An exercise on a sustainable design aspiration with the situated FBS ontology of designing

Riva Tomasowa
Architecture Department, Faculty of Engineering, Bina Nusantara University
Jakarta, Indonesia 11480

Corresponding author’s email: rivatomasowa@binus.ac.id

Abstract. The paper elaborates John Gero and Udo Kannengiesser’s model of designing (situated FBS), which illustrates the process of cognition in designing. In the series of their papers, several examples are built to explain each stage that occurs. This paper contributes to providing another exemplary, explaining the process of cognition in situated FBS. The dry run analysis is used to explore all the stages that occur in the development, with case examples in designing sustainable architecture. The discussion maps an instance of developing ideas with sustainable aspects that include eight processes from situated FBS. This map focuses on the continuity of the processes and their translation. The continuity of existing operations requires several bridging methods, most of which are formed by constructive memories. In order to increase awareness of sustainable design, basic knowledge, design vocabularies, and design success stories that are collected into constructive memory play a significant role in achieving design requirements.

Keywords: designing, design model, design process, sustainable design, situated FBS

1. Introduction
Since 1990, the FBS model has tried to explain the phenomena of design cognition, although obstacles and limitations have emerged in the initial model. A barrier that is understood is the problem when the cognitive activity occurs, and where the event works. Situated FBS is a proposed model of the theory of design developed by John Gero and his colleagues. This design theory aims to explain the similarity of design patterns in a broad sense. From this broadening of understanding, there are more specific design state spaces in situated-FBS.

Several series of John Gero and Udo Kannengiesser's publications explain how the model works and recognize. In those articles, designing windows on a façade [1] and designing a turbocharger [2] were used as examples. However, the cases mainly used to define the 20 processes that grouped in eight states. Several gaps founded in the run require further explanation, how the information passed each state.

This article describes 35 continuous processes of a series of design cognition in the situated FBS model. The discussion identifies each change in the design state space according to its characteristics. Subsequently, it is making it easier for researchers to coding each process and covers the introduction of the developed situated-FBS model in the following section. Afterward, it describes the design
scenario context to initiates the dry run analysis, which further explained in Section 4. The remain section discusses the elaborated process and the findings.

2. Situated FBS Framework
The introduction of design prototypes [3] initiates the FBS categorization. It states that the function (F) is a group of cognitive activities classified as purpose (teleological). Then behavior (B) is a category for attributes that support the purpose of designing. Lastly is the structure (S), which is a development of attributes, in the form of interconnected components. In a further development, the FBS model addresses problems in the design process, which cannot explain when and where the cognition transpires. Previous design model theories can only describe what happens in a single world context.

Figure 1. The situated FBS framework with 20 processes [2].

In recognizing design cognition, the situated-FBS model has three main focuses: what is the design content, how the content translates, and when translation happens. Those three concerns answer the incapability of other design cognition models. As a consequent, the situated-FBS model expands into three distinct environments (external world, interpreted world, and expected world) and three linked interaction processes (interpretation, focussing, and action) [4] shown in figure 1b. Furthermore, the interaction processes are elaborated into the push-pull process (interpretation), and comparison, focussing (focussing), also transformation (action), as shown in Figure 1a. Overall, the established model, now has 12 design state spaces, three worlds, and 20 distinct processes that are group into eight FBS framework processes. The characterization – such as interaction classes, process types, and starting-ending locus, separates those processes. Read Gero and his colleagues’ function-behaviour-structure publication for complete explanations as well as the book [5].

3. Designing Scenario
The scope of this research is to explain the workflow of design cognition in linear mode. Therefore, the design scenario’s dry run analysis is running with three conditions that must be satisfied, which are:

1. all the 20 situated-FBS processes are covered;
2. all the operations are linked continuously without any focus shift. The interaction types like interpretation (push-pull process) and focussing (focussing or comparison) can start a process from each end, while a transformation (action) type only formulates forward; and

3. the dry run will terminate after the Reformulation type III ended (even though this is not indicating a completed design process).

Accordingly, those provisions guide this analysis planned into these 35 linear steps, as follow:

![Diagram of Situated-FBS workflow](image)

**Figure 2.** Situated-FBS workflow.

Additionally, examining the design process needs context as requirements from outside the designer environment. The context for this example describes the case of the early design phase of a residential building in the tropics. There are several external requirements (either in the form of FR, BR, or SR), namely client demands, site characteristics, and space requirements. The following case examples are complex but can explain the purpose of this presentation. The following section explains a further elaboration of this setting.

4. **Mapping of the Designing Processes**

4.1. **Formulation**
The first process classification is formulation, which consists of processes 1-10, as shown in figure 2. This formulation divided into four groups, 3 of which can occur simultaneously or quickly.

The first group is running processes 1, 2, and 3 that explicitly describe the design problem; only the last two processes are optional. The interaction class of those processes is the interpretation, which is characterized by a cognitive movement that starts from the external world to the interpreted world. The type of process that occurs is a push-pull, which has direction back and forth, and can stop at one end, depending on the driver of a stronger process between expectation or data [6].
Process 1 – Requirement to Interpreted Function (FR \( \cup \) F): a process built by the purpose translate into qualitative objectives, definitions, and functions of the external world. Process 2 – Requirements to Interpreted Behavior (BR \( \cup \) B): a process of parsing the attributes, abstraction, properties, parameters, or statements. Process 3 – Requirement to Interpreted Structure (SR \( \cup \) S): built by the description of components, entities, dimensions, arguments, and variables related to each other to form a detailed description. Table 1 shows their detail description.

Table 1. Example of Formulation (1st group).

|   | (FR) | Client requirement: achieve indoor comfort | \( \cup \) | (F) | Enhancing ventilation, controlling noise, providing daylight |
|---|------|------------------------------------------|---|---|----------------------------------------------------------|
| 2 | (BR) | Challenges on the site: wind speed, sound buffer, solar radiation, and daylight transmission | \( \cup \) | (B) | Ideal air changes, sound reverberation, dry bulb temperature, lumens |
| 3 | (SR) | Theoretical approaches: building form, orientation, fenestration | \( \cup \) | (S) | Glazing area and position, types of opening, buffer materials |

The second group is the movement process of the first group that produces constructive memory [7]; they are processes 4, 5, and 6. These processes include multiple interactions classes – interpretation and focus. They caused by the process that occurs in the same design state-space at the interpreted world but also supported by interpretations from the external world and the focus of the expected world. Those processes are collecting information from storage (past constructive memory). Each can consist of past design experience or common knowledge [1, 7], which will conclude new in-depth purposes, attributes, and components.

Process 4 – Interpreted Function to Interpreted Function (F \( \uparrow \) F): describe as a process of finding and adding new goals, in the previous process 1. Process 5 – Interpreted Behaviour to Interpreted Behaviour (B \( \uparrow \) B): describes as a process that adds and develops attributes from previous conditions (process 2). Process 6 – Interpreted Structure to Interpreted Structure (S \( \uparrow \) S): describes as a process that adds new related components, which support the design goal. The following table (Table 2) provides examples of the processes.

Table 2. Example of Formulation (2nd group).

|   | (F) | Enhancing ventilation, controlling noise, providing daylight | \( \cup \) | (F) | Optimum cross ventilation for the living room, facing a low noise backyard with a wide opening for breeze and daylight |
|---|------|----------------------------------------------------------|---|---|----------------------------------------------------------|
| 5 | (B) | Ideal air changes, sound reverberation, dry bulb temperature, lumens | \( \cup \) | (B) | Minimizing sun exposure, cooling down the North and the West area, optimizing the indirect daylight on the openings |
| 6 | (S) | Glazing area and position, types of opening, buffer materials | \( \cup \) | (S) | Vegetation as the buffer, threshold space between outdoor and indoor, use swing or sliding windows |

The third group is the priority sorting process (processes 7, 8, and 9 - Fig. 2) to focus on a subset, which class of interaction and type of process called focussing. This process takes place from the interpreted world, leading to the expected world, which may stop at either end (back and forth). Though, unlike push-pull process types, this process is more selective than loading content.

Process 7 – Interpreted Function to Expected Function (F \( \leftrightarrow \) Fe): running the process that focuses on the chosen subset of goals (process 4) for further exploration. Process 8 – Interpreted Function to Expected Behaviour (B \( \leftrightarrow \) Be): running the process that focuses on a subset of the process 5 attributes. Thus, the selected attribute initiated the derivation for the next stage. Process 9 – Interpreted Function to Expected Structure (S \( \leftrightarrow \) Se): running the process that focuses on a subset of the process 6 components. At this stage, the realization of the structure determined by several selected variables. Table 3 shown the elaboration of this third group of processes.
Table 3. Example of Formulation (3rd group).

| Group | Description | Equivalent |
|-------|-------------|------------|
| 7 (F^i) | Optimum cross ventilation for the living room, facing a low noise backyard with a wide opening for breeze and daylight | (Fe^i) Focusing on providing indirect daylight |
| 8 (B^i) | Minimizing sun exposure, cooling down the North and the West area, optimizing the indirect daylight on the openings | (Be^i) Focusing on indirect daylight for casual activity at the living room |
| 9 (S^i) | Vegetation as the buffer, threshold space between outdoor and indoor, use swing or sliding windows | (Se^i) Focusing on South orientation as it has the lowest radiation, and creating a setback before the opening as a threshold space |

The final group is the formulation that has action as the interaction class, which only moves in the expected world. The transformation type of process translates the function to the behaviour design state-space. **Process 10 - Expected Functions for Expected Behavior (Fe^i → Be^i):** is the process of changing selected goals, which are still relatively abstract (process 7). And then, associating them to the construction of attributes. The development of the expected behaviour is also supported by focused process 8. Thus, the designer now has his/her goal definition based on the range of his/her understanding (Table 4).

Table 4. Example of Formulation (4th group).

| Group | Description | Equivalent |
|-------|-------------|------------|
| 10 (Fe^i) | Focusing on providing indirect daylight | (Be^i) Including previous process 8 (Table 3); Newly defined: Quality of illumination: simple visual task; daylighting with low penetration of radiation |

4.2. Synthesis

Next, in the synthesis stage, the process is to re-measure the logical steps and their consequences so that they conveyed in the design structure. Therefore, the type of interaction that follows at this stage is the action class, in which all processes have a transformation type. This synthesis stage has two processes, namely: **Process 11 - Expected Behavior in the Expected Structure (Be^i → Se^i):** is a synthesis process that describes the design attributes of the previous state space (process 10) to have more concrete variables; **Process 12 - Expected Structure to Be an External Structure (Se^i → S^i):** is a synthesis process that converts a concrete variable (process 11) into a series of symbolic representations or icons. This stage is the process of producing preliminary artifacts.

Table 5. Example of Synthesis.

| Group | Description | Equivalent |
|-------|-------------|------------|
| 11 (Be^i) | Previously on process 8 and 10 (Table 3): Focusing on indirect daylight for casual activity at the living room; Quality of illumination: simple visual task; daylighting with low penetration of radiation | (Se^i) Including previous process 9 (Table 3); Directing on the mind: Full height and width opening facing the backyard; The roof overhang covers the opening, creating a porch; Reflected bright color flooring to pass the daylight |
| 12 (Se^i) | Including previous process 9 (Table 3); and Directing on the mind: Full height and width opening facing the backyard; The roof overhang covers the opening, creating a porch; Reflected bright color flooring to pass the daylight | (S^i) Sketching the site perimeter with North icon as a reminder of orientation; Figuring the building footprint on the site; Developing the sketch on the South area with the openings; Simulating the sun rays penetrating the interior; Annotating some progress on key developments, measurements, etc. |
4.3. Analysis
The subsequent stage is analysis, which continues to shape initial ideas. This stage is also divided into two processes by forming coordinated ideas, also rebuilding attributes that are incomplete or require comprehensive details. Process 13 and 14, respectively, categorized as interpretation (a push-pull process) and action (transformation) class type.

**Process 13 – External Structure to Interpreted Structure** ($S^e \triangleright S^i$): is the process of developing structure from a visual feedback structure (process 12) through interpretation that is immediately constructed by the designer by adding new relationships of known variables (process 9) and constructive memories (process 6). **Process 14 – Interpreted Structure to Interpreted Behaviour** ($S^i \rightarrow B^i$): is a process of transformation combining new attributes that emerged from expressed relationships in the development of the last artifacts (process 13), so that it retains established reasoning.

| Process | Description |
|---------|-------------|
| 13      | Sketching the site perimeter with North icon as a reminder of orientation; Figuring the building footprint on the site; Developing the sketch on the South area with the openings; Simulating the sun rays penetrating the interior; Annotating some progress on key developments, measurements, etc. |
| $\triangleright$ | Including previous process 9 (Table 3) and process 6 (Table 2); also Newly developed: The porch overhang requires a portal frame, which reduces the range of span; using trees to act as a canopy extension as well as buffer |

| Process | Description |
|---------|-------------|
| 14      | Including previous process 9 (Table 3) and process 6 (Table 2); also Newly developed: The porch overhang requires a portal frame, which reduces the range of span; using trees to act as a canopy extension as well as buffer |
| $\rightarrow$ | Including previous process 5 (Table 2) and Process 8 (Table 3); next Designed attributes: Light roof construction with significant sloping, reinforced portal frame structure, evergreen trees as shade, light-colored flooring |

4.4. Evaluation
Up to the evaluation stage, this process has a class of interaction in the form of focus, which connects the expected world with the interpreted world. The process is comparing the attributes between expectations and the current developments.

**Process 15 – Expected Behaviour to Interpreted Behaviour** ($B^e \leftrightarrow B^i$): is the stage for reviewing the initial expectations of a design indexed in the form of attributes (process 11), is it still relevant to the attributes that have been developed (process 14) to date. This evaluation produces selected attributes whose values support the achievement of design goals.

| Process | Description |
|---------|-------------|
| 15      | Including previous process 5 (Table 2) and Process 8 (Table 3); next Process 14: Light roof construction with significant sloping, reinforced portal frame structure, evergreen trees as shade, light-colored flooring |
| $\leftrightarrow$ | Including previously process 8 (Table 3) and process 10 (Table 4); |

| Process | Description |
|---------|-------------|
| 15      | Including previously process 8 (Table 3) and process 10 (Table 4); |
| $\leftrightarrow$ | Trees do not cover the eye level visualization (evaluating height); Roof cover with high resistance of heat (evaluating R-value); Useful daylight illuminance (evaluating lux); Space activity (evaluating area); Semi-reflective material and finish for walls and floors (evaluating light ray); Budget (evaluating cost) |
4.5. The Bridging Stages

There is a missing link when the results of the evaluation (process 15) are about to go through the documentation stage. As shown in Figure 3, the pattern is reiterating procedures from undertaken events earlier (process 7, 10, 11). However, the difference lies in the development of the Evaluation results (process 15 and 16), which filter out attributes that are no longer relevant for the next process (Table 8). This process has a similarity to Reformulation type 3, such as the combination of the formulation and synthesis processes. Arguably, this is a cognitive action to retrieve the previous developed constructive memories in order to respond to the current design situation.

Process 16 – Interpreted Behaviour to Interpreted Function (Bᵢ → Fᵢ): provides a new interpretation of interpreted functions, which are interpreted, from the appearance of reasoning about interpreted behavior in process 19.

![Figure 3. The missing link (the bridging stages).](image)

Table 8. Example of Bridging Stage (3rd group).

| 16 (Bᵢ) | Including previously process 8 (Table 3) process 10 (Table 4) and evaluation process 15 (Table 7) → (Fᵢ) New goals: affordable, simple construction |
|---|---|

4.6. Documentation

Documentation is a significant leap process from the Evaluation stage, which consists of three actions (process 12, 17, and 18). Moreover, all of them have a unidirectional transformation process, which brings design cognition from the expected world to the external world.

Process 12 – Expected Function to External Function (Seᵢ → Se): produces structured design components (which are also representations of symbolic or iconic artifacts); hence, they imply design solutions. Process 17 – Expected Behaviour to External Behaviour (Beᵢ → Be): produces a description of the design solution attributes that strengthen the configuration of an external structure (process 12). Process 18 – Expected Function to External Function (Feᵢ → Fe): produces a description of the design purpose, which starts from the initial goal definition (process 7), which supports the realization of the external structure (process 12).

Table 9. Example of Documentation.

| 12 (Seᵢ) | Including previous process 9 and 11 (Table 5); Emergent components form the bridging process: 3-meter span structural grids; Adopting some visual reference from magazines → (Sᵢ) Additional sketches to the previous drawing: Structural grids every 3 meters; Define a compositional façade; Swing orientation of the openings; omit the sliding options; Giving shadows to express the depth; Put some annotations to describe the materials; Add some technical details; Add some pieces of furniture to define the space and activity range |
|---|---|

| 17 (Beᵢ) | Including previous process 8 (Table 3) and process 10 (Table 4), with evaluation result (process 15) → (Bᵢ) Developing structured attributes as defined design approaches: Indirect daylight; Comfortable visual task illumination (100-200 lux); Trees as a buffer; Light-colored materials; Affordable cost |
|---|---|

| 18 (Feᵢ) | Previously on process 9: Focusing on providing indirect daylight → (Fᵢ) Newly defined purpose: Using daylighting for simple visual activity in the living room and porch |
4.7. Reformulation type 1

After a long run processing design cognition, those ideas settled and represented into design artifacts at the Documentation stage. Then the artifacts become part of the environment outside the designer, which gives influence in determining the next design direction. The next stage, called Reformulation I. There are two classes of interactions running here; they are interpretation and focussing.

Process 13 – External Structure to Interpreted Structure (S′ ⊆ S): is the process of reinterpreting external structures (process 12) by calculating the possibility of new components supporting the structure. Gero and Kannegesser call this push-pull process as an explorative process right on the artifacts. Process 6 – Interpreted Structure to Interpreted Structure (S′ ⊆ S): is the process of developing structural components that originate from constructive memory. Process 9 – Interpreted Structure to Expected Structure (S′ ⇔ Se): is a process that triggers the 2nd type reformulation, which introduces new ideas about components and their relationships or reduces their level.

Table 10. Example of Reformulation I.

| 13 | (S′) | Previous process: A porch on the South area; Opening on the setback façade; Portal frame to support the porch roof; Trees as a buffer In this state, the designer realizing: The composition of the portal frame could be better, more to horizontal expression than vertical; The window’s rhythm must be an odd number; Double swing doors in the middle |
| d | Additional sketches to the previous drawing: Structural grids every 3 meters; Define a compositional façade; Swing orientation of the openings; omit the sliding options; Giving shadows to express the depth; Put some annotations to describe the materials; Add some technical details; Add some pieces of furniture to define the space and activity range |
| 6 | (S′) | Previous process: A porch on the South; Wide opening: full height & width; Portal structure; Trees buffer; Opening composition |
| In this state, the designer realizing: The composition of the portal frame could be better, more to horizontal expression than vertical; The window’s rhythm must be an odd number; Double swing doors in the middle |
| 9 | (S′) | Previous components: A porch on the South; Wide opening: full height & width; Portal structure; Trees buffer; Opening composition |
| In this state, the designer realizing: The composition of the portal frame could be better, more to horizontal expression than vertical; The window’s rhythm must be an odd number; Double swing doors in the middle |
| ⇔ | (Se′) | Including previous process 9 and H (Table 5); Emergent components form the bridging process: 3-meter span structural grids; Adopting some visual reference from magazines New idea: Natural color tones to match tropical ambient |

4.8. Reformulation type 2

The Reformulation II is the development of detailed ideas, which are very carefully related to explicit artifacts. Whereas Reformulation type 2 brings the expression of ideas back to the state of behavior, like logical reasoning. Similar to Reformulation type 1, the process 4 in Reformulation type 2 has a class of interactions, and various types of processes (action, focussing, interpretation/push-pull) because the process moves dynamically in three worlds (examples in Table 11).

Process 14 - Structures Translated into Translated Behavior (S′ → B′): continues the transformation from structures to behaviour state-space. It interpreted the artifacts into a higher level of abstractions in a notion of rationale. Meanwhile, simultaneously establishing attribute relationships.

Process 19 - External Behavior to Interpreted Behavior (B′ ⊆ B′): states the selection of attributes that became an external expression, which can be a formal description of conceptual design. Process 8 - Behavior Interpreted into Expected Behavior (B′ ⇔ Be′): develops the behaviour into a higher abstraction of attributes and more explicit relationships between them, which match the expectations and reality. Process 5 - Behavior Translated into Translated Behavior (B′ ⊆ B′): build more rigid attributes with the support of constructive memory, which is the process of designer internalization.
Table 11. Example of Reformulation II.

| 14  | (S) | Previous set components (Table 10) including a new idea of natural color tones | ⟷ | (B') | Including previous process 14 (Table 6) and 5 (Table 2); Emergent attributes: visual balance, styles |
|-----|-----|--------------------------------------------------------------------------------|----|-----|--------------------------------------------------------------------------------|
| 19  | (B°) | Developing structured attributes as defined design approaches: Indirect daylight; Comfortable visual task illumination (100-200 lux); Trees as a buffer; Light-colored materials; Affordable cost | ⊃ | (B') | Including previous process 14 (Table 6) and 5 (Table 2); Emergent attributes: visual balance, styles |
| 5   | (B)  | Including previous process 14 (Table 6) and 5 (Table 2); Emergent attributes: visual balance, styles | ⊃ | (B') | Retrieving from the constructive memory: Level of comfort as on the tropical resort, natural ambiance but modern |
| 8   | (B)  | Including previous process 14 (Table 6) and 5 (Table 2); Emergent attributes: visual balance, styles | ⇐ | (Bε) | Shaping all the attributes into a comfortable space with simple construction at a multipurpose living area |

For the time being, Process 2 – Requirements to Interpreted Behavior (BR° ⊃ B°) is excluded to avoid focus shift, which will make this run even more complicated.

4.9. Reformulation type 3

The last transformation is Reformulation III. This group of processes returns the behaviour state-space to the function state-space as a final fulfillment that concludes the objectives of the refined attributes feedback. Interaction classes that occur are in the form of actions, focussing, and interpretation/push-pull, which is similar to the type of process. As a result, the transformation of cognition moves from the interpreted world towards the expected world. It is a self-acceptance process to recognize what has been done by far. The experiences will be stored back to constructive memory (examples in Table 12).

Process 16 – Interpreted Behaviour to Interpreted Function (B° ⟷ F°): provides a new understanding of interpreted functions. The consideration comes from the reasoning of interpreted behavior in process 8. Process 20 – External Function to Interpreted Function (F° ο F°): provide a new version of purpose (similar to process 16) by the support of external function documentation (process 18). Process 4 – Interpreted Function to Interpreted Function (F° ο F°): justifies function by reaffirming the acceptable purposes. Process 7 – Interpreted Function to Expected Function (F° ⇐ Fε): internalize the selected purposes as completion of focused goals.

Table 12. Example of Reformulation III.

| 16  | (B) | Including previous process 14 (Table 6) and 5 (Table 2); Emergent attributes: visual balance, styles | ⟷ | (F) | New goal: creating a tropical resort-like ambiance on the South area |
|-----|-----|--------------------------------------------------------------------------------|----|-----|--------------------------------------------------------------------------------|
| 20  | (F°) | New goal: creating a tropical resort-like ambiance on the South area | ⇐ | (F°) | Previously defined purpose – process 18 (Table 9): Using daylighting for simple visual activity in the living room and porch New proposed function: the indoor living room is extendable to the outside porch for relaxing activities |
| 4   | (F°) | New proposed function: the indoor living room is extendable to the outside porch for relaxing activities | ⊃ | (F°) | With the consideration of the previous process 4 (Table 2); Justification: realizing that the site is not spacious, the offset between the porch and the site perimeter is required to get daylight and the convenience of visibility |
| 7   | (F°) | With the consideration of the previous process 4 (Table 2); Justification: realizing that the site is not spacious, the offset between the porch and the site perimeter is required to get daylight and the convenience | ⊃ | (Fε) | Acceptable purposes: The South area as a center of activity during the day with an adequate daylighting, and extendable indoor-outdoor spaces with transparent wall to let the light penetrates |
5. Conclusion
The appearance of behaviour state-space in this workflow is very significant. It demonstrates that strengthening the concepts of sustainable design by elaborating on the attributes is very helpful for the designer in producing the design moves. The concepts of sustainable design will also be easier to grasp from the visualization of artifacts that have successfully implemented. That way, the influences of design manifestations become a potential constructive memory load.

Furthermore, constructive memory will be more accessible if the relationship has many connections with other concepts. This dry run has shown that the parameters of a sustainable approach cover many aspects of the design component. For example, composition, structure, and have cost associative way of thinking conserves in constructive memory as a tool to face other design challenges in the future. The workflow demonstrates collecting (process 4, 7, 10, 11), retrieving (process 16, 7, 10, 11), and storing (process 20, 16, 4, 7) process of memory activities as a repetitive set of cognitive activity.

Overall, the model of designing theory has many derivations of workflows. The example only shows one possibility that satisfied the conditions and thus the opportunity to clarify the cognition state exchange reached. A map of the design cognition characteristics and the processes outlined are expected to help explore other design tasks. This research shows evident in differences in design cognitive state entity conditions.

6. References
[1] J S Gero and U Kannengiesser 2004 The situated function-behaviour-structure framework Des. Stud 25 4 373–391
[2] J S Gero and U Kannengiesser 2014 The Function-Behaviour-Structure Ontology of Design An Anthology of Theories and Models of Design (London: Springer London) 263–283
[3] J S Gero 1990 Design Prototypes: A Knowledge Representation Schema for Design AI Mag 11 426
[4] J S Gero and U Kannengiesser 2000 Towards a Situated Function-Behaviour-Structure Framework as the Basis for a Theory of Designing Artif. Intell. Des. 1–5
[5] J W Kan and J S Gero 2017 Quantitative Methods for Studying Design Protocols (Dordrecht: Springer Netherlands)
[6] J S Gero and U Kannengiesser 2007 A function–behavior–structure ontology of processes Artif. Intell. Eng. Des. Anal. Manuf. 21 4 379–391
[7] J S Gero 1999 Constructive Memory in Design Thinking Design Thinking Research Symposium: Design Representation 4 29–35