27TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
11-12 SEPTEMBER 2025, UNIVERSITY OF MALTA, MALTA

MEASURING STUDENTS' FRAMING AND REFRAMING IN DESIGN: A SEMANTIC DISTANCE APPROACH

Hernan CASAKIN[1], Hadas SOPHER[1], Or H. ANIDJAR[1] and John S. GERO[2]
[1]Ariel University, Israel
[2]University of North Carolina at Charlotte, United States of America

ABSTRACT
Understanding the cognitive processes of framing and reframing (F-RF) is foundational for fostering effective problem-solving and decision-making in design education. This study introduces a novel method to measure F-RF behaviours during design tasks, addressing a gap in existing assessment techniques.
F-RF is fundamental to design problem-solving, influencing how problems and solutions are perceived and approached. Frames are conceptual lenses based on the designer's knowledge, experience, and values, which affect information interpretation and guide decision-making. Effective framing supports problem definition and redefinition and idea exploration. Despite their significance, methods for assessing F-RF remain underexplored. A case study involved five undergraduate architectural students tasked with designing a small museum during a 65-minute session was explored from the F-RF perspective. Using Natural Language Processing (NLP) to analyse semantic distances in their verbalisations, the study tracked F-RF behaviours. Results showed a contrasting relationship across the design process between the number of frames generated and their semantic distances. While the number of frames decreased in the Designing and Finalising phases of the design activity, it increased in the Debriefing phase. The proposed approach advances design research by enabling measuring cognitive behaviours in design education.

Keywords: Design process, design education, natural language processing, framing and reframing, cognitive processes, assessment methods

1 INTRODUCTION
Framing and reframing (F-RF) are fundamental cognitive mechanisms in design problem solving. Frames are structures influencing how problems are conceptualised and solutions are developed. They are shaped by a designer's knowledge, expertise, and values. Understanding F-RF is critical for advancing problem-solving and decision-making skills in design education.
In the design process, designers must deal with problems that are inherently ambiguous and context dependent. Designers start the process by setting preliminary objectives and defining problems that guide the development of solutions [1]. This dynamic interplay is characterised by F-RF, where designers prioritise certain aspects and contextualised them within a broader framework [2]. For this study, frames are defined as sets of co-activated concepts grounded in the student's prior knowledge, experiences, and value systems [3].
The process of F-RF enables a comprehensive understanding of the design situation, and the relationships between the ideas that shape the design problem. Cross [4] highlights that framing problems reflect the essence of the design activity, as it involves structuring and articulating the different problem's aspects. While F-RF is extensively discussed in design literature [5], much of the research remains theoretical, with qualitative approaches dominating the field. This theoretical emphasis has resulted in limited empirical research on framing behaviours and a scarcity of quantitative methodologies for characterising and evaluating F-RF. Developing quantitative tools for analysing and measuring this essential cognitive activity remains a largely undeveloped area. Based on advances in Natural Language Processing (NLP), empirical data on the semantic distances of frames can be characterised, measured, and analysed systematically. Semantic distance refers to the measure of how

closely related or distant two concepts are in terms of their meaning. In design, measuring semantic distance provides a basis for understanding the cognitive leaps designers make when framing and reframing problems, as it quantifies the degree of divergence in their thought processes.

An exploration of F-RF using NLP methods can lay the ground for quantifying and interpreting framing behaviours, offering new insights into design cognition and enabling cross-session comparisons. This paper seeks to characterise and quantify F-RF behaviours through an NLP-based approach during design sessions, with implications for design education. We demonstrate the method through an analysis of data from a small-scale study using students, as a precursor to a large scale statistically significant study. The research aims to address the following questions:

- How does the number of frames generated by the students vary across the design process?
- What is the temporal variation of students' semantic distances of frames across the design process?
- What is the relationship between the number of frames and their semantic distances generated by students across the design process?

2 FRAMES AND DESIGN

The idea of a "frame" was introduced by Goffman [6] to help organise experiences, enabling individuals to understand and react to their surroundings. Shortly after, Minsky [7] applied the concept to artificial intelligence, defining frames as cognitive tools for dealing with new situations. These early interpretations of framing have since influenced fields like psychology, engineering, and design. Bateson [8] described framing as a mental boundary-setting mechanism, distinguishing relevant from irrelevant information to guide decisions. Framing, as a process, also refers to values, beliefs, and perspectives. Fisher [9] expanded this notion, defining frames as semi-structured elements that help people interpret and arrange information. In problem-solving, framing shapes how challenges are defined, including constraints, objectives, and instructions [10].

In design, framing is referred to the generation and co-activation of concepts [11]. It is the process through which designers structure situations, consciously or subconsciously, by focusing on certain aspects to emphasise or integrate different elements of the situation. This process of framing includes intentions and assumptions about a desired and acceptable design solution. Changing or adjusting a problem's frame can significantly affect the solutions developed [12].

2.1 Framing and reframing and the design process

Van der Bijl-Brouwer and Dorst [13] introduced frame creation as a design method to foster meaningful value in support of innovation. At the start of the design process, when problems are often vague or undefined, framing plays a key role. Designers use framing to make the problem more comprehensible and structured. This skill is central to design thinking and is based in Schön's reflective practice theory [2]. Frames serve as cognitive structures that guide designers based on their beliefs, perceptions, and experiences, offering a reference point for decision-making.

As designers deepen their understanding of a situation, they become more aware of frames and more capable of constructing and assessing them [14]. Framing is inherently subjective. It is shaped by individual judgments, experiences, and perspectives of the design situation. Throughout the design process, framing activity develops as new issues, conflicts, and opportunities emerge. Initial frames give rise to the construction of new subsequent frames, a process known as reframing (RF). RF occurs when designers reinterpret problems, generating new occurrences and revisiting them through reoccurrences. Through reflective dialogue with the design situation, designers continuously frame and reframe problems as needed [2]. This iterative activity leads to new or modified frames, reframes problem statements, and redefines goals, needs, and expectations [15]. F-RF facilitates generative interpretations of design situations, aimed at producing effective design outcomes [3], [5].

3 METHOD

3.1 Case study

The research presented in this paper is based on a controlled experiment in the form of a case study. Five female students in the third year of architectural studies worked individually on a design task in a single design session. The experiments took place in a lab setting. Sessions were divided into three phases: 1) Designing – in which students explored ideas to deal with the design task; 2) Finalising –

where they refined and consolidated their final design; and 3) Debriefing – where students described their design after completion. The three parts lasted 40, 15, and 10 minutes respectively, totalling 65 minutes. Participants were required to verbalise their thoughts to enable recording their design activity. A camera captured the participants' sketches. The design task required designing a small museum located in an urban area characterised by historical and modern buildings [16].

3.2 Data processing

The data consists of the recordings and transcriptions of verbalisations produced during the five individual sessions. Protocol analysis techniques [17] were used to provide evidence of design thinking and the F-RF activity. A total of 5.25 hours of verbalisations were recorded, transcribed, and segmented into one-minute epochs.

3.3 Identifying nouns and design frames

In this study, a frame is defined as being composed of nouns as labels of concepts. By tracking nouns as fundamental components of frames we claim we identify the concepts in a frame, even if incompletely. The design process is analysed by syntactically tracking the distribution of nouns, considered as the design issues generated during the design activity [18]. The first and repeated occurrences of design issues generated during the sessions are identified automatically using an algorithm pipelined through YAP [19]. NLP methods were used in automating the initial stages of data preparation, encompassing tasks of transcript cleaning, tokenisation, and stemming. A main analysis focused on the identification of occurrence and reoccurrence of nouns. For instance, using an NLP script, verbalisations such as "The library located in the park has two floors" were parsed to extract concepts like “library,” “park,” and “floor” for further analysis. This step was essential for categorising and structuring the data in a way that facilitates exploring linguistic patterns.

3.4 Characterising and measuring design frames

Once the design concepts are identified, following the principle of coactivation of concepts, we use them to identify, characterise, and measure frames. We describe the process, including steps for extracting and analysing nouns and assessing their semantic value from verbalised design concepts using NLP. Initially, a frame is composed of all the nouns in a sentence. However, if the sentence has parts divided by commas, each part is considered potentially to be a frame. Based on the frame’s role in meaning making, the semantic value of a frame is calculated as the mean of the semantic value of its nouns. A sentence could be composed of one or more frames each with different numbers of nouns.

To calculate the semantic value of each frame we used the BERT machine-learning model [20]. It is based on a transformer architecture and is designed to understand the context of words in a sentence by considering the surrounding words. Its bidirectional approach to natural language processing allows BERT to generate more accurate representations of words and sentences compared to previous models. BERT has been widely adopted in both academia and industry due to its performance on various natural language understanding tasks.

4 RESULTS AND DISCUSSION

The results below exhibit F-RF behaviour, measured in the students’ verbalisations for each part of the experiment. Changes in the number of frames and their semantic distances indicate shifts in how students’ structure and restructure the problem.

4.1 Temporal variation of students’ number of frames

The blue curves in Figure 1 illustrate the temporal variation in the number of frames generated across the three phases of the design session. In the Designing phase, there was an initial increase in frame generation, reflecting active exploration and idea generation. The “best-fit” curve obscures this activity. However, in the following stages of this phase, frame generation decreased, suggesting a transition toward refining previously generated ideas. During the Finalising phase, frame generation initially increased and thereafter decreased, again indicating a narrowing of focus as students shifted from exploration to the refinement of key ideas. Contrary to expectations, the Debriefing phase revealed an increase in frame generation, with students revisiting prior frames and introducing new ones.

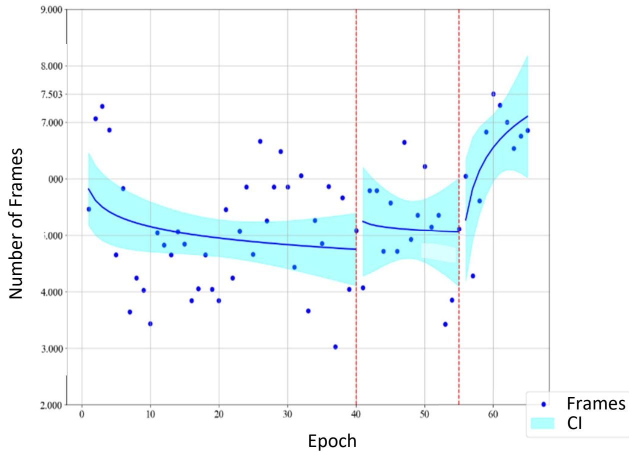

Figure 1 .Temporal variation of students' number of frames in the Designing, Finalising, and Debriefing parts of the design process (CI: Confidence Interval)

The trends observed, which need to be taken with caution given this is a case study, partly align with existing cognitive theories in design. The early increase in frame generation during the Designing phase supports the notion that this stage emphasises divergent thinking and broad exploration [1]. However, the decrease later in the phase suggests that students might have lacked strategies to maintain prolonged exploration of ideas. The decrease in the Finalising phase is consistent with the expected transition to convergent thinking, where students narrow their focus, refine, and consolidate ideas [14]. The unexpected increase in frame generation during the Debriefing phase suggests a shift toward reflective engagement. Unlike the Designing and Finalising phases, which required real-time ideation and decision-making, the Debriefing was conducted retrospectively, without the immediate need to produce a design outcome. This change in this experimental condition might have allowed students to articulate their reasoning more fluently, resulting in higher frame generation. These likely supported not only revisiting prior concepts and frames but also elaborating them further while they consider the implications of their designs. This behavior aligns to some extent with Schön's [2] concept of reflective practice, implying that debriefing fosters an increased understanding.

4.2 Temporal variation of students' semantic distances of frames

The blue curves in Figure 2 show the temporal variation in the semantic distances of frames (SDFs) generated by students. During the Designing phase, SDFs increased over time, suggesting that they introduced semantically diverse ideas, reflecting active divergent thinking. In the Finalising phase, SDFs continued to increase rather than decrease, contrary to what is expected in a convergent stage. This result

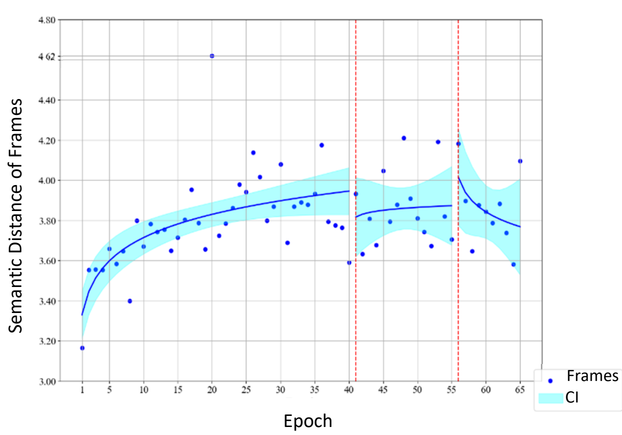

Figure 2 .Temporal variation of students' semantic distances of frames in the Designing, Finalising, and Debriefing parts of the session (CI: Confidence Interval)

indicates that students continued exploring new unrelated concepts while finalising their designs. In the Debriefing phase, SDFs decreased, reflecting a shift toward synthesising and summarising the design.
The increase in SDFs during the Designing phase supports the understanding that divergent thinking characterises this stage, as students explore diverse ideas [10], [21]. However, the continued increase in SDFs during the Finalising phase suggests a misalignment with typical design models, where convergence is expected [5]. This result highlights students' challenges in integrating most promising ideas into cohesive final solutions, pointing to the need for instructional support to enhance synthesis skills [22]. The decrease of SDFs in the Debriefing phase indicates reflective synthesis, where students consolidate their ideas into coherent retrospective narratives. As expected in this phase, this outcome emphasises reflective skills in fostering connections between prior concepts, rather than introducing new ones.

4.3 Relationship between the number of frames and their semantic distances

Comparing Figures 1 and 2 reveals an inverse relationship between frame generation and semantic distances across the design phases. In the Designing phase, frame generation decreased over time, while SDFs increased, indicating that as students created fewer frames, they introduced semantically diverse concepts. During the Finalising phase, frame generation continued to decline and SDFs increased, suggesting ongoing exploration of few new semantically distant ideas despite the narrowing focus. In the Debriefing phase, frame generation increased, while SDFs decreased. This suggests that students not only revisited and consolidated earlier frames but also narrowed their ideas further.
The inverse relationship in the Designing phase, where frame generation declined while SDFs increased is unexpected. This highlights students' challenges in generating and developing as many ideas as possible, while exploring broader conceptual semantic spaces [1], [11]. This phase reflects their dual cognitive behavior of focused refinement and divergent thinking. With fewer frames being created, conceptually distinct ideas with higher semantic divergence are created. This behavior may indicate a deliberate effort to expand the design space, even as the overall focus narrows. The decreasing number of frames may reflect the prioritisation of quality or novelty over quantity, emphasising broader semantic leaps rather than incremental elaboration. In the Finalising phase, the continued decline in frame generation and rising SDFs suggest difficulties in transitioning to convergence, stressing challenges in synthesising diverse ideas into integrated final solutions [14], [21]. In contrast, in the Debriefing phase, the increase in frame generation paired with decreasing SDFs is also unexpected and indicates reflective engagement. This inverse relationship can be explained by the shift from broad exploration to focused refinement. Initially, each new frame introduces diverse concepts, leading to higher semantic value. However, as this stage progresses and more frames are created, the focus shifts to building on and elaborating existing ideas and consolidating them, rather than generating new ones. This results in less semantic divergence between successive frames, as the concepts become more related and specific to the evolving solution.

5 CONCLUSIONS

This study introduced a novel NLP-based methodology to characterise, measure and analyse framing and reframing (F-RF) behavior in design, focusing on the temporal variation in frame generation and semantic distances across different phases of the design process. This capability has been lacking in design research. The observations suggest that while students engage in idea exploration during the Designing phase, they face challenges transitioning to convergence during finalisation. The unexpected rise in semantic distances during the Finalising phase indicates the need for targeted educational interventions to support idea synthesis and refinement. The reflective engagement observed in the Debriefing phase demonstrates the value of fostering practices that enable students to connect and elaborate further on diverse ideas. This emphasises the iterative and ongoing nature of framing and reframing in design.
This research contributes to design education by providing a systematic framework for characterising and measuring cognitive behaviours in framing and reframing. Future studies should expand this approach to larger cohorts and diverse contexts, such as design studios, to statistically validate and generalise the findings. Integrating this methodology into real-time feedback systems could further enhance educational outcomes by supporting the development of effective F-RF design skills. Future work may also explore how framing patterns align with established frameworks such as the FBS ontology and the Double Diamond design process model.

ACKNOWLEDGEMENTS

This research was supported by the ISRAEL SCIENCE FOUNDATION (grant No. 798/22).

REFERENCES

[1] Cross N. *Design thinking: Understanding how designers think and work*, 2011 (Bloomsbury Academic, London).

[2] Schön D. A. *The reflective practitioner: How professionals think in action*, 1983 (Basic Books, New York).

[3] Kelly N. and Gero J. S. Reviewing the concept of design frames towards a cognitive model. *Design Science*, 2022, 8, E30.

[4] Cross N. *Designerly ways of knowing*, 2007 (Springer, London).

[5] Dorst K. *Frame innovation: Create new thinking by design*, 2015 (MIT Press, Cambridge, MA).

[6] Goffman E. *Frame analysis: An essay on the organisation of experience*, 1974 (Harvard University Press, Cambridge, MA).

[7] Minsky M. A framework for representing knowledge. In Winston P. (ed.) *The psychology of computer vision*, 1975, pp. 211-277 (McGraw-Hill, New York).

[8] Bateson G. *Steps to an ecology of mind*, 1972 (Ballantine Books, New York).

[9] Fisher K. Locating frames in the discursive universe. *Sociological Research Online*, 1997, 2(3). Available: https://www.socresonline.org.uk/2/3/4.html.

[10] Tversky A. and Kahneman D. The framing of decisions and the psychology of choice. *Science*, 1981, 211, 453-458.

[11] Gero J. S. and Kan J. T. Empirical results from measuring design creativity: Use of an augmented coding scheme in protocol analysis. In *Proceedings of the Fourth International Conference on Design Creativity (ICDC)*, Atlanta, November 2016, pp. 1-8 (International Design Society, Glasgow).

[12] Silk E. M., Rechkemmer A. E., Daly S. R., Jablokow K. W. and McKilligan S. Problem framing and cognitive style: Impacts on design ideation perceptions. *Design Studies*, 2021, 74, 101015.

[13] van der Bijl-Brouwer M. and Dorst K. Advancing the strategic impact of human-centred design. *Design Studies*, 2017, 53, 1-23.

[14] Dorst K. and Cross N. Creativity in the design process: Co-evolution of problem–solution. *Design Studies*, 2001, 22, 425-437.

[15] Paton B. and Dorst K. Briefing and reframing: A situated practice. *Design Studies*, 2011, 32, 573-587.

[16] Casakin H. and Kreitler S. Correspondences and divergences between teachers and students in the evaluation of design creativity in the design studio. *Environment and Planning B: Planning and Design*, 2011, 38, 592-611.

[17] van Someren M. W., Barnard Y. F. and Sandberg J. A. (eds.) *The think aloud method: A practical guide to modelling cognitive processes*, 1994 (Academic Press, San Diego, CA).

[18] Casakin H., Sopher H., Gero J. and Anidjar O. The use of occurrences of ideas for constructing and characterising the design space. In *Proceedings of the International Design Conference DESIGN 2022*, Cavtat, Dubrovnik, May 2024, pp. 905-914 (Design Society, Glasgow).

[19] Tsarfaty R., Seker A., Sadde S. and Klein S. What's wrong with Hebrew NLP? And how to make it right. *arXiv preprint*, arXiv:1908.05453, 2019.

[20] Devlin J., Chang M. W., Lee K. and Toutanova K. BERT: Pre-training of deep bidirectional transformers for language understanding. *arXiv preprint*, arXiv:1810.04805, 2018.

[21] Gabora L. Reframing convergent and divergent thought for the 21st century. *arXiv preprint*, arXiv:1811.04512, 2018.

[22] Sosa R. and Gero J. S. Design and change: A model of situated creativity. In Bento C., Cardoso A. and Gero J. S. (eds.) *Approaches to creativity in artificial intelligence and cognitive science*, IJCAI03, Acapulco, 2003, pp. 25-34 (Springer, Berlin).