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SITUATED CREATIVITY INSPIRED IN PARAMETRIC DESIGN ENVIRONMENTS

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Abstract: Current literature shows that there is a lack of empirical evidence support the understanding of design creativity in parametric design environments (PDEs). Situated creativity which regards the changing context of design environment has been suggested to be an index for design novelty and unexpected discoveries. In PDEs, the nature of its dynamic design process expresses frequent change of design situation, which is potentially beneficial for evoking situated creativity. Aiming to explore situated creativity inspired in PDEs, this study proposes a theoretical framework based on Gero's FBS model in which the method of protocol analysis is adopted. Furthermore, a pilot study involves two students in a design experiment has been conducted to test the framework. In the end, several preliminary results regarding the relationship between situated creativity and parametric design processes have been developed.

Keywords: *situated creativity, parametric design, FBS model*

1. Introduction

Parametric design is increasingly popular in the architectural design industry recent years. In parametric design environments (PDEs), by changing parameters, particular instances can be altered or created from a potentially infinite range of possibilities (Kolarevic, 2003). But will these possibilities inspire design creativity? Previous studies on design creativity in PDEs show that parametric tools advance design processes in a variety of ways (Iordanova, Tidafi, Guité, De Paoli, & Lachapelle, 2009; Schnabel, 2007). However, the relationship between design creativity and PDEs remains controversial. Analysis of literature shows that there is a lack of empirical evidence supporting the understanding of creativity inspired in PDEs.

Situated creativity which regards the changing context of design environment is described as an index of design novelty (Tang & Gero, 2001) and making unexpected discoveries(Suwa, Purcell, & Gero, 1999). Gero (1998) defines design situation as "where you are when you do what you do matters", which means designers cognition behaviour during design process is affected by their interaction with design environments and responds to the changing design situation. Parametric design is a rule-based, dynamic design process controlled by variations and constraints. Therefore, we are wondering whether designers' situated creativity is evoked by the dynamic characteristic of parametric design. Aiming to explore this issue, this study proposes a theoretical framework based on Gero's FBS model (Gero, 1990) in which the method of protocol analysis is adopted. Furthermore, a pilot study involves two students in a design experiment has been conducted to test the framework. In the end, several preliminary results regarding the relationship between situated creativity and parametric design processes have been developed.

2. Background

2.1. Protocol analysis of parametric design

Parametric design is a new digital design method increasingly applied in architecture, and characterised by parametric relationship control, rule algorithm design and multiple solution generation (Karle & Kelly, 2011). Previous studies on designers' behaviours in PDEs show that parametric tools advance design creativity in a variety of ways: for instance, evidence indicates that the generation of ideas is positively influenced in PDEs (Iordanova, et al., 2009); Schnabel (2007) shows that PDEs are beneficial for generating unpredicted events and can be responsible for accommodating changes. However, researchers have typically studied design behaviour in PDEs mostly by observing students interactions with PDEs in design studios or workshops. Arguably, this approach can hardly provide an in-depth understanding of designers' behaviours in PDEs. This empirical gap will be addressed in the present study by adopting the method of protocol analysis.

Protocol analysis is a method widely used for cognitive studies into designers' behaviour during design processes (Cross, Dorst, & Christiaans, 1996; Ericsson & Simon, 1980). It has been applied across a variety of design environments (Kan & Gero, 2009; Kim & Maher, 2008). The general procedure of protocol analysis is that the protocol data (in this case, the video-recorded information of designers' behaviour) collected from the experiment is transcribed and segmented; a customized coding scheme is then applied to categorise segments. In the following section, we will introduce the function-behaviour-structure (FBS) model (Gero & Kannengiesser, 2004) to create a customised coding scheme, where the characteristics of parametric design are reflected.

2.2. Situated creativity

Generally speaking, creativity is to generate or produce something that did not exist or was not known before (Gero, 1990). Creativity expressed in design processes is a complex issue. One of the idea proposed by Clancy (1997) is design situatedness which means designers' concept is affected by the changing design context--- includes what designers "see" and their interpretation of design situation. Moreover, design situatedness includes a concept of constructive memory (Dewey, 1896). It claims that memory in a design process is constructed in responds to the current design needs, and keeps adding to existing knowledge or experiences. Tang and Gero defined situated creativity as design novelty provoked from design situation and design situatedness (Tang & Gero, 2001). They proposed a method of using protocol analysis to study designers' situatedness creativity in sketch environments, the results shows that expert designers have statistically more novelty of design situatedness than the novice in the perceptual, functional and conceptual levels. Some other studies suggest that designers use sketches as a basis for reinterpreting what had been draw, and their concept changes are influenced by the change with design environment (Schon & Wiggins, 1992).

Based on Tang and Gero's (2001) definition of situated creativity and Clancy's (1997) concept of design situatedness, in this study situated creativity is defined as new varieties and unexpected discoveries inspired by the changing design situation during design process (the scope is within the context of a single design process rather than considering the influence of other social context).

2.3. Situated creativity in PDEs

Design media or environment is absolutely related to creativity (Mitchell, 2003). By changing parameters or switching between geometry modelling and rule algorithm interface, design context is changing frequently in PDEs. This dynamic characteristic of parametric design presents its unexpectedness, uncertainty and changeability feature, which is potentially beneficial for changing of design situation and evoking situated creativity. Therefore, the relationship between situated creativity and characteristic of parametric design needs to be explored.

3. Theoretical framework development

In this study, Gero's FBS model (1990) is introduced as the foundation for theoretical framework development. Since publication, FBS model has been applied to a variety of studies on designers' behaviour. Later, Gero & Kannengiesser (2004) further developed the FBS model into a situated FBS ontology by introducing interaction in three worlds : the external world, interpreted world and expected world. Although the situated FBS model are claimed to be able to capture more meaningful design processes (Kan & Gero, 2009), in this study, we still adopt the original FBS model for the following reasons: Firstly, this study focuses on the reformulation processes where situated creativity is supposed to be expressed. Reformulation processes have already been clearly demonstrated in the original FBS model; therefore, it is not necessary to apply the more complex situated FBS model. Secondly, the 10 variables of situated FBS model (5 variables in original FBS model) as coding scheme would be too detailed for a 40 minutes conceptual design.

3.1. Reformulation processes

Among the eight design processes indicated in FBS model (Figure 1), three reformulation processes are suggested to be the dominant process where situatedness is expressed (Gero, 1998). Reformulation process means transition from structure back to function, expected behaviour and structure, which indicates generation of design intention based on structure related consideration. Evidence show that reformulation processes can potentially lead to creative results by introducing new variables or a new direction (Kan & Gero, 2008).

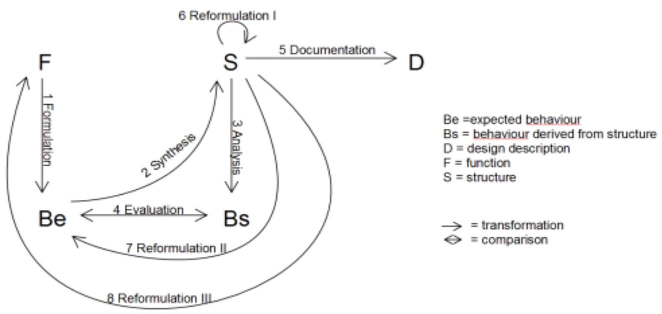

Figure 1. FBS model (Gero & Kannengiesser, 2004)

In PDEs, besides thinking from the perspective of design knowledge, designers also consider from the aspect of rule algorithm. At the rule algorithm level, designers think about the way to make use of parametric tools to serve their design concept. For instance, they will consider the establishment of parametric relationship, the selection of component to achieve certain purpose, etc. Furthermore, there is reformulation process exist at the rule algorithm level as well: the reformulation of rule algorithm reconstructs the relationship of the parametric logic and introduces new variables into the rule relationship. Figure 2 is a theoretical framework for exploring situated creativity in PDEs. This framework interprets situated creativity mainly from three reformulation processes. Each of the reformulation process is represented by new variables and old instance respectively from perspective of structure, behaviour and function, which provided basis for coding scheme development.

1. Reformulation 1 process: reformulation of the design state space in terms of structure or introduction of structure variables. Empirical studies shows that the reformulation of structure is the predominant type of reformulation process (McNeill, Gero, & Warren, 1998). In PDEs, reformulation of structure variables includes: new variables of new structure elements, new parametric relationship and new parameters; old instance includes changing of geometric elements, parameters and parametric relationship.
2. Reformulation 2 process: reformulation of the design state space in terms of behaviour or introduction of behaviour variables. In PDEs, reformulation of expected behaviour variables includes: new variables of intention for achieve certain design knowledge or rule related purpose; old instance includes changing of constraints, change of rule related intention, etc.
3. Reformulation 3 process: reformulation of design state space in terms of function variables or introduction of function variables. This process has potential to change the expected behaviours and structure, however, it rarely happens. In PDEs, reformulation of function includes: new variable of function intention and interpretation of requirement; old instance includes revisiting the design brief.

3.2. Unexpected discoveries

With the changing design context, unexpected discovery as essence of situated creativity (Suwa, et al., 1999) also needs to be explored. Parametric design are suggested to be beneficial for generating unexpected events and accommodate for constant changing (Schnabel, 2007). Unexpected discoveries happen mostly from the introduction of new variables, and these new variables sometimes depend on old revisit instance. For instance, Suwa & Purcell (1999) describe unexpected discovery as a "new" perceptual actions that has a dependency on "old" physical actions. Similarly, in this study, we define unexpected discoveries as a "new" behaviour intention depends on an "old" structure action. Another aspect helps us understand the situated creativity is constructive memory, which is mainly based on old instance. Figure 2 indicates the location of unexpected discovery and constructive memory as well.

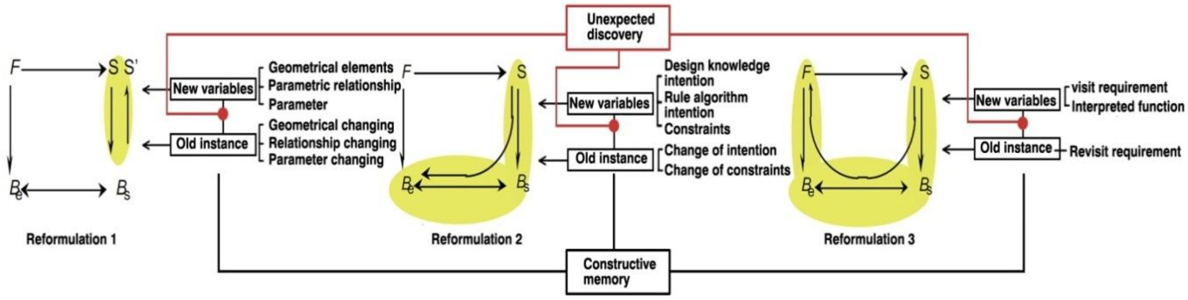

Figure 2. Theoretical framework for exploring situated creativity in PDEs (After Gero's FBS model)

4. A pilot study

4.1. Experiment setting

Aiming to test the theoretical framework, this study proposed to use protocol analysis to explore situated creativity in PDEs. In devising an experiment to collect protocol data from PDEs, 2 students are involved to complete a design task using commercial parametric design software (Grasshopper in this study) in 60 minutes. Each of participants, all master of architecture students, has had at least two years of parametric design experience. The expectation is that some typical design behaviour patterns which may inspire situated creativity in PDEs will be identified.

The experiment environment is a computer, a pen and paper, with two video cameras. The design task is to generate a conceptual form for the tower part of a high-rise building. During the design process, both "think aloud" and "retrospective method" are applied to collect protocol data. Designers' verbalization and design actions are video-recorded for later use as protocol data. Generally, the two students show a good ability of manipulates forms in Grasshopper as well as representing the advantages of parametric design. The main modelling time is respective 36 minutes and 49 minutes.

4.2. Protocol analysis

For the pilot study of the two students, we use a customised coding scheme developed based on FBS model to code cognitive behaviour of the designers. The segmentation is according to semantic meaning in terms of function, behaviour and structure. There are respectively 199 and 174 segments from the two protocol data, and over 80% of the meaningful design processes can be coded. The coding scheme is developed based on Gero's FBS model (Gero & Kannengiesser, 2004) where characteristic of parametric design are reflected. The main category is function-behaviour-structure, and each category is divided into design knowledge based level and rule-algorithm based level (as shown in table 1).

Table 1. Coding scheme

Category	Sub-category	Name	ID	Description
Function (F)	Design knowledge	Requirement-old	F-D-Ro	Considering or revisiting the requirement
		Requirement-new	F-D-Rn	Read design brief
		Interpret function-new	F-D-In	Initial definition or interpretation of function
Structural Behaviour (Bs)	Design knowledge	Intention-new	Bs-K-In	behaviour interpreted from structures
		Perceptual-Old	Bs-K -Po	Revisit model
		Perceptual-New	Bs-K -Pn	First attention to model
	Rule algorithm	Intention-new	Bs-R-In	Attention of existed rule
Expected behaviour (Be)	Design knowledge	Intention-New	Be-K-In	Interpret expected behaviour from design knowledge
		Constraints-new	Be -K-Cn	Setting constraints
		Constraints change-old	Be-K-Co	Changing constraints
	Rule algorithm	Intention-new	Be-R-In	Interpret expected behaviour form rule making
Structure	Design	Intention-New	S-K -In	Expected structure, including geometry

(S)	knowledge			element making
		Geometry change-old	S-K-Go	Changing geometry
	Rule algorithm	Intention-new	S-R-In	Define components used to generate element
		Parameter -New	S-R-Pn	Setting parameters
		Parameter change-old	S-R-Po	Changing parameters
		Relationship-New	S-R-Rn	Setting parametric relationship
		Relationship change-old	S-R-Ro	Changing parametric relationship

4.3. Results

1. In order to better understand the relationship between "old" instances, "new" variables and situated creativity, four types of transitions are proposed as shown in table 2. "New" means the first time a design instance appeared, while "Old" means a design instance appeared after the first time. During design process, it is very likely that a "new" intention is inspired by an "old" instance. That is also an interesting process potentially introducing new variables and reconstructing design problems.

Table 2. Four type of transition

Type	Name	Example
Type1	New to New	Be-K-In> S-K -In
Type2	New to Old	S-K –In> S-R-Po
Type3	Old to New	Bs-K–Po> S-R-Pn
Type4	Old to Old	Bs-K –Po >S-R-Po

Although reformulation processes have been suggested to have more possibilities of introducing new variables and indicate situated creativity in sketch and traditional CAD environment (Gero, 1998), there is a lack of empirical evidence to support the role of reformulation processes in PDEs in terms of situated creativity. Figure 3 & 4 illustrate the percentage of eight design processes in FBS model in terms of the four transitions types between new intentions and old instances (see table 2). The vertical axis represents the percentage of the eight design processes occupied in total design processes. What we want to find out is the differences of reformulation processes allocated in the four transition types. Protocol data analysis shows that both of the two students have exhibited more reformulation processes (sum of reformulation1, 2 and 3) in type1 and type 3 transitions than in type 2 and 4 transitions. In type 1 and type 3 transitions, new variables are introduced. Therefore we believe that reformulation processes in PDEs also indicate the introduction of new variables and potentially provoke situated creativity.

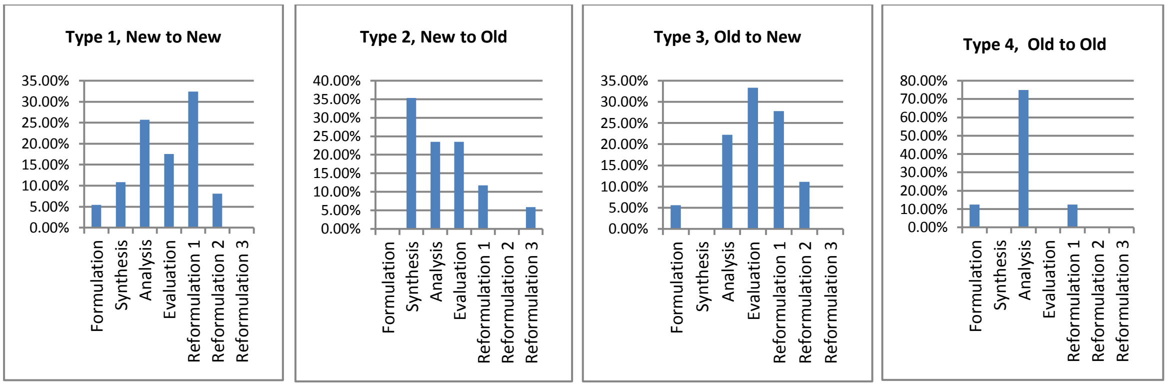

Figure 3. Four types of design process of student 1

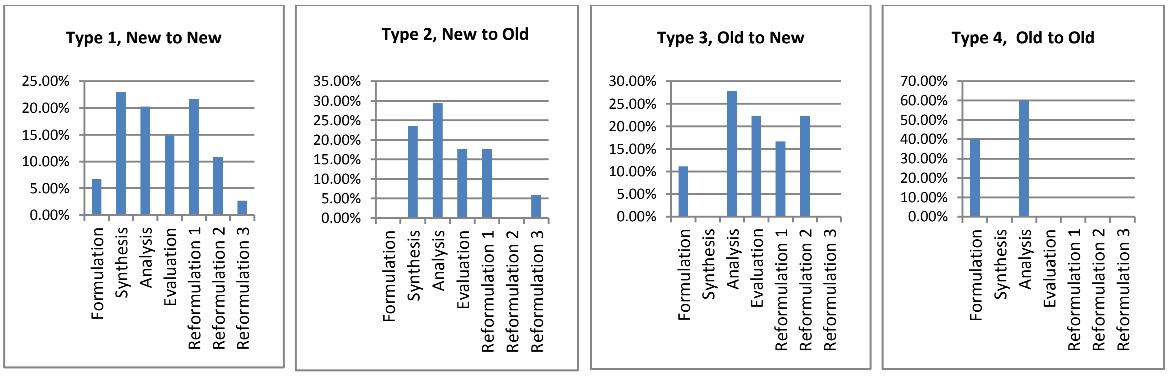

Figure 4. Four types of design process of student 2

2. Figure 5 and 6 illustrates the distribution of reformulation processes and unexpected discoveries along the whole design process. The vertical axis represents the percentage of reformulation processes occupied in the eight design process and the percentage of unexpected discoveries transitions in all the four types of transitions. The horizontal axis represents the design time: For student 1, we calculate the coding every three minutes, so that the max number of horizontal axis 12 means 36 minutes. Student 2 spent 49 minutes on the main model, so we calculate every 4 minutes--because we count percentage, it doesn't matter for the different division of time. What we would like to know is the relationship between the unexpected discovery and reformulation processes, as well as their distribution along the whole design process. As shown in Figure 5 and 6, the two students both have three reformulation processes during the whole design process. The same as previous studies in sketch and CAD environments (McNeill, et al., 1998), reformulation 1 in PDEs is the predominant reformulation type. However, compared to sketch environment in which reformulation 2 diminished during design process, reformulation 2 distributed averagely during parametric design processes. That might because there are more activities on perceptual and evaluation in PDEs due to the changing design context. The unexpected discovery in this study is defined as a "new" behaviour intention depends on an "old" structure action. Figure 5 and 6 shows that the unexpected discovery distribution during design process is very similar with the reformulation processes. That means reformulation processes are beneficial for inspiring unexpected discovery in PDEs. From detail coding, the most likely happens unexpected discovery pattern is S-R-Po> Bs-K-In. This pattern means

unexpected discoveries usually happens when designers change a parameter and then evaluating whether the change is appropriate from design knowledge perspective.

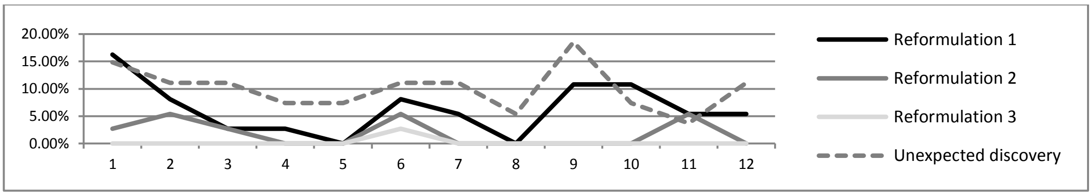

Figure 5. Reformulation processes of student 1

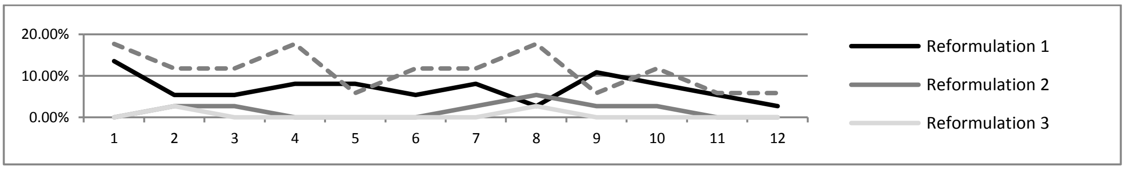

Figure 6. Reformulation processes of student 2

3. Designers' thinking shifts between design knowledge and rule algorithm level during the whole design processes. Figure 7-9 demonstrates distribution of these two levels in reformulation processes. Vertical axis represents the percentage of coding in the two levels in reformulation processes. Horizontal axis represents design time which is the same as Figure 5 & 6. Figure 7 shows that in reformulation 1 process, both of the two students consider rule-algorithm level more than design knowledge level. Moreover, in the end of the design session, rule algorithm thinking is rising. Figure 8 shows that in the reformulation 2 processes, the percentage of rule algorithm and design knowledge is almost similar. Additionally, there is relatively little reformulation 3 happens (figure 9).

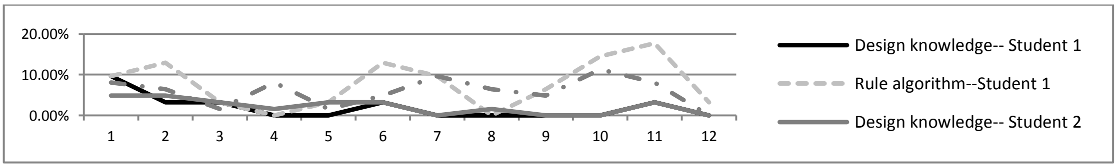

Figure 7. Two design levels in Reformulation 1 processes

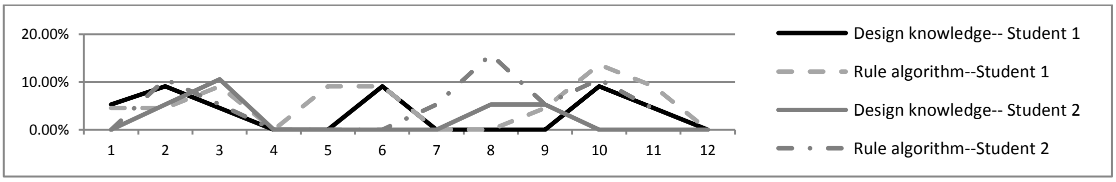

Figure 8. Two design levels in Reformulation 2 processes

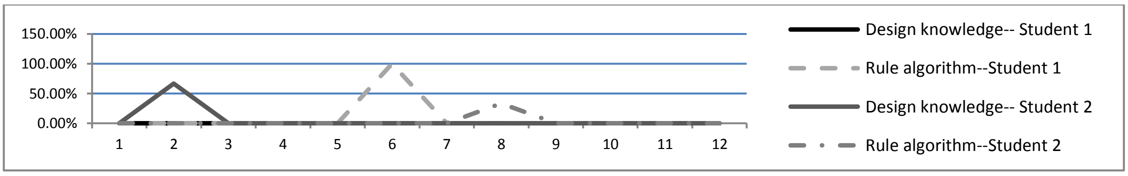

Figure 9. Two design levels in Reformulation 3 processes

5. Conclusion and future work

This study proposes a theoretical framework for exploring situated creativity in PDEs. To test the framework, some preliminary results from a pilot study show that:

- Reformulation processes plays dominant role in introducing new varieties and potentially inspire situated creativity in PDEs;
- Reformulation processes are beneficial for inspiring unexpected discovery in PDEs. Among the three reformulation processes, the predominant type is reformulation 1. In addition, the most likely happened pattern of unexpected discovery is evaluating from design knowledge perspective which have a dependency on parameter changing.
- Design knowledge thinking and rule algorithm thinking transfer during the whole design process. The rule algorithm activities in PDEs have significant impact on reformulation 1 process. Additionally, there are relatively little reformulation 3 process happens.

The next stage of this study is to conduct a main study with a larger number of designers in order to identify designers' behavior patterns in terms of situated creativity. In the main study, we will compare designers' behavior in PDEs with traditional modeling environments to further explore the role of parametric design plays in evoking situated creativity. Results of the main study will help to test the validity of the theoretical framework and explore factors inspire situated creativity during parametric design process.

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