Exploring the Term 'Experiment' in Industrial Design

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Abstract: The term 'experimental design' is widely used to describe both a design product or process and also the methodology of research. However, considering the experimental design processes, the term is not defined or described in detail except by few design theorists. On the other hand, recent publications in innovation literature emphasize the importance of it and suggest handling the design process as an experiment, stating that experimentation leads to innovation. Taking these as a start point, this paper examines 'experimentation' as a methodology for industrial design process, focusing on its definitions and descriptions.

The paper aims to build a background on experimentalism, to explore its evolution in science and art in order to expand the scope of the term leading both to rigour of experimental science and also the exploration of experimental art in style. Besides, experimenting has been a key subject discussing design in comparison to science and art, so the background aims to build interdisciplinary arguments. As the most robust approaches on experimenting, the design education in Bauhaus and the description of experimenting in reflective practice by Donald Schön is discussed. About the relationship between experimenting and innovation, the economics of experimenting and the guidelines for companies to experiment are elaborated.

For further understanding, the term 'experiment' is explored in design literature via a content analysis in two important periodicals, 'Design Issues' and 'Design Studies', and the contexts in which the term 'experiment' were used are also categorized.

Key words: Experimental design; Innovation

1. The term 'experiment' in science, art and design

Building an interdisciplinary background requires a historical review of experimentalism in natural science and art. In this paper, which is based on the findings of a MSc dissertation in the Graduate Program of Industrial Product Design at Istanbul Technical University (ITU) [14], it is not intended to cover a full story of experimentalism, but rather to pinpoint emerging patterns in the evolution of experimentalism in these fields, which will be discussed parallel to design literature. The aim is to suggest a framework for further understanding of the issue experimental design processes.

1.1. 'Experimentalism' in natural sciences

Experimentalism has been one of the leading paradigms of science. It refers both to a mental act, 'thought experiments' in earlier history and also to physical acts like Galileo's, Newton's, and Boyle's experiments, and it is a new way of looking at an old phenomenon. It is important to understand how and in which circumstances this development has took place. [13, 17]

Robert Boyle is often remembered as a key figure in elaboration of experimentalism and Scientific Revolution, who conducted the air-pump experiment in pneumatics in 1660s in Royal Society of London. Differently than before, Boyle made the experience of the experiments public, encouraged witnesses; and all the methods, materials and circumstances were reported detailed. Although the experiments also attracted opposition, Royal Society and their vigorously advertisements which pointed the experiments as a paradigm played a great role as a support. [1, 13, 17]

To distinguish the new experimental movement from the old movements, Kuhn (1977) describes three novelties;

- **Attitude toward the role and status of experiment:** Experiments were performed to see how nature would behave under previously unobserved, often nonexistent circumstances.
- **Major emphasis given to experiments:** In these experiments nature was constrained with conditions, which could not be attained without the forceful intervention of man.
- **Physical science became instrumental:** New experimental devices like telescopes and microscopes were introduced, which were the property of craftsmen and pharmacists till then, and were re-evaluated. [13]

1. 2. Science and design

'Experimenting' has been a central issue when discussing design in relation to science, focusing on their differences, superior relationships and learning cycles in between. Buchanan (1995) discusses two fundamental differences between science and design. Firstly, the subject matter of science must be discovered in scientific inquiry, however, in design it is created through invention, planning, or other methodologies. Secondly, there is determinacy in science, as discovery implies that there is something constantly available waiting to be uncovered, which may be confirmed by other experimental techniques. Whereas, there is no determinacy in design; the subject matter is open to alternative resolutions even with the same methodology. Shortly, the scientist 'discovers' a natural process or law, but the designer 'invents' a possible application or a new use suited to a particular product. [3] Parallel to that, Simon (1988) states "*The natural sciences are concerned with how things are… Design is concerned with how things ought to be*." And Cross (1999) defines the 'things to know', 'ways of knowing' and 'ways of finding out' for science, art and design as shown in Table 1, where he classifies 'experimenting' as a 'way of finding' out in science.

Table 1. 'Things to know', 'ways of knowing', 'ways of finding out' in science, art and design [5]

	things to know	**ways of knowing**	**ways of finding out**
science	natural world	rationality and objectivity	experiment and analysis
art	human experience	reflection and subjectivity	criticism and evaluation
design	artificial world	imagination and practicality	modeling and synthesis

Glanville (1999) focuses on superior relationships between science and design. He criticizes the world of science, stating that the experiments are done by radical simplification. He emphasizes the role of the

'experimenter', who chooses to do experiment, sets it up, observes, determines what the outcomes are and carries out the actions. As the experimenter is influenced by social factors and acts accordingly, the whole process is deeply embedded in the active involvement of the experimenter. [8] The importance of experimenter in design will be discussed mentioned later in the paper with recent views in innovation literature.

The (scientific) research, Glanville (1999) describes as a design activity and as a branch of design, in which the designer is central, and through which the world of the scientific knowledge, which is designed, is constructed. And he suggests, "*So the act of design, as we understand and value it, has much to offer as an example of how science and scientific research might be in a new era*."

Lastly, Cross (1999) emphasizes that design world must avoid importing research from science or art, but also avoid to ignore them, which have much stronger histories of inquiry, scholarship, and research than design. He suggests drawing upon those histories and traditions where appropriate, while building the own intellectual culture of design, acceptable and defensible in the world on its own terms with an intellectual culture.

1.3. Experimentation of reflective practitioner

Schön (1983) has written the most comprehensive definition and description of experimenting in design process, also comparing it to scientists' experiments. He suggests that to experiment, in the most generic sense, is to act in order to see what the action leads to and that the most fundamental question of experimenting is, *"What if?"*.

Schön (1983) classifies the experiment in design in three categories, which he defines as follows;

- **Exploratory experiment:** When action is undertaken only to see what follows, without accompanying predictions or expectations. It is the probing, playful activity by which one can get a feel for things. It succeeds when it leads to the discovery of something.
- **Move-testing experiment:** When action is taken in order to produce an intended change, in order to see what happens. The affirmation is not gained by getting what is intended, but rather by 'liking' what is got from the action, taking the consequences as a whole.
- **Hypothesis testing experiment:** It is similar by logic to researchers'. The practitioner puts forward hypothesis and the limits the practice context and the disconfirmation of a hypothesis is when the predicted consequences are not got from it. [16]

According to Schön (1983), in practice all kinds of experiment occur at the same time as follows:

> When the practitioner reflects-in-action in a case he perceives as unique, paying attention to phenomena and surfacing his intuitive understanding of them, his experimenting is at once exploratory, move testing, and hypothesis testing. The three functions are fulfilled by the very same actions. And from this fact follows the distinctive character of experimenting in practice. [16]

Schön (1983) also describes the process of experimenting and its distinctive rigour as 'playing a game', where "*the primary interest is changing situation*". The play is with a moving target, as the phenomena changes during the experiments, and the experiment will depend on the changes produced by earlier moves. The resistances to change shouldn't be ignored too; the inquirer should both experiment rigorously, and remain open to failure. When a move fails to do what is intended and produces consequences considered to be undesirable, the inquirer criticizes and restructures it, and tests the new theory by inventing a consistent move. The learning sequence, initiated by the negation of a move, terminates when new theory leads to a new move, which is affirmed. In the practice context, priority is placed on the interest in change and therefore on affirmation, and it is what sets the

boundaries of experimental rigour. [16]

1.4. Experimental art

In art history, 'experiment' has been attributed great importance regarding artistic nature, process and style. Therefore, subjecting experimental art might build a background to explain 'experimental design' as a style.

According to Dewey (1934), the artists are born as experimenters, they have to express an intensely individualized experience, they have to not repeat themselves and they operate experimentally to open new fields of experience. Gombrich (1995) states that the roots of experimentalism in art goes back to French Revolution, when artists became self-conscious about style and began to experiment to launch new movement. As examples of experimenting, he indicates 'Art Nouveau' and their technical experiments with materials in building ornaments; and modern architects who avoided all kinds of ornaments and so broke with the traditions of many centuries.

Focillon (1995) describes the term style by means of experimenting. He suggests that each style at every epoch passes through the ages and phases of being, which are the experimental stage, the classical age, and the age of refinement. The experimental stage is where style is seeking to define itself. And in the classical state the experimental unrest is solidified and greatest propriety of the parts with stability, security has been reached. [7]

Poggioli (1968) calls experimentalism as one of the primary characteristics of avant-gardes. For them, experimentalism forms the artist to transform the public. It is a 'laboratory' in a pure sense, which aims the progress of art itself. It differs from traditional and many modernist movements, as it is not essentially a matter of art. It also differs from the romantic experimentation, as it not just searches for new forms to destroy the rules, but also aims at creation of 'a *new morphology of art, a new spiritual language*'. [15]

1.5. Unity of traditions of science, art and design, and Bauhaus

Buchanan (1995) explores the evolution of design and its relationship with art through a historical review. He states that at the time following Renaissance, there has been a loss in the humanistic dimension of production, and design became a servile activity rather than a liberal art, being practiced by chance and intuition. And the progressively refined tools resulted in further division of the circle of learning, and specializations. The efforts to reunite design with the arts of making starts in the 19th century, when Ruskin, Morris, and others attempted to elevate the status of craft production as an alternative to mass production and evolved with the cultural and philosophic revolution at the beginning of the 20th century. Buchanan (1995) calls Gropius among the first to recognize design as a new liberal art of technological culture. [3]

Bauhaus is one of the most cited names mentioning experimental processes in design, where experimentation was strongly encouraged and practiced [3, 4, 9]. Bauhaus was guided by the idea to bring art and technology together to form a new, modern unity, to anchor art in society. The foundation course at the Bauhaus represented this mentality and its purpose was " *to encourage students to experiment and to explore their own creative talents, and to teach fundamental design skills through an understanding of an objective science of design"*. Instead of theory leading the way, the conclusions drawn from analysis and discussion of experiments were progressively distilled into a generalized 'theory of design'. [4]

2. Experimenting and innovation

Experimenting has been handled as an important issue in recent innovation literature. The reason to re-issue experimenting is that it leads to innovation and the 'economics of experimenting' has changed. [20]

To start with the earlier economic influences in design theory, Bürdek (2005) describes the economic conditions for design to develop methods after WWII. With the economic upswing in the industrialized countries characterized by a market economy, competition intensified. In this situation, design had to adapt to the changed conditions, when it was not possible to continue practicing subjective and emotional methods, while industry was rationalizing. It was an obvious step for designers to integrate scientific methods into the design process. [4]

Parallel to that, Thomke (2003) states that the economics of experimenting has changed with the technologies available, and it is now possible to perform more and faster experiments toward innovation. Schrage (1999) explains this by stating that quantitative differences create qualitative differences; when the cost and quality of the raw material of innovation transforms, the definitions of risks and value creation change as well.

2.1. Definition and description of 'experimenting' in innovation literature

Thomke (2003) defines experimenting for innovation shortly as to learn by trying things out. Via models, prototypes, controlled environments, and computer simulations, innovators reflect, improvise, and evaluate the ideas that are generated in organizations. He categorizes experiments as ideal and real world experiments as the sciences do. In ideal experiments, innovators separate an independent (cause) and a dependent (effect) variable and manipulate the former to observe changes in the latter, to learn the relationship between them, which can be tested in other settings. When all relevant variables are known, statistical techniques and protocols allow for the most efficient design and analysis of experiments. However, in real world experiments, environments are changing, linkages between variables are complex, and often variables are uncertain (technical, production, need and market uncertainties). With these uncertainties, experimentation is much more informal or tentative, and innovators are making progress through iterations, guided by insight where solutions might lie. [20]

Thomke (2003) summarizes this experimentation process as a four-step iterative cycle as follows;

- **Design:** What is expected to learn from the experiment is defined. Hypotheses are formulated based on prior knowledge, data, observations, and experiments or generating new ideas through brainstorming.
- **Build:** (Physical or virtual) prototypes and testing apparatus – models – are built.
- **Run:** The experiment is conducted in either laboratory conditions or a real setting.
- **Analyze:** The result is analyzed, compared against the expected outcome, and the understanding is adjusted accordingly. During this analysis step, most of the learning can happen. [20]

It is possible to disqualify failed experiments from the potential solution space and continue the search from the 'design' step of another cycle. However, in most cases, an error or a failed experiment can help to adjust mental, computer, or physical models; and deeper understanding and less uncertainty is gained as a result. Then the experiment can be modified and 'iterated' again. Or if the results of a first experimental cycle is satisfactory or address the hypothesis in question, the experimenter stops. [20]

Experimentation encompasses success and failure, both of which are equally important for learning. The ability to experiment quickly is also important as rapid feedback shapes new ideas by reinforcing, modifying, or complementing existing knowledge [20]. Kelley (2001), calls this approach *"Fail often to succeed sooner"* and

argues that good companies embrace a culture of mini-failures, defining failure as the flip side of risk taking.

2.2. Guidelines for experimenting

For experimenting in companies, Thomke (2003) suggests six principles, one of them being *"Managing projects as experiments"*, which refers to a general approach of 'experimental thinking'. Schrage (1999) suggests a similar list focusing on prototyping, and both lists are shown in Table.2.

Table 2. Experimenting and prototyping guidelines suggested for companies [18, 20]

Guidelines for unlocking the potential for experimenting [20]	**Guidelines for prototyping [18]**
1. Anticipate and Exploit Early Information through "Front-Loaded" Innovation Processes	1. Ask, Who benefits?
2. Experiment Frequently but Do Not Overload Your Organization	2. Decide what the main paybacks should be and measure them. Rigorously.
3. Integrate New and Traditional Technologies	3. Fail early and often.
4. Organize for Rapid Experimentation	4. Manage a diversified prototype portfolio.
5. Fail Early and Often but Avoid "*Mistakes*"	5. Commit to a migration path. Honour commitment.
6. Manage Projects as Experiments	6. A prototype should be an invitation to play.
	7. Create markets around the prototypes.
	8. Encourage role-playing.
	9. Determine the points of diminishing returns.
	10. Record and review relentlessly and rigorously.

2.3. Users who experiment

Thomke (2003) states that for companies, market research as a learning-by-experimentation cycle is costly, time consuming, complex, and changing. Many companies abandoned market research but instead headed towards equipping customers with tools to design and develop their own products, ranging from minor modifications to major new innovations. These user-friendly tools, usually in form of 'toolkits', allow the customers to run what-if experiments themselves deploying new technologies like computer simulations and rapid prototyping. [20]

What Thomke (2003) calls *"experimentation of users"*, Hippel (2005) names as *"democratization of innovation"*. He states that although to adapt this mentality requires fundamental changes for firms and industries, a democratized and user-centric system for innovation appears well worth striving for.

3. Content analysis for the term 'experiment'

When exploring the term 'experiment' in design theory, it was necessary to conduct a systematic search to see to what extend the term exists and in which contexts it has been the focus. For that, the articles in the periodicals 'Design Issues' and 'Design Studies' were searched for the term 'experiment' via quantitative content analysis.

The content analysis covers 'Design Issues' from spring 1984, when it started to be published, until 2009, when this study was completed. The issues were grouped in time periods of 5 (+/-1) years and analyzed separately. 'Design Studies' is analyzed between January 2000 and November 2008. The reasons for that is the time limitation of the study and the pattern observed through findings in 2000s, which will be mentioned in the results. This analysis is compared to the analysis of 'Design Issues' in 2000s.

3.1. Procedure of the Study

In the procedure of the study, the steps that Krippendorff (2004) suggests were used as guideline. The units of

the content analysis are the articles of 'Design Issues' and 'Design Studies' in the mentioned time periods. The articles were searched full text for the term 'experiment' and its derivatives, 'experimenting', 'experimentation' and 'experimental'. Each sentence with the term 'experiment' was determined as a sample and they were listed in tables. Then, the codes were specified in two levels, firstly, according to 'Category 1' which is as follows;

1. experimental design processes
2. experimental design research
3. experiment in other fields than industrial design

As a second categorization, contexts were listed aiming to be as narrow as to form a classification but also as general as not to allow interpretations. The first six contexts are about industrial design, the next six can be considered together with, 'fields other than industrial design' in the former list. 'Category 2' is as follows;

1. design history and cultural studies in design
2. design methodology, cognition and creativity
3. design education
4. design strategy and management
5. user research
6. architecture and urban planning
7. graphic and visual communication design
8. advertising and new media
9. art
10. mathematics, natural sciences and medicine
11. social sciences
12. engineering

Each sentence with the term 'experiment' is numbered according to these categories. If in a sentence, the term 'experiment' is used more than once, the sentence is marked this many times accordingly. The numbers forming the statistics are shown graphically in the figures.

3.2. Results of the study

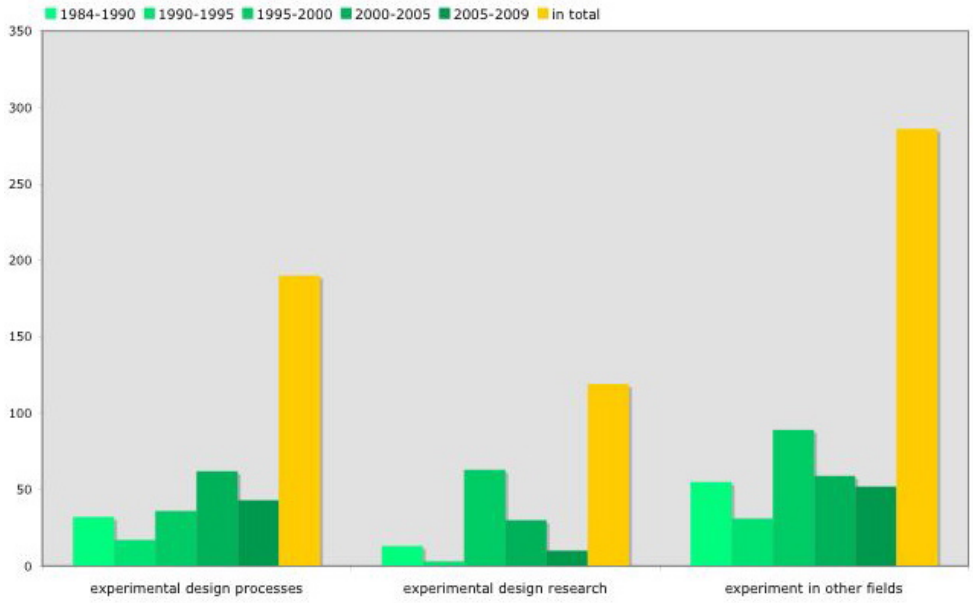

Figure 1. Content Analysis of Design Issues – Category 1

According to Figure 1, in 'Design Issues' in all the time periods the term 'experiment' was used mostly mentioning other disciplines rather than industrial design. This result will be explained further parallel the results of 'Category 2'. In the industrial design context, the term was used mostly when mentioning experimental design processes, where the values are increasing in 2000s. This can be interpreted that the importance given to the

subject of experimenting in design process is increasing.

Figure 2 shows that the number of the term in 'Design Studies' for 'experiments for design research' is more than 5 times higher than the closest value. The reason for that might be the perspective of 'Design Studies' and the importance it gives to the experiments conducted for research. Besides, in 2000s in total, the number of the word 'experiment' in 'Design Studies' is more than 4 times higher than the number in 'Design Issues'. Checking the ratio of pages of two periodicals doesn't alone justify the result, which can again be interpreted that the importance given to the subject of experimenting in design process is also rising.

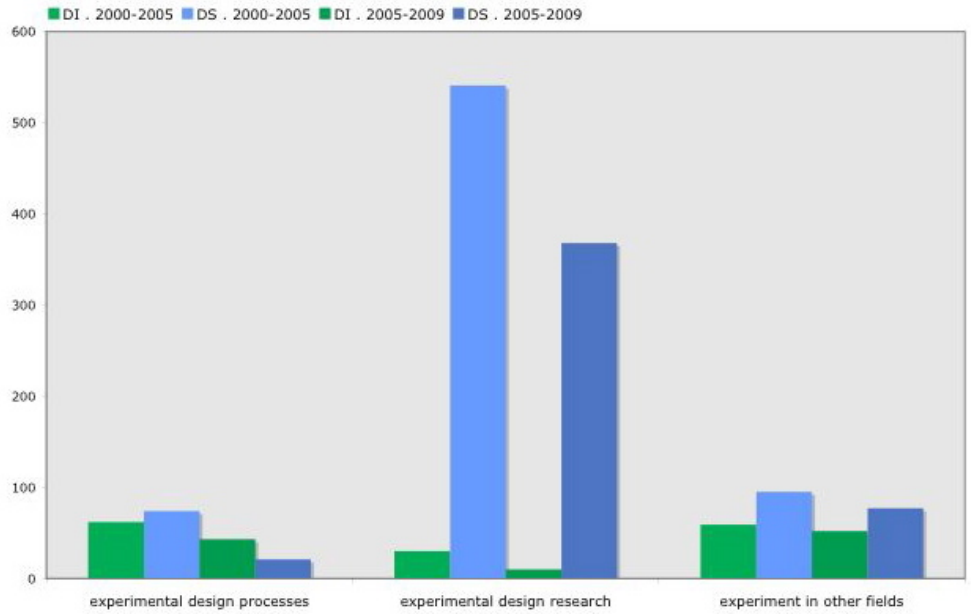

Figure 2. Content Analysis of Design Issues and Design Studies in 2000s – Category 1

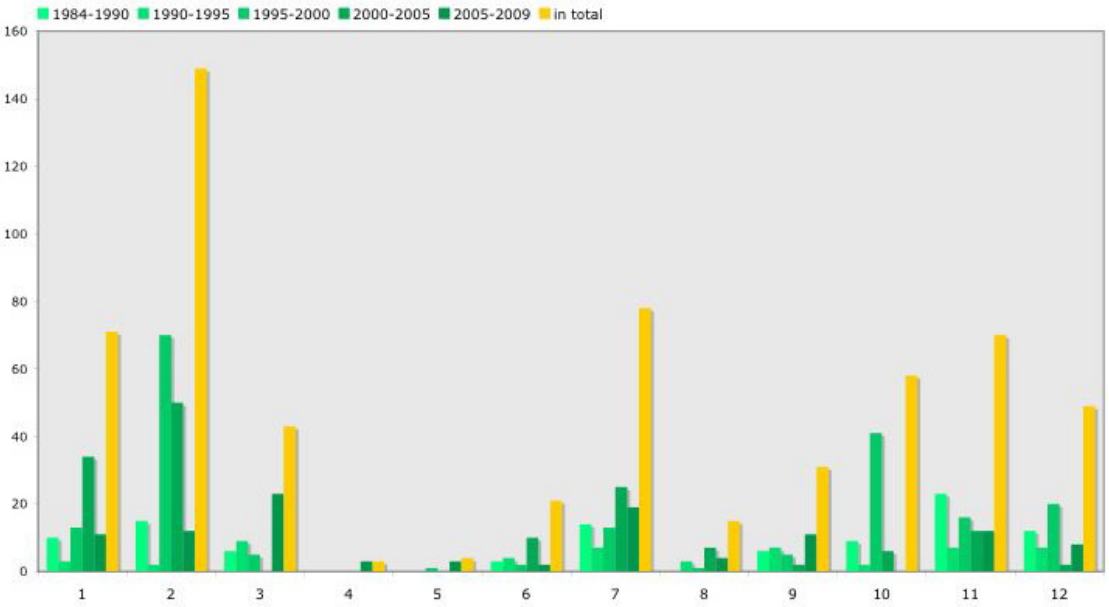

Figure 3. Content Analysis of Design Issues – Category 2

Figure 3 shows that the term was used mostly in the context of 'design methodology, cognition and creativity' in 'Design Issues'. The next highest values are for 'design history and cultural studies in design', 'graphic and visual communication design' and 'social sciences', and then 'mathematics, natural sciences and medicine',

'engineering' and 'design education'. This inference is interesting when considering all the design fields and their values in total, and it might suggest that the term 'experiment' is not just a term that the design literature borrows from the science and art literature, but also it is well assimilated into its own culture. This can also be observed in the number of the term, referring to 'experimental design processes' in the results for 'Category 1'.

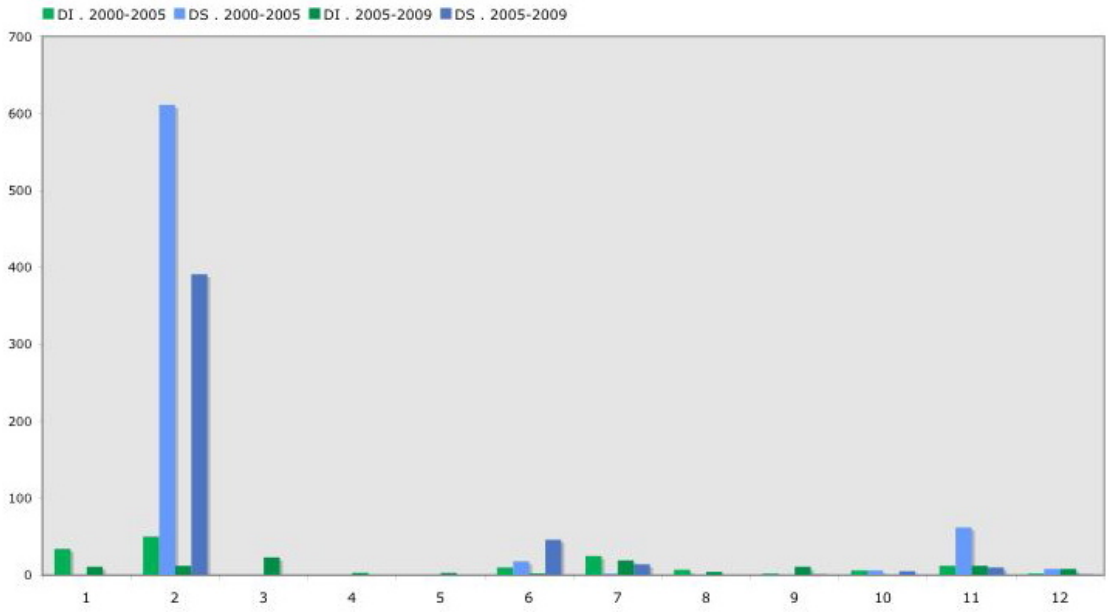

Figure 4. Content Analysis of Design Issues and Design Studies in 2000s – Category 2

Similar to Figure 2, Figure 4 shows that the term 'experiment' was used in 'Design Studies' in 2000s mostly for mentioning 'design methodologies, cognition and creativity', which can again be interpreted as the perspective and the scope of 'Design Studies'.

One of the most important results of the study is that the term '*experiment*' is used in a very wide variety of contexts, which affirms the importance of 'experimenting' in design. As the 'thought experiments' existed before the scientific revolution, the term experiment already exists in design theory and is firmly integrated, but needs to be studied further in detail.

6. Conclusion

This paper aimed to explore the term 'experiment' in industrial design and to emphasize and justify its role and importance. The conceptual background is constituted by exploring art, science, and design literatures to form interdisciplinary correlations. The aim was to build a framework for describing the term. It was also challenging, also considering the results of the content analysis, as the term has been used widely in various contexts.

Schön (1983)'s definition and description was still the most comprehensive approach to experiment in design process, which builds the base for further studies. The subjects such as handling design process as an experiment, the early failure and suggested guidelines for experimenting etc. are discussed mostly through innovation literature, but it needs to be included in design research as detailed. It is important what Thomke (2003) puts forward, that the economics now demands experimenting in design, as it was the reasons for developing the design methodology after the WWII.

An important result, which has been drawn from the content analysis is that the term 'experiment' already exists and is well assimilated into design theory, but it more akin to the form of 'thought experiments' in science

history. Besides, the term is embraced in a wide variety of contexts; it is a fertile basis for interdisciplinary design studies and would help providing an integrated approach to design. Therefore, the experimental design processes will always be subject of rigorous research in design field.

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