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Evaluate the Relationship Between Fixation in The Design Process and the Level of Expertise of Designers

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Abstract
In the context of creativity in design, much research has been done with an endeavor to discover the factors advocating creativity in design. Though, not much effort has been put in identifying of the factors disrupting creativity. One phenomenon that acts as an obstacle to creativity in design, or detracts from it, is the phenomenon of fixation. The term "design fixation" is often used interchangeably to refer to situations where designers limit their creative output because of an overreliance on features of preexisting designs, or more generally, an overreliance on a specific body of knowledge directly associated with a problem. It is understood as the inability to solve design problems by employing a typical or familiar method, ignoring new or better ones. In this research, an attempt has been made to investigate the factors that create fixation in design by examining how the previous knowledge of designers affects design. This way, a structure was presented to better understand the factors of fixation in the stages of the design process. Then it was explored what the differences and similarities in designers with different levels of expertise are. Finally, the formation of fixation in the design process stages, under the influence of the designers expertise level as an intervening variable, was explained. And so, the designers will be able to recognize the causes of their fixation and prevent fixation in design or at least reduce its amount. Also, design teachers, with awareness of these causes, will be able to guide students to stay away from this phenomenon.

Keywords: fixation; design process; precedent knowledge; level of expertise

1. introduction

There are several definitions about what fixation is and what it encompasses. All of the definitions of fixation share characteristics, such as the persistent -and often unconscious commitment to a limited set of alternatives. Design fixation is described as the inability to solve design problems by employing a typical or familiar method ignoring new or better ones, self-imposingconstraints, or limiting the space of solutions merely by means of developing variants. Design fixation is described as the inability to solve design problems by employing a typical or familiar method ignoring new or better ones, self-imposing constraints , or limiting the space of solutions merely by means of developing variants (Moreno,2014:3).

Several causes can contribute to design fixation and Some are the subject of research studies. Researchers suggest that design fixation may depend on expertise (e.g. , linsey et al. , 2010), or designer's unfamiliarity of principles of a discipline or domain knowledge (e.g. , Purcell & Gero,1996 ; cross, 2004), on personality types (e.g. ,Toh, Miller & Kremer,2012), on the unawareness of general technological advances, or on conformity due to proficiency in the methods and supporting technologies of an existing solution (e.g. , Luchins, & Luchins,1959)

Youmans and Arciszewski (2012) undertake an extensive literature review on design fixation, leading to the following proposed categorization of fixatio tynpes:Unconscious Adherence, Conscious Blocking and Intentional Resistance (HOWARD,2013:2). The term "design fixation" is often used interchangeably to refer to situations where designers limit their creative output because of an overreliance on features of preexisting designs, or more generally, an overreliance on a specific body of knowledge directly associated with a problem . These design fixations may be unintentional or intentional, and may be conscious strategies or unconscious influences on the designer (Youmans & Arciszewski, 2014). the studies stated that There are a number of causes that can contribute to the emerging of design fixation: example solutions, inspirational material, ill-defined problems, expertise or unfamiliarity with certain domain knowledge, previously generated ideas, feelings of ownership and it appears that even the will to be 'different' can cause design fixation (Jansson and Smith 1991; Moreno et al. 2015; Purcell and Gero 1996; Smith 2003). Jansson and Smith (1991) were the first to conduct research into the fixation in the domain of engineering and design, in which they tested the effects of examples on creative idea generation. Jansson and Smith defined design fixation as "blind, sometimes counterproductive adherence to a limited set of ideas in the design process" . Ideally, designers move past existing ideas to create novel designs. But designers often

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experience “fixation,” where new ideas are similar to existing designs. An example concept in brief or early attachment to one’s initial ideas, can limit the range of designs considered. (Leahy et al,2018)

Jansson and Smith showed that designers can become fixated on previous designs and example solutions. This raised a number of important questions : For Design Research ;For Design Practitioners ; For Design Education. (HOWARD,2013:1). They found that showing example solutions can reduce the range of design solutions generated by a designer, and that aspects of the example solution, including aspects that were shown to violate goals of the problem statement, can find their way into the designers’ solutions. A number of later experiments by others used the same and similar design problems to further investigate the issue of design fixation . Purcell and Gero suggested that the susceptibility of a designer to fixation may depend on the discipline of the designer, and that design fixation is more likely if the example problem embodies principles that are in line with the knowledge base of that discipline. These studies, as a whole, demonstrate that introducing examples can cause design fixation, resulting in less creativity during ideation (Linsey et al,2010). When designing a new product, individuals usually do not create something new from scratch. Instead, they transform, combine, or adapt elements of existing designs to generate new ideas (Ward, 2007). However, looking at existing designs may not always provide inspiration to individuals. Empirical studies on design processes have revealed that consulting existing designs may instead negatively impact the quality of the design solution. When individuals are given an example solution to look at, they often tend to produce a solution similar to the example provided. Individuals do not copy ideas only from relevant examples that fulfill the task requirement, design replication occurs even when the example is a poor one that does not fit the task requirement (Sio and Kotovsky,2015 :71).

Fixation is a widespread phenomenon which is not only limited to creative processes, but can occur in a wide variety of cognitive domains (Finke et al. 1992). Functional fixedness was further explored, not in problem-solving but in design, where the problems are more open-ended. (HOWARD,2013:1) One of the most well-known examples of this failure in the domain of creative problem solving is the phenomenon of functional fixedness. Here, people fail to see new ways of using objects that could lead to an original solution to a problem, because they remain bound to previously activated prescription of the object (Agogué et al. , 2014). For example, people appear to be unable to see new ways of using objects which could lead to an innovative solution to a problem, because they are blocked or fixated on well learnt uses or properties of the object. The reason for this result, it is argued, lies in how the well established, everyday functions of objects prevent the problem solver from seeing this unusual and innovative use (Purcell and Gero, 2006).

Alexander and Chermayeff, also saw that the designers, utilizing some well-known solution – which they were already aware of previously – start the act of design, saw the danger in these existing solutions and believed that these existing solutions, act as bromide images and when designing, they prevent the expansion and discovery of better solutions. (ansari, 1388, p. 7)

During the design process, design fixation can emerge when example solutions are presented (Agogué et al. ,2011 ; Christensen & Schunn , 2007 ; Jensen ,2010; Linsey et al. , 2010 ; Tseng, I. et al. , 2008) , when there has been a considerable amount of resources invested on a potential solution (Viswanathan & Linsey ,2011), when there are weak or ill-defined problem connections either internally (within component elements of the problem) or externally (between the problem and other problems or external factors) (MacCrimmon & Wagner, 1994) , and when there are more vertical (refined version of same idea) than lateral transformations (moving from one idea to another)(Goel,1995).

In this research, firstly the phenomenon of fixation in the designing process, is studied, and it has endeavored so that this phenomenon, is described in various levels and steps of desig. In the next step, the effect of the designer's prior knowledge in the process of design, was evaluated and in particular, its relation to the designer's measure and level of expertise, was studied. Ultimately, the phenomenon of fixation’s way of occurrence in correlation with the designer's level of expertise, was evaluated and defined in various levels and steps of designing.

2. Design Process and Fixation

Design fixation is mostly identified and studied indirectly by analyzing design ideas, prototypes and artifacts when a design process has ended (Sio et al. 2015; Vasconcelos and Crilly 2016). b). At that moment it is too late designers avoid or overcome their fixation. Identifying fixation during the design process, instead of when the project has already ended, can transform the occurrence of design fixation into a learning process. For that reason,we want to find ways through which fixation can be identified during the development stages of a design process.

According to the recommended models, which have been presented for the designing process – ranging from the most primitive models to the recently proposed models – the steps and phases of designing can be classified in several general steps and phases. Most of these models can be categorized into three phases consisting of; analysis (design problem space), synthesis (solution space) and evaluation. In this approach, models presented by Asimov, Archer, Jones, Royal Institute of British Architects (RIBA), Boekholt, Lawson, etc can be pointed at.(Figure 1)

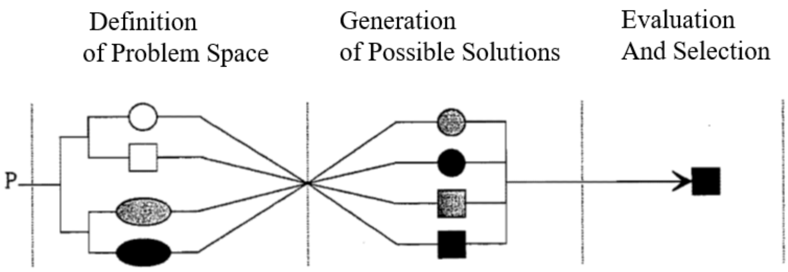

Fig. 1. schematic model of design problem solving by Boekholt (Vries,1990 : 14)

Lawson, describes the three essential steps of common designing as such: Analysis, Synthesis and evaluation. Analysis involves exploring relationships, looking for patterns in the information available, and the classification o objectives. Analysis is the ordering and structuring of the problem. Synthesis on the other hand is characterized by an attempt to move forward and create a response to the problem – the generation of solutions. Appraisal involves the critical evaluation of suggested solutions against the objectives identified in the analysis phase. (Lawson,2005:37) .(Figure 2,3)

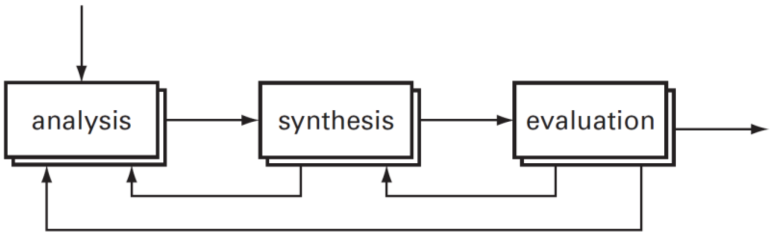

Fig. 2. A generalized map of the design process (Lawson,2005:38)

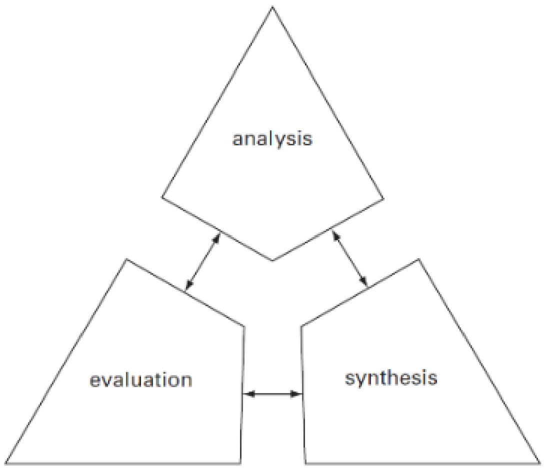

Fig. 3. A more honest graphical representation of the design process (Lawson,2005:40)

Maps of the design process similar to those already discussed for architecture have been proposed for the engineering design process (Asimow 1962) and (Rosenstein, Rathbone and Schneerer 1964), the industrial design process (Archer 1969) and, even, town planning (Levin1966).

Asimov (1962), for instance, identified three such stages: analysis, synthesis, and evaluation (see Figure 1). The common ground for these models – which all have been following in the footsteps of their predecessors and brought forward some new attention to detail, and also have divided the process of designing into multiple steps or various levels, while working towards defining this process which largely includes them – is the three-part

Analysis corresponds to gathering the relevant information (or preparing the problem) and framing (or (re)formulating) the problem, synthesis is associated with the search for an appropriate solution, and evaluation can be described as the validation of the proposed solution. If the evaluation stage yields unsatisfactory results, the whole process is repeated. (Bonnardel et al ,2017)

model (Tri-Leveled): problem-finding (defining the problem), solution generation and evaluation.

In this section, by basing the focus on this tri-leveled model; the factors, and conditions for the formation of fixation are discussed and analyzed.

2.1. Problem Finding (Problem Space)

Problem identification and construction is viewed as an important cognitive process with important implications for creativity. More creative individuals engage in problem identification and construction. (Reiter-Palmon,2009:13)

Designers with good perception of the design problems are equipped with relevant skills, knowledge and effect in the context of the design problem. These designers will be able to provide a clear definition of the problems, develop a better question list used for eliciting requirements, create a better requirement list, and generate better conceptual design solutions. (Ommi,20۱۷ : ۱) More novel problem statements have reflected an increase in unique concepts. (Creeger,20۱9)

According to (Abdulla, Paek, Cramond, & Runco, 2018) Problem identification is the process of recognizing and conceptualizing an issue from multiple angles, considering opportunities that may arise from these different conceptualizations, and analyzing the root of the issue before engaging in problem-solving . (Rubenstein,2020:1)

One can view creative conceptual design not as the invention of a new configuration, but rather as a designer's insight into formulating a problem in a conceptually new or different way. In the same direction, design fixation can occur even during the problem formulation way prior to creating alternative design solutions. (Condoor,2007)

Wiley (1998) suggests that although experts might solve problems more efficiently than novices due to their structured knowledge, this knowledge can also limit their solution search to a known space in which the best solution may not reside. Accordingly, Kim and Ryu (2014) compared the design process of expert and novice designers and concluded that expert designers are more effective at framing design problems as well as being more committed to their own previously developed design concepts, which means that they may exhibit more fixation than novice designers. A similar relation was noted in a student context: it was found that graduating engineers are often less innovative than freshmen students (Lai, Roan, Greenberg, & Yang, 2008). One of possible approach to breaking or mitigating design fixation, beyond defixation instructions, is to assist the designer in finding a new way to frame the problem, which may lead to new and improved solutions. (Linsey et al,2010)

2.2. Ideation (Solution Space)

Most research on design fixation focuses on the idea generation phase in the early stages of the design process. Specifically, the influence of external stimuli on creative idea generation, like example solutions and inspirational material, has been researched rather extensively. (Schut,et al ,2019)

Crilly and Cardoso (2016) even propose a specific name for fixation on idea generation in the earlier phases, namely 'ideation fixation'. Humans tend to rely upon and use prototypes in their initial approach to design solutions because access to the prototype requires significantly less cognitive effort than does the processing of individual exemplars. (Condoor,2007) Design fixation is a phenomenon that can negatively impact design outcomes, especially when it occurs during the ideation stage of a design process. (Moreno,2014:1)

Research on idea generation in engineering has revealed two types of cognitive limitations in the context of fixation. First, the tendency to become focused on specific options early in the design process has been identified as limiting the variety of designs considered (Vimal, Tomko & Linsey, 2016; Lindsey, 2010; Cross, 2001; Jansson & Smith, 1991; Purcell & Gero, 1996). Second, designers may form an early attachment to their initial ideas, thus leading to
few alternatives. (Leahy et al,2018)

Design process success depends highly on ideation stage results. Extensive studies have focused on the improvement of metrics for evaluating ideation processes and associated mechanisms: quality, quantity, novelty (originality), workability (usefulness), relevance, thoroughness (feasibility), variety, and breath . Some of these have considered design fixation in a quantitative and direct way; or as a qualitative incidental discovery; or measured indirectly as linked to one or more of the ideation metrics. (Moreno,2014:4) However, even with no provided example, there is an initial example evident to each designer: their first generated idea. (Leahy et al,2018)

2.3. Evaluation

Feedback interventions, or design reviews, are common educational practice in design disciplines at university level (Goldschmidt et al. 2010; Yilmaz and Daly 2014) and can benefit the design process greatly (Crilly 2015). During these design reviews, the students communicate their design ideas, goals and expected user interactions in words, sketches and early models to the instructor, their peers and other stakeholders. They, in turn, react with questions and comments to get clarification on aspects of the design and the choices made. This feedback can encourage the students to take convergent or divergent paths in their design process (Cardoso et al. 2014; Yilmaz and Daly 2014, 2016), helping them develop their design idea. When receiving feedback on their design there is always an inherent contradiction with which designers have to deal. As Crilly states, "Designers must remain open to the possibility that their ideas are limited or misdirected whilst also being persistent in developing their nascent ideas in the face of negative feedback" (Crilly 2015). When a designer is too persistent in developing an idea, fixation can emerge. Alternately, when a designer is too open to the possibility that something might be wrong with their ideas, it might be that many valuable ideas never get developed (Csikszentmihalyi 1999).

it is expected this tension between openness and persistence to become visible through how the children react towards the design feedback that is posed. Research has for example shown that university students can react negatively towards feedback that asks for clarification of certain aspects of the design. As a result, they either end up being too descriptive (Cardoso et al. 2014) or become defensive and try even harder to convince everyone of the quality of their design (Cardella et al. 2014; Cummings et al. 2015). These types of interactions could inhibit a student's critical thinking processes, since they will not easily engage in reflective or evaluative thinking about the state of their idea when they feel they have to justify it. (Schut,et al ,2019)

With regard towards what was examined in this section, in table 1, the effective factors in formation of fixation in design, was explained in the three essential steps of designing process (Problem-Finding Phase/ Solution Generation Phase/ Evaluation phase), to determine what factors in each of the stages, have a part in the emergence of this phenomenon.

Table 1
The fixation formation factors in the design process (Authors)

Design process stages	Fixation factors
Problem domain	- Addressing issues known to others (Lack of effort or ability to find a new issue) - Prioritizing issues based on introduced priorities - Framing issues with known methods - Staying in issues of the past due to the formation of a personal view (personal or group aspiration) that prevents the discovery of new problems
Solution domain	- Utilizing experienced solutions due to the inability to create new solutions - Utilizing experienced solutions due to the skill in using it or belief in its permanent infallibility (believing in design principles) - Using experienced and approved solutions (by employer or public taste) due to low risk - Staying in the initial solution (the first idea) due to an inability to have divergent thinking or a lack of motivation to produce multiple solutions - Limited knowledge range (specialized and non-specialized) to use deductively - The inability to discover correlation in information (both in specialization fields and in relation to information outside the specialization fields)
Evaluation domain	- Applying previous evaluation criteria - Prioritizing non-qualitative criteria (Such as economy, executability, and …)

3. Design Process and Precedent Knowledge

prior knowledge is widely recognized as an intrinsic element of any creative design process (Oxman, 1999). As McDermott (1982) put it, given the understanding that design is an ill-structured activity, and that the set of constraints applicable to specific design problems is often substantial, one can hope to surmount these problems only when significant volumes of domain specific knowledge can be combined and fused together at every stage of the problem solving process . (UYSAL ÜREY, 2019 : 40)
Bonnardel and Marmeche (2005) suggest that the designer's past experiences, which are stored in terms of his/her prior knowledge, are often the sources of inspiration in the formation of new ideas (pp. 422-435). In this sense "designers accommodate the known to the new" and thus develop the new ideas through integration with "what they already know" (Oxman, 1990, p. 23). To Oxman (1990b), design occurs in this sense as "a dynamic process of adaptation and transformation of the knowledge of prior experiences to accommodate them to the contingencies of the present" (1990b, pp. 17-28).
In this context creativity in design occurs as "the sudden interlocking of two previously unrelated, skills or matrices of thought" (Koestler, 1964, p. 121), and emerges as a cognitive process entailing the "activation and recombination of previous knowledge elements in a new way to generate new properties based on the previous ones" (Bonnardel & Marmache, 2005, pp. 422-435). Thus, the studies on design creativity show that people depend mostly on past experiences, types and precedents, even when they are instructed to be as original and imaginative as possible. In this perspective, the new ideas that are developed are deemed creative and original to the extent that they move away from their initial sources of inspiration (Bonnardel & Marmache, 2005, p. 422-435).
Today, it is widely accepted that the design ability grows in parallel with the extent of the acquired domain knowledge and the problem solution strategies that are operated on that knowledge. The obvious implication of this information is that, if designers or students of design are provided with ever-growing databases consisting inter- or intra-disciplinary sources, their success in producing creative designs would only increase (Bonnardel & Marmache, 2005, pp. 422-435).
At the start of the design process, the designers are considered to analyze existing systems looking for analogies. They then proceed to bring up a first solution concept that acts as the starting point from which to tackle the design problem they face with. In this process, the designer focuses on the smaller parts of the wider problem, by means of subproblems , using a retrieval system that continuously recalls prior knowledge from his/her long-term memory. Since ill-defined design problems require substantial amounts of relevant prior knowledge, the retrieval system employed on them operates as a device to recognize the solution alternatives. As the design problems are downsized to a series of subproblems as such, these smaller parts can be handled better as well-defined problems (Fig. 4) (Simon, 1973, pp. 181-201).

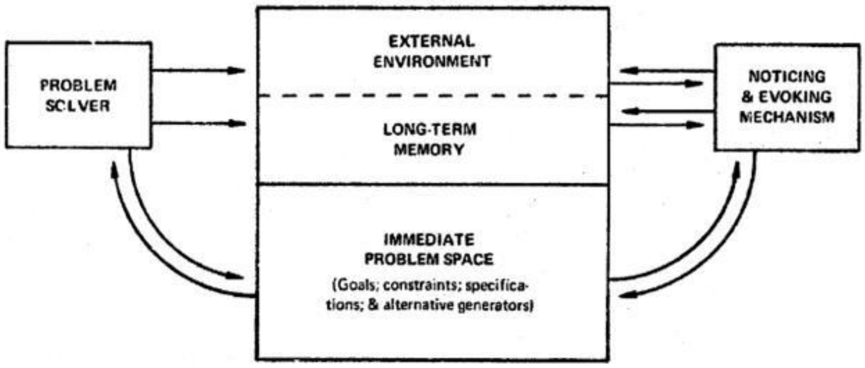

Fig. 4. A model for ill-structured problems
(Simon, 1973)

there are essentially two types of prior knowledge that are employed in design: declarative (or domain-specific) knowledge, and procedural knowledge (Goel, 2001). Declarative knowledge refers to the general knowledge about the 'things' that we learn within our lifetime and it essentially consists of the 'facts' that we know. Procedural knowledge, on the other hand, involves the procedures used for the processing of declarative (or domain-specific) knowledge (Goel, 2001, pp. 221-241).
Prior knowledge is also categorized as personal or cultural in terms of its source. If prior knowledge emerges exclusively on the basis of the specific, personal experiences of the individual who possesses it, it is considered personal. On the other hand, if it is formed by a multitude of phenomena shared by the wider society, or at least a community, it is deemed as cultural (Shore, 1996, pp. 56-65). Architectural types for instance are the cultural forms of this prior knowledge. (UYSAL ÜREY, 2019 : 41)
In this context, design creativity is seen as "the ability to innovatively re-represent the schema or the particular structural content of the externalized representation" (Oxman, 1996, p. 333).
Jansson et. al. (1992) defines three cognitive processes that are active in this process of using schemas (or prior knowledge) in architectural design: identification, where designers use types or prototypes for categorizing, understanding and representing design problems; synthesis, where they adapt or transform types or prototypes to fulfill the requirements associated with the problem; and evaluation, where they assess themselves concerning those types or prototypes. These processes are believed to work in a consecutive and repetitive manner towards the realization of a complete architectural design . (UYSAL ÜREY, 2019 : 42)
The formation of types, or the process of typification, is an outcome of the process of generalization or categorization. Oxman (1990b) describes typification as "the abstraction and classification of salient aspects of precedents in terms of both situations and solutions" (p. 17-28). One of the most evident applications of this process is formal typification, where classes of formal types are produced as based on certain known precedents. Typification also occurs in the perception of the design problem, where the designer tries to match the problem with a similar solution type that he/she previously encountered with. (UYSAL ÜREY, 2019 : 43)
The problem, knowledge, and solution are viewed as three integral parts of design, and can be established as three evolvable spaces. As they interact with each other, the design process is pushed forward . The three evolvable spaces interact with each other through a series of mappings, forming the innovative design as a problem-knowledge solution co-evolution. According to model (figure 5), the problem presented to the designer is analyzed and resolved with the support of knowledge, which is mapped from the background knowledge and modified to be adopted for solution seeking. As the solutions are generated, they map back to the problem space to stimulate problem reframing from new perspectives. The problem-knowedge solution co-evolution is a composite process during which the problem is clarified and resolved from fuzziness to satisfying solutions. The final result of the design is added to the background knowledge and works as the new case knowledge for future design. (Hui, 2020 :4-5).
Boling et. al. (2019), have identified several primary modes of precedent use: linear, Field-Specific Sources and Validation of Judgment, Direct Model for Invention, Abduction/Analogic Reasoning/Inspiration, Problem Framing, Design Talk.
- A linear use of precedent is one in which the bridge between precedent and a design decision or action is conscious, direct, and simply connected to the design.
- Using the architectural canon, or less systematized bodies of recognized precedent (sometimes the bodies of work produced by famous designers), designers can draw on precedent knowledge that they share with many other designers and use it to guide or validate their own design decisions or actions.
- Engineers in particular use precedent knowledge in a combinatory way, incorporating precedent designs directly into new ones when subsystems are required for a complex situation and existing examples can be used with minimal adaption.
- The abductive use of precedent involves allowing the experience of what exists to suggest possibilities for that which is still to be designed. Analogic reasoning is a method of activating stored schema based on the identification of connections, parallels, or similarities

between, what are typically perceived as dissimilar item the case of what we perceive as inspiration, analogic reasoning utilizing multiple schema may occur and, because these processes are not linear, they appear to be - or are experienced as - unexplainable leaps from what is known to something entirel new.

- In this use of precedent, the designer's knowledge is not being used to guide specific design actions, but to explore, understand and define the situation overall.
- Lawson (1994) offers a vivid description of such talk amon architects they all used a single term derived from separate but overlapping, bodies of precedent knowledge and probably from experiential memories the team also shared. (Boling, 2020 : 7-11)

Now, It should be noted studies in creativity have shown how knowledge can create "fixation and how it can become a core rigidity instead of a core capability. Hence, knowledge can support but it can also limit design capabilities, and it is not always easy to devise compromises. Decades of cognitive psychology studies has demonstrated that previously acquired and existing knowledge or idea can limit creative ideation, leading to fixation. While creative tasks involve the exploration of new and original solutions, people tend to follow "the path of least resistance" and provide solutions based on common and undemanding design heuristics (Camarda et al. , 2017)

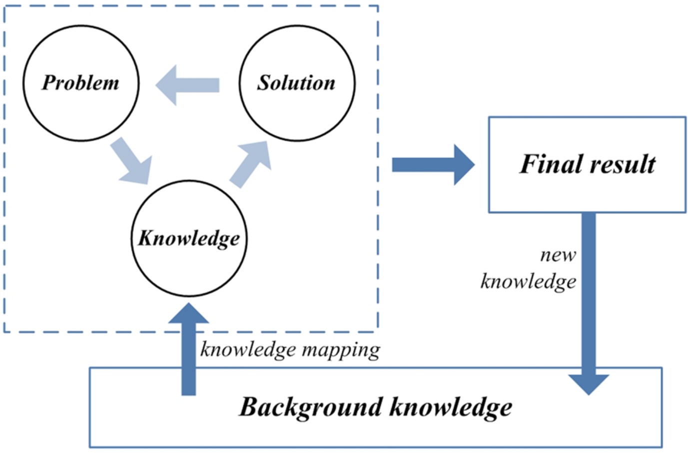

Fig. 5. Problem-knowledge-solution co-evolution based model
(Hui, 2020 : 5)

4. Levels Of Expertise And Precedent Knowledge

According to the literature, one needs a certain level of maturity to practice design well, as expertise in design is essentially a culmination of design knowledge and experience in the form of schemas. Lawson (2004) indicates that, the educational period of the designer helps him/her to develop a knowledge of design solutions, in the form of 'the pool of precedents' or the 'domain-specific knowledge' (p. 456). The designers who are considered experts are characterized by a vast pool of precedents and prior knowledge, which are stored as solution schemas to be employed at different design projects (Lawson, 2004, p. 456). For expert designers, the schemas of precedents or types do much more than just carrying the visual information and geometry. They also convey all the concepts related to that schema, including but not limited to the materials, functions, organization principles, and significant instances of that schema (Lawson, 2004, p. 443). The schemas of expert designers are observed to be greater in number, in detail and in the extent of information that they hold (Purcell & Gero, 1991, p. 83).

(Uysal Ürey, 2019 : 42-43) an Expert ordinarily deals with design task at various levels of abstraction. In doing this, expert reduces amount of information he has to attend to at one time. High-level decisions can be made based on limited amount of information, and then these decisions can be refined based on information. For example in cases where a task has a significant amount of structure, it is sometimes possible to view the task as a hierarchy of subtasks with strong temporal interdependencies; In such cases, the fact that a prior subtasks has been completed successfully may implicitly contain a great deal of information. human experts make extensive use of their knowledge of the task domain in determining how to organize their problem solving efforts in ways that exploit whatever structure the domain has. (Mcdermott,1981:582

Lawson (2004) defines five stages, which the designer has to undergo in his/her journey to gain expertise in design:

1. Formation of a developing pool of precedents
2. Attainment of design schemas
3. Development of certain guiding principles (e.g. sustainable design)
4. Development of the skill of recognizing the design situation without the need of an in-depth analysis
5. Formation of design gambits or a 'repertoire of tricks' that are fused within the schemas used for recognizing the design situations (Lawson, 2004, p. 456-457)

Hubert Dreyfus (2003) also, pointed out that the nature of the problem that is considered in a problem solving situation depends on the level of expertise of the problem solver. Dreyfus distinguishes five distinct levels of expertise, corresponding with five ways of perceiving, interpreting, structuring and solving problems: (1) A

novice will consider the objective features of a situation, as they are given by the experts, and will follow strict rules to deal with the problem. For an **advanced beginner** (2) the situational aspects are important, there is a sensitivity to exceptions to the 'hard' rules of the novice. Maxims are used for guidance through the problem situation. A **competent** problem solver (3) works in a radically different way. He selects the elements in a situation that are relevant, and chooses a plan to achieve the goals. This selection and choice can only be made on the basis of a much higher involvement in the design situation than displayed by a novice or an advanced beginner. Problem solving at this level involves the seeking of opportunities, and of building up expectations. There is an emotional attachment, a feeling of responsibility accompanied by a sense of hope, risk, threat, etc. At this level of involvement the problem soolving process takes on a trial-and-error charcater, and there is a clear need for learning and reflection, that was absent in the novice and the beginner. A problem solver that then moves on to be **proficient** (4) immediately sees the most important issues and appropriate plan, and then reasons out what to do. The real **expert** (5) responds to specific situation intuitively, and performs the appropriate action, straightaway. No problem solving and reasoning that can be distinguished at this level of working. (dorst,2003)

One of the other differences between novices and experts is what Ball et al. (2004) stated.they found experts use more analogies than novices do, so experience seems to increase retrieval frequency. Expertise also enhances the ability to retrieve high-level principles derived from sets of analogies (schema-driven). Novices tended to use more case-driven analogies (analogies where a specific concrete example was used to develop a new Solution) rather than schema-driven analogies (more general design solution derived from a number of examples) . This difference can be explained because novices have more difficulty retrieving relevant information when needed and have more difficulty mapping concepts from disparate domains due to a lack of experience.

However Case-based reasoning is a usual cognitive process for experts, since they have a large library of cases at their disposal. Experts can refer to such cases in order to engage in analogy-making for solving design problems. Analogy-making is, however,double-edged:on one hand, it allows experts to consider promising ways for designing a new object; on another hand, it can restrict the bound aries of the space of research, the extent of design ideas, the range of procedures to be used and thus, reduce creativity. In contrast, novice designers have only a few reference cases to deal with new design problems, which may restrict their space of research of innovative ideas. (Bonnardel and Marmèche, ,2004 : 178)

In summary , the competence level of the designer in correlation to the measure and the type of their prior knowledge, and also the form of retrieving this information, is displayed in the table below (Table 2) .In this table, the level of expertise of designers, is divided into two levels: novice and professional. In the first section, the prior knowledge of the designers, in terms of its extent and their fields of expertise, is explained. The issue was then addressed that how at each level of expertise, the designers' prior knowledge is classified and prioritized.

In the next section, the type of reference of designers to their previous knowledge according to the level of designers was examined and ultimately, their level of fixation to these references was described.

Table 2
The correlation between designer 's level of expertise and designer 's precedent knowledge (Authors)

	Expertise level	
	professional	**novice**
The Extent of information / The scope of information	High / specialized and non-specialized	Low / General
Classifying and prioritizing the information	The ability to create hierarchy and prioritization	The inability to recognize important information (issues)
	Establishing guidelines and achieving personal design patterns	No personal classification
The type of reference and retrieval of prior knowledge	Indirect(Referring to the principles and prototypes)	Direct(Referring to the previous examples themselves, not their principles)
	All features (function, materials, organization, etc.)	mostly visual and geometric
commitment to referrals	Possibility of skepticism in prior information	Immense and hard commitment on prior information

5. Expertise In Design and Fixation Types

Even years of professional experience are not enough to avoid fixation (Jansen & Smith, 1991; Purcell & Gero, 1996; Smith, 1995). Many studies demonstrated that there are some differences between the design acts and processes of experts and novice designers (alipour, 2021). Researchers suggest that design fixation may depend on expertise , or designer's unfamiliarity of principles of a discipline or domain knowledge , on the unawareness of general technological advances, or on conformity due to proficiency in the methods and supporting technologies of an existing solution. (Moreno,2014:3). Wiley (1998) suggests that although experts might solve problems more efficiently than novices due to their structured knowledge, this knowledge can also limit their solution search to a known space in which the best solution may not reside. Accordingly, Kim and Ryu (2014) compared the design process of expert and novice designers and concluded that expert designers are more effective at framing design problems as well as being more committed to their own previously developed design concepts, which means that they may exhibit more fixation than novice designers (Vasconcelos and Crilly,2016:12) .

Differences in skill between novices and experts have been attributed to differences in their representation of knowledge. while novices may represent problems or task situations in terms of irrelevant features that do not lead to a correct solution, experts tend to focus on more profound features. As expertise develops, knowledge becomes more structured and better integrated with past experiences, so that it can be retrieved from memory in larger chunks. This has been examined in different domains.also Some researchers have reported that experts have a large domain knowledge base and tend to represent problems qualitatively. Even when solving ill-defined problems, in which the goal may not be clearly defined and possible alternative solutions might be too many, experts are generally aware of what type of relevant knowledge might be useful for solving the given problem (Casakin and Goldschmidt,1999: 154).

As with the experience of individuals (i.e. accumulated practical knowledge), their disciplinary background (i.e. field of practice or study) also relates to inspiration and fixation(Vasconcelos and Crilly,2016:12).

when experts face a problem which requires non-routine thinking such as a creative design task, their expertise in a specific field acts a constraint . Their mental model repository pertains primarily to their domain of expertise, leading them to fixation. This type of constraint, emerging due to an expert's extensive, domain specific knowledge, might detrimentally effect the completion of design tasks. The primary matter concerns here is the educational or training process that allows an expert to accumulate knowledge from a specific field or domain. Constrained design problems often presented in engineering science courses focus on a problem solving approach in which the students need to identify one core issue and divert their whole focus to that issue. This type of an approach is not helpful in the early stages of engineering design when an innovative solution is desired. At this stage, designers require diverse thinking and defocusing from the solutions already generated. (Viswanathan and Linsey, 2011).

Expertise also enhances the ability to retrieve high-level principles derived from sets of analogies schema driven . Novices tended to use more case-driven analogies analogies where a specific concrete example was used to develop a new solution rather than schema-driven analogies more general design solution derived from several examples (Linsey et al. ,2010).

Some design researchers demonstrated that expert designers do not attempt to fully understand the design problem before making solutions, move rapidly to early solution conjectures and continue the process of exploring and defining problems and solutions together. The solution-focused approach of expert designers may cause fixation on initial concepts instead of adopting a fresh alternative (alipour, 2021).

Another issue is that social evaluation and to a lesser extent social surveillance, have a deleterious effect on creativity. Using self-reported measure of intrinsic motivation, an experimental study has demonstrated that both creativity and intrinsic motivation are lower when participant perform the creative task in a typical social evaluation condition compared to a condition in which the evaluation are more informational (i.e. participants expect constructive feedback on their performance) (Camarda et al. , 2017)

Also In McLellan and Nicholl research, which was acknowledged by students and teachers alike that generating original ideas is difficult for the students. Many of the generated design ideas are derived from popular culture or examples shown by the teacher, since this is an easily accessible source of inspiration for them (McLellan and Nicholl 2009; Nicholl and Mclellan 2007a, b). As a result, many of the designs became stereotypical in nature, showing the ideation fixation-effect and exemplifying how thinking along the 'path-of-least-resistance' can influence a design (Ward 1994). It also became apparent that students became fixated on the first idea that came to mind and that they were not motivated to think of multiple ideas. They did not understand the concept and the possibility of accepting or rejecting ideas. The students simply wanted to go with their first idea for which they had already worked out how to proceed. A case study by Luo (2015) found comparable results regarding design fixation during an engineering design project with primary school students aged 8 to 11. Similar to the results of Nicholl and McLellan, these younger students fixated on popular culture, common features, and their first design ideas (Luo 2015). Here we see how the occurrence of concept fixation hampers the student's creative thinking processes. The students' fixation on the constructed image of the final design prevents them from further developing their idea. Since they already have an exact image of how the design will look and function their creative thinking is set to a halt. Their CT (convergent thinking) is hampered because they see no need to critically reflect on the state of their already 'perfect' design. Consequently , they will also not explore alternative solutions for these sub-problems within the problem space (DT- divergent thinking). (Schut,et al ,2019)

For novices, the difficulty of generating any potential solutions may increase the perceived value of their initial ones. Engineering students may lack awareness of strategies to support the exploration of other solutions that are different from one's initial ideas (Cross, 2001; Sachs, 1999). Crismond and Adams (2012) compare novice to expert designers whereby expert designers *"practice idea fluency in order to work with lots of ideas by doing divergent thinking, brainstorming, etc."* in comparison to novice designers who *"work with few or just one idea, which they can get fixated or stuck on, and may not want to discard, add to, or revise"*. In contrast, if expert designers are more prone to fixation than novices (Kim &

Ryu, 2014) it may suggest that experts stick to their early ideas because they perceive it as leading to great designs. Rowe (1987) highlighted that students' ideas are often minor variations on the same idea. Novice engineering designers also appear to have a sense of attachment to early solution ideas, and hang onto ideas even when they realize they may be extremely problematic or have major flaws (Leahy et al,2018).

The discoveries in the starting section of the search, which was the source of the fixation formation factors in the designing process, indicates that in each step of the consisting, including problem finding, ideation (creating solutions), and also their evaluation, which factors are most plausible to result in the discussed phenomenon. In the next section, the correlation between the designers' prior knowledge in terms of vastness or their field or fields of expertise, was presented via a table.

In this section, according to table 3, as a summary of the last two sections and in continuation of the previous subjects, the fixation formation factors in the design process will be presented based on the designer's level of expertise.

Table 3

The fixation formation factors in the design process According to designer's level of expertise (Authors)

professional	**novice**	
- Staying in issues of the past due to the formation of a personal view (personal or group aspiration) that prevents the discovery of new problems	- Addressing issues known to others (Lack of effort or ability to find a new issue) - Prioritizing issues based on introduced priorities - Framing issues with known methods	Problem domain
- Utilizing experienced solutions due to the skill in using them - Commitment to design patterns(or principles) defined and developed by the designer - Using experienced and approved solutions (by employer or public taste) due to low risk	- Utilizing experienced solutions due to the inability to create new solutions - Limited knowledge range (specialized and non-specialized) to use deductively - The inability to discover correlation in information (both in specialization fields and in relation to information outside the specialization fields) - Staying in the initial solution (the first idea) due to an inability to have divergent thinking (for example: brainstorming , …)	Solution domain
- Prioritizing non-qualitative criteria (Such as economy, executability, and …)	- Applying previous evaluation criteria	Evaluation domain

6. Conclusion

By exploring the theories and models that have attempted to describe the design process and explain the distinct steps in it, three main steps (problem identification, solution generation, evaluation) have been identified in the design process, which were a kind of intersection between the presented models. This research emphasizes on the fact that creativity and inevitably along with it, fixation, does not take place solely in the phases of ideation and solution generation, but occur in any of the three steps. The causes of fixation in these three steps were analyzed and identified in every step to see how the designer falls victim to this trap.

Although, it is worth noting that in the exploration of the models and maps of the design process, it was mentioned that the formation of fixation can be examined in each of these stages, whether carried out separately or simultaneously and co-evolving (as suggested by Dorst). Following, by examining the role of the designer's previous knowledge in the design process, a structure was presented showing in which steps during the design process, fixation may occur and what factors are effective in creating it in each of the stages. On the other hand, while investigating the effective factors in the designers level of expertise, it was concluded that the influence of previous knowledge differed depending on the different levels of expertise of designers and possessed different attributes. With the discovery of the effect of the variable of expertise as an intervening variable, ultimately, a structure was presented on the formation of fixations in each of the design stages – depending on the designers level of expertise – which indicated that the phenomenon of fixation may occur at every level of design expertise or proficiency, and that how and under what influences this phenomenon may occur in each stage of the design process.

Referencing this structure, professional designers manage to overcome the fixation or mitigate it, with knowledge of its factors and avoiding them. Also, the design teachers, by considering the students' competence level, will be able to spread the necessary awareness and to prevent them from falling into the traps of fixation.

References

Agogué, Marine; Kazakçı, Akın; Hatchuel, Armand; Le Masson, Pascal; Weil, Benoit et al.. (2014). The impacts of examples on creative design : explaining fixation and stimulation effects. Journal of Creative Behavior, Creative Education Foundation, 2014, 48 (1), pp.1-12. hal-00707354

Alipour, Leyla (2021) . The Relation between Design Expertise and the Quality of Design Idea, Int. J. Architect. Eng. Urban Plan, 31(1): 1-11 January 2021 ,DOI: 10.22068/ijaup.31.1.585

Ansari, Hamidreza (2009) 'Generators and Processors in Architecture Design Process' , Honar-Ha-Ye-Ziba Memari-Va-Shahrsazi,39: 5-14 .

Asimov, M. (1962). Introduction to design . Englewood Cliffs, NJ: Prentice-Hall.

Ball, L. J., Ormerod, T. C., and Morley, N. J. (2004) 'Spontaneous Analogising in Engineering Design: A Comparative Analysis of Experts and Novices' ,Des. Stud., 25_5 : 495–508.

Boling, E. (2020) 'The Nature and Use of Precedent in Designing' ,In J. K. McDonald & R. E. West, *Design for Learning: Principles, Processes, and Praxis*. EdTech Books. Retrieved from https://edtechbooks.org/id/precedent

Bonnardel, N., & Marmèche, E. (2004) 'Evocation processes by novice and expert designers: Towards stimulating analogical thinking' ,Creativity and Innovation Management, 13(3): 176-186.

Bonnardel, Nathalie ; Wojtczuk, Alicja ; Gilles, Pierre-Yves and Mazon, Sylvain. (2017) 'The creative process in design' ,The Creative Process: Perspectives from multiple domains, 2017. hal-01778728

Camarda, Anaëlle; Ezzat, Hicham; Cassotti, Mathieu; Agogué, Marine; Weil, Benoit and Le Masson , Pascal (2017). 'The role of Expertise in Design Fixation: Managerial Implications for Creative Leadership' . The 24th Innovation and Product Development Management Conference, Jun 2017, Reykjavik, Iceland.

Casakin, Hernan ; Goldschmidt, Gabriela (1999) 'Expertise and the use of visual analogy: implications for design education' ,Design Studies,Volume 20, Issue 2,1999,Pages 153-175

Condoor, Sridhar ; LaVoie , Donna (2007) 'Design Fixation: A Cogntive Model' International Conference On Engineering Design, ICED'07, 28 - 31 AUGUST 2007, Cite Des Sciences Et De L'industrie, Paris, France

Creeger, Samantha (2019) 'Design problem exploration' Graduate Theses and Dissertations, Iowa State University Capstones

Crilly, N., & Cardoso, C. (2016) 'Where next for research on fixation, inspiration and creativity in design ?' , Findings from an international workshop. Design Studies, 50: 1–38.

Dorst, C. H. (2003). The problem of design problems. In E. Edmonds, & N. G. Cross (Eds.), Expertise in Design, Design Thinking Research Symposium 6 Creativity and Cognition Studios Press.

Dubberly , hugh (2004). How do you design? A compendium of models .dubberly design office,2501 harrison street, san Francisco,CA

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). Creative cognition: Theory, research and application. Cambridge: MIT Press.

HOWARD, Thomas J. ; MAIER, Anja M. ; ONARHEIM, Balder and Friis-Olivarius, Morten (2013) 'Overcoming Design Fixation Through Education And Creativity Methods' , International Conference On Engineering Design, ICED13:19-22 AUGUST 2013, SUNGKYUNKWAN UNIVERSITY, SEOUL, KOREA

Hui, Qian; Li , Yan ; Tao ,Ye and Liu, Hongwei (2020) 'Triple‑Helix Structured Model Based on Problem‑Knowledge‑Solution Co‑evolution for Innovative Product Design Process' , Chinese Journal of Mechanical Engineering, 33:94 . https://doi.org/10.1186/s10033-020-00519-2

Jansson, D.G. and Smith, S.M. (١٩٩١) 'Design fixation' , Design Studies, 12(1), 1991 : 3-11.

Lawson, Bryan (2005) 'How Designers Think ; The Design Process Demystified' , (4th ed.). Routledge. https://doi.org/10.4324/9780080454979

Leahy, Keelin ; Seifert, Colleen M. ; Daly, Shanna and McKilligan, Seda (2018) 'Overcoming Design Fixation in Idea Generation' , Industrial Design Conference Presentations, Posters and Proceedings. 15

Linsey, J. S. ; Tseng, I. ; Fu, K. ; Cagan, J. ; Wood, K. L. and Schunn , C. (2010) 'A Study of Design Fixation, Its Mitigation and Perception in Engineering Design Faculty' , Journal of Mechanical Design, APRIL 2010, Vol. 132 / 041003-1

Mcdermott, J. (1981) 'Domain knowledge and the design process' , 18th Design automation conference : 580-588.

Moreno, Diana P. ; Hernández, Alberto A. ; Yang,Maria C. ; Linsey, Julie S. and Wood, Kristin L. (2014) 'A Step Beyond To Overcome Design Fixation: A Design By Analogy Approach' , Design Computing and Cognition DCC'14. J.S. Gero (ed), © Springer 2014

Ommi, Amirali ; Zeng,Yong and C. Marsden ,Catharine (2017) 'Design Problem Perception In Engineering Design Teams' , CEEA17; Paper 119 University of Toronto; June 4 -7

Reiter-Palmon, Roni and Robinson, Erika J. (2009) Problem identification and construction: What do we know, what is the future?, Psychology Faculty Publications. 28.

Rubenstein, Lisa DaVia ; Callan, Gregory L. ; Neumeister, Kristie Speirs ; Ridgley, Lisa M. and Finch, Maria Hernandez (2020) How problem identification strategies influence creativity outcomes , Contemporary Educational Psychology 60 (2020) 101840

Sio, Ut Na; Kotovsky, Kenneth and Cagan, Jonathan (2015). Fixation or inspiration? A meta-analytic review of the role of examples on design processes, Design Studies, Volume 39, 2015, Pages 70-99, ISSN 0142-694X, https://doi.org/10.1016/j.destud.2015.04.004.

Schut, A., Klapwijk, R., Gielen, M., van Doorn, F., & de Vries, M. (2019) 'Uncovering early indicators of fixation during the concept development stage of children's design processes' , International Journal of Technology and Design Education, 30(5) :951-972. https://doi.org/10.1007/s10798-019-09528-2

UYSAL ÜREY, Z.C. (2019) 'The Cognitive Use of Prior Knowledge in Design Cognition: The Role of Types and Precedents in Architectural Design' , Journal of

Contemporary Urban Affairs, 3(3) : 39-50. https://doi.org/10.25034/ijcua.2019.v3n3-4

Vasconcelos, Luis A. ; Crilly Nathan (2016) 'Inspiration and fixation: Questions, methods, findings and challenges, Design Studies' . Volume 42 : 1-32, ISSN 0142-694X . https://doi.org/10.1016/j.destud.2015.11.001. (https://www.sciencedirect.com/science/article/pii/S0142694X15000940)

Viswanathan, Vimal and Linsey, Julie (2011). UNDERSTANDING FIXATION: STUDY ON THE ROLE OF EXPERTISE . ICED 11 - 18th International Conference on Engineering Design - Impacting Society Through Engineering Design.7.

Vries, de, A. E. (1990). Problem solving in design : a comparison of three theories. (OCTO-report; Vol. 9003). Eindhoven University of Technology.

Youmans, R., & Arciszewski, T. (2014) 'Design fixation: Classifications and modern methods of Prevention', Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 28(2): 129-137.