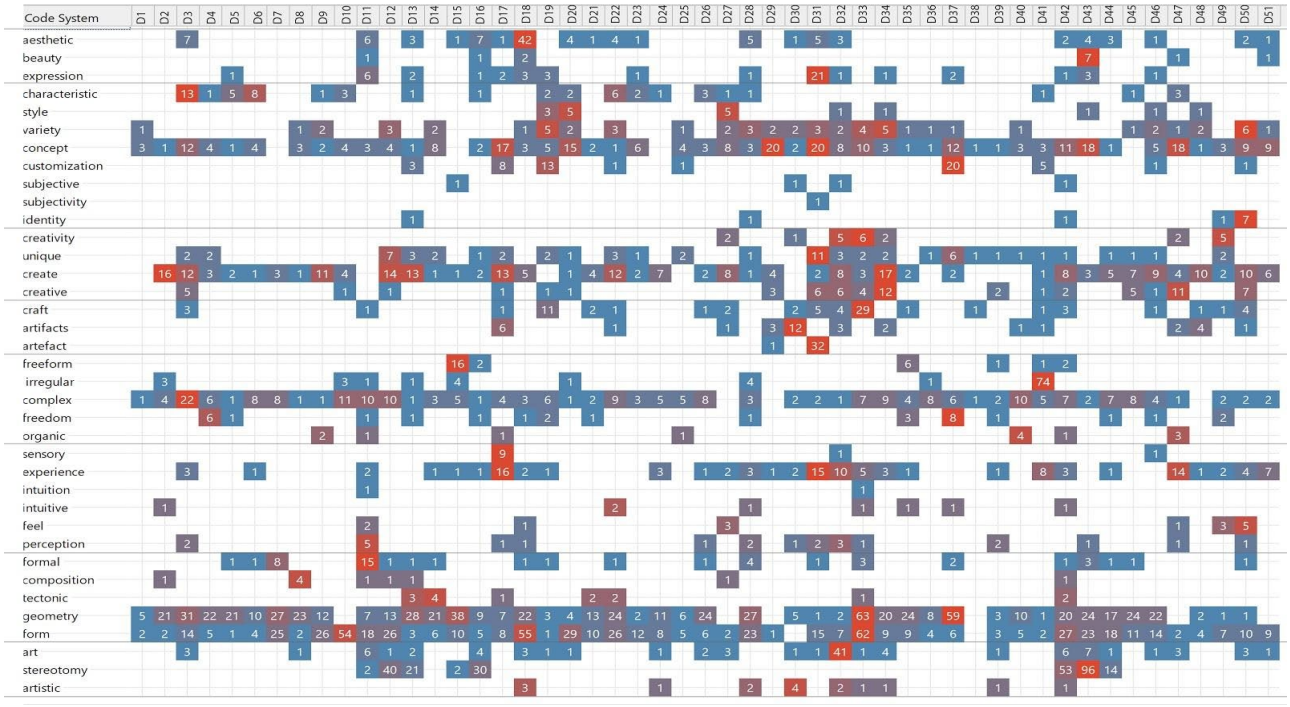

Figure 2: Code system matrix in detail

When we look at the total quantity of the codes, it is clear that group 8, which includes form, geometry, composition and tectonic, is the frequently used group. It means that the formal values of architecture are the most discussed aspects of it. On the other hand, the group 5,

which includes craft, artifact and artefact, is the less discussed aspects (Figure 3).

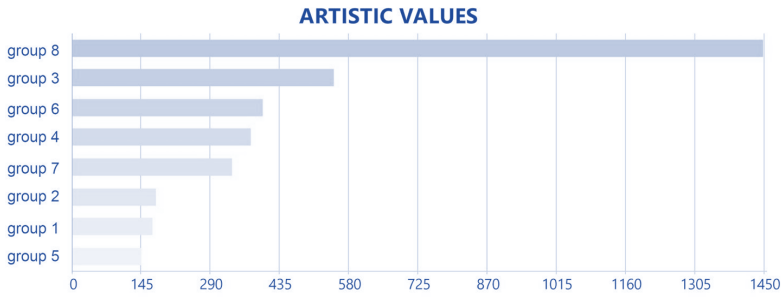

Figure 3: Code system in summary within the groups.

Looking at the relationship between digital fabrication in art and architecture in selected articles:

- Codes in group 3 (characteristic, identity, variety, style, concept, customization, subjective, subjectivity) and group 8 (Formal, composition, tectonic, geometry, form) are the most discussed codes. These codes are essential concepts for a study in the context of architecture and digital fabrication.
- Codes in group 1 (aesthetic, beauty, expression), group 2 (art, stereotomy, artistic) and group 5 (craft, artifact, artefact) are less discussed codes. Words directly related to art and craft are not discussed in the articles. There is also less discussion on the aesthetic values of digital fabrication.
- Codes group 7 (sense, experience, perception, intuition) are also less discussed codes even if these are very crucial concepts in architecture.

In addition to an overall analysis of how the coded words is used, the frequently used words also analysed and the results show us the main focus of this topic as; material, structure, process and technology.
In general, material, structure, process, technology are the most frequently used words in these publications without any segmentation. This result shows us the focus of the research in the last ten years.

6. DISCUSSION

The paper presents a critique on contemporary scientific research and argues for artistic emphasis in the field of digital fabrication. The

arguments build upon historical and contemporary integrations of art, science and technology. It examines today's digital fabrication artefacts and the tendencies of scholars and designers and try to find out over-emphasise on certain aspects of design over artistic and poetic aspects. It questions the apparent lack of sensibility towards soft factors and how we accommodate the intangible human needs and desires in our designs provided all the fabrication opportunities according to the results.

As we see from literature analysis results, technology, structure and material are commonly used codes and there is an overemphasis on the engineering and material science aspects of design in literature over the last ten years. It is necessary to emphasize that this issue is at least as valuable as the question of how and that this aspect should be investigated more in scientific research. This result will not only bring a critical perspective to the subject, but will also guide future studies. Future research could continue to explore the reason for omission of artistic aspects.

In addition to demonstrating and criticising the issue this paper also argues the artistic aspects of architecture. Today the threefold of science, technology and art emphasis is still a prevailing topic in terms of today's digital fabrication artefacts and stories behind them.

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