DR.SC.-01 REQUEST FOR APPROVAL OF THE DISSERTATION TOPIC[1]

GENERAL INFORMATION AND PERSONAL CONTACT INFORMATION OF THE DOCTORAL CANDIDATE

First and last name, and title of the doctoral candidate:	Fanika Lukačević, mag. ing. mech.		
Provider of the study programme:	University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture		
Name of the study programme:	Mechanical Engineering, Naval Architecture, Aeronautical Engineering, Metallurgical Engineering		
Scientist ID of the doctoral candidate:	35003293		
Approval of topic for acquiring a PhD *(please fill in appropriate box)*:	☐ within programme-based doctoral study	☐ on the basis of scientific achievement	☒ Dual doctorate (Cotutelle de these)
First and last name of mother and/or father:	Verica Lukačević i Vladimir Lukačević		
Date and place of birth:	27.9.1995., Nova Gradiška, Croatia		
Address:	Sokolgradska ulica 7, Zagreb, Croatia		
Telephone / mobile phone number:	+38591 953 3539		
1 **E-mail:**	fanika.lukacevic@fsb.hr		

CURRICULUM VITAE OF THE DOCTORAL CANDIDATE

Education *(in chronological order, with most recent first)*:	1. **University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture**, *Mechanical Engineering*, Master's degree, Croatia (2019/2020) 2. **University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture**, *Mechanical Engineering*, Bachelor's degree, Croatia (2017/2018)
Work experience *(in chronological order, with most recent first)*:	1.7.2020. – today: Assistant, Chair of Design and Product Development, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb (teaching, research, cooperation with industry)

[1] Please name file as: DR.SC.-01 – Last name and first name of Doctoral Candidate.doc
Please send the filled -out form DR.SC.-01, in electronic and written format, and signed, to the appropriate Registrar's Office.

Bibliography and active participation in conferences:	1. Lukačević, Fanika; Li, Shumin; Becattini, Niccolò; Škec, Stanko Comparing EEG Brain Power of Mechanical Engineers in 3D CAD Modelling from 2D and 3D Representations. // Proceedings of the Design Society Cavtat - Dubrovnik, Hrvatska: Cambridge University Press, 2022. str. 901-910 doi:10.1017/pds.2022.92 (lecture, international peer review, full paper, scholarly) 2. Horvat, Nikola; Martinec, Tomislav; Lukačević, Fanika; Perišić, Marija Majda; Škec, Stanko The potential of immersive virtual reality for representations in design education. // Virtual reality, 26 (2022), 1227-1244 doi:10.1007/s10055-022-00630-w (international peer review, article, scholarly) 3. Lukačević, Fanika; Škec, Stanko; Martinec, Tomislav; Štorga, Mario Challenges of utilising sensor data acquired by smart products in product development activities. // Acta Polytechnica Hungarica, 19 (2022), 4; 165-187 doi:10.12700/APH.19.4.2022.4.9 (international peer review, article, scholarly) 4. Martinec, Tomislav; Škec, Stanko; Lukačević, Fanika; Štorga, Mario Modelling Proportions and Sequences of Operations in Team Design Activities. // Proceedings of the Design Society, Volume 1 Göteborg, Švedska / Online: Cambridge University Press, 2021. str. 2187-2196 doi:10.1017/pds.2021.480 (lecture, international peer review, full paper, scholarly) 5. Lukačević, Fanika; Škec, Stanko; Törlind, Peter; Štorga, Mario Identifying subassemblies and understanding their functions during a design review in immersive and non- immersive virtual environments. // Frontiers of Engineering Management, 8 (2021), 412-428 doi:10.1007/s42524-020-0099-z (international peer review, article, scholarly) 6. Lukačević, Fanika; Škec, Stanko; Perišić, Marija Majda; Horvat, Nikola; Štorga, Mario Spatial perception of 3D CAD model dimensions and affordances in virtual environments. // IEEE access, 8 (2020), Access-2020-40098, 18 doi:10.1109/ACCESS.2020.3025634 (international peer review, article, scholarly) 7. Horvat, Nikola; Škec, Stanko; Martinec, Tomislav; Lukačević, Fanika; Perišić, Marija Majda Identifying the effect of reviewers' expertise on design review using virtual reality and desktop interface. // Proceedings of the Design Society: DESIGN Conference Dubrovnik, Hrvatska: Cambridge University Press, 2020. str. 187-196 doi:10.1017/dsd.2020.304 (lecture, international peer review, full paper, scholarly 8. Horvat, Nikola; Škec, Stanko; Martinec, Tomislav; Lukačević, Fanika; Perišić, Marija Majda Comparing Virtual Reality and Desktop Interface for Reviewing 3D CAD Models. // Proceedings of the Design Society: International Conference on Engineering Design / Wartzack, Sandro ; Schleich, Benjamin ; Guerreiro Gonçalves, Milene ; Eisenbart, Boris (ur.). Delft, The Netherlands: Cambridge University Press, 2019. str. 1923-1932 doi:10.1017/dsi.2019.198 (lecture, international peer review, full paper, scholarly)
TITLE OF THE PROPOSED TOPIC	
Croatian:	Model kognitivnoga opterećenja u računalom potpomognutom konstruiranju
English:	A model of cognitive load in computer-aided design
Title in the language of the dissertation (if it is not Croatian or English)	-
Area/field/branch (if the doctoral study is performed in a branch)**:**	Engineering / Mechanical Engineering / General Mechanical Engineering (Design)

PROPOSED OR POTENTIAL MENTOR(S)

(name the second mentor in case of interdisciplinary research or if there is another reason for more than one mentor)

	First name and last name, and title:	Institution, country:	E-mail:
First mentor:	Assoc. Prof. Stanko Škec, PhD. M.E.	University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia	stanko.skec@fsb.hr
Second mentor:	Assoc. Prof. Niccolò Becattini, PhD. M.E.	Politecnico di Milano, Italy	niccolo.becattini@polimi.it

MENTOR'S COMPETENCES – list of up to five relevant works published in the last five years

First mentor:	1. Horvat, Nikola; Kunnen, Steffen; Štorga, Mario; Nagarajah, Arun; Škec, Stanko Immersive virtual reality applications for design reviews: Systematic literature review and classification scheme for functionalities. // Advanced engineering informatics, 54 (2022), 101760, 21 doi:10.1016/j.aei.2022.101760 2. Horvat, Nikola; Martinec, Tomislav; Lukačević, Fanika; Perišić, Marija Majda; Škec, Stanko The potential of immersive virtual reality for representations in design education. // Virtual reality, 26 (2022), 1227-1244 doi:10.1007/s10055-022-00630-w 3. Lukačević, Fanika; Škec, Stanko; Perišić, Marija Majda; Horvat, Nikola; Štorga, Mario Spatial perception of 3D CAD model dimensions and affordances in virtual environments. // IEEE access, 8 (2020), Access-2020-40098, 18 doi:10.1109/ACCESS.2020.3025634 4. Martinec, Tomislav; Škec, Stanko; Horvat, Nikola; Štorga, Mario A state-transition model of team conceptual design activity. // Research in engineering design, 30 (2019), 1; 103-132 doi:10.1007/s00163-018-00305-1 5. Škec, Stanko; Cash, Philip; Štorga, Mario A Dynamic Approach to Real Time Performance Measurement in Design Projects. // Journal of Engineering Design, 28 (2017), 1-32 doi: 10.1080/09544828.2017.1303665
Second mentor:	1. Lukačević, Fanika; Li, Shumin; Becattini, Niccolò; Škec, Stanko Comparing EEG Brain Power of Mechanical Engineers in 3D CAD Modelling from 2D and 3D Representations. // Proceedings of the Design Society Cavtat - Dubrovnik, Hrvatska: Cambridge University Press (2022), 901-910 doi:10.1017/pds.2022.92 2. Li, Shumin; Becattini, Niccolò; Cascini, Gaetano Correlating design performance to EEG activation: Early evidence from experimental data. // Proceedings of the Design Society, 1 (2021), 771-780 doi:10.1017/pds.2021.77 3. Horvat, Nikola; Becattini, Niccolò; Martinec, Tomislav; Škec, Stanko Identifying Indicators for the Use of Virtual Prototypes in Distributed Design Activities. // Computer-Aided Design and Applications, 19 (2021), 2; 320-335 doi: 10.14733/cadaps.2022.320-335 4. Jia, Lizhen; Becattini, Niccolò; Cascini, Gaetano; Tan, Runhua Testing ideation performance on a large set of designers: effects of analogical distance. // International Journal of Design Creativity and Innovation, 8 (2020), 1; 31-45 doi: 10.1080/21650349.2019.1618736 5. Becattini, Niccolò; Cascini, Gaetano; O'Hare, Jamie Alexander; Morosi, Federico; Boujut, Jean-Francois Extracting and analysing design process data from log files of ICT supported co-creative sessions. // Proceedings of the Design Society: International Conference on Engineering Design: Cambridge University Press (2019), 129-138 doi: 10.1017/dsi.2019.16

TOPIC OUTLINE

Summary in Croatian *(no more than 1000 characters with spaces):*	Konstruktorova izvedba u CAD aktivnostima određuje kvalitetu, cijenu i vremenske rokove suvremenoga procesa konstruiranja. Unatoč značajnome utjecaju konstruktorove izvedbe na uspješnost procesa, njezini ključni elementi i odnosi među njima još uvijek nisu utvrđeni, kao ni utjecajni čimbenici. Cilj predloženoga istraživanja jest razviti metodu za mjerenje i analizu kognitivnoga opterećenja u CAD aktivnostima, koja bi trebala omogućiti procjenu konstruktorove izvedbe i prepoznavanje čimbenika čijom ju je manipulacijom moguće unaprijediti. Kako bi se to postiglo, potrebno je definirati teorijske modele kognitivnoga opterećenja i izvedbe konstruktora u CAD aktivnostima, koji će poslužiti kao teorijska osnova razvoja metode. Primjena metode za mjerenje i analizu kognitivnoga opterećenja doprinijela bi 1) planiranju i upravljanju konstrukcijskim aktivnostima te 2) evaluaciji, odabiru i razvoju CAD sustava.
Summary in English *(no more than 1000 characters with spaces):*	The engineering designer's performance in CAD activities determines the quality, cost, and timelines of the contemporary engineering design process. Despite the significant influence of the engineering designer's performance on the process' success, its key elements, their relations, and influencing factors are yet to be defined. The proposed research aims to develop a method for measuring and analysing the cognitive load in CAD activities that should enable the assessment of the engineering designer's performance and identification of factors whose manipulation may improve it. The first step forward is defining the theoretical models of cognitive load and engineering designers' performance in CAD activities, which will ground a basis for developing the method. Implementation of the method for measuring and analysing the cognitive load may inform 1) the planning and management of design activities and 2) the evaluation, selection, and development of CAD systems.

Introduction and overview of research conducted hitherto *(suggested length: 7000 characters with spaces)*

Engineering design is a process in which stakeholders (e.g. industrial designers, engineers, and customers) constantly generate and use design information [1]. The process is divided into design activities, during which requirements and descriptions of a design problem (input information) are transformed into the representations of a technical system (output information) - informational objects which describe the design characteristics (e.g. form, position, and dimensions) and the design properties (e.g. function) [2]. The design characteristics and properties are described with the sets of information presented in different formats, such as symbolic (e.g. language or mathematic symbols), iconic/pictorial (e.g. sketches, drawings, photographs, three-dimensional (3D) models), or diagrammatic (e.g. graphs, schematics, relationship diagrams) [3]. The iconic/pictorial representations are particularly important in engineering design since they present design characteristics visually and spatially, which is essential in describing and developing the technical systems belonging to the group of material objects [4]. In the contemporary engineering design process, engineering designers regularly employ computer-aided design (CAD) systems (CAD software and human-computer interaction (HCI) tools) for generating, manipulating, interacting with, and using digital versions of these representations (i.e. CAD representations) [5]. CAD systems play a fundamental role in the majority of engineering design activities (i.e. CAD activities) by influencing engineering designers' performance – one of the essential factors determining the quality, the cost, and the timelines of the engineering design process.

Despite its importance for the engineering design process, the definition of CAD activity performance has not yet been formalised regarding the key elements, relationships among them, and influencing factors. With their theoretical model, O'Donnell and Duffy provided a basis for understanding the performance at the product development level, which is based on efficiency (related to the process and described by the amount of invested resources) and effectiveness (related to the evaluation of the achieved outcomes) as the key elements of the design activity performance [6]. Accordingly, the literature studying CAD activities has predominantly focused on describing the process and outcomes of performing the CAD activities using behaviour-related metrics (e.g. the number and the sequences of the CAD operations and actions [7]) and outcome-related metrics (e.g. the quality and functionality of the resulting CAD representations compared to the design task requirements and goals). For example, previous studies have noted the variability in the number, the type, and the sequences of adding entities and features in CAD environments during the generation of 3D virtual models, without mentioning the potential reasons for such results [8]. Furthermore, it has been shown that the resulting CAD representations' quality depends on the characteristics of CAD systems as well as the characteristics of engineering designers (e.g. experience and expertise) [8] [9]. These studies suggest how to analyse CAD processes and imply that different factors influence them. However, the studies are primarily descriptive in nature; they do not focus on measuring or thoroughly analysing the factors influencing the obtained results. In addition to the insufficient understanding of the phenomenon, the available literature highlights the associated paucity of support for its measurement and analysis (e.g. in the form of guidelines or method) [10]. Consequently, engineering design lacks the knowledge and the means to measure, assess, and consequently improve the performance in CAD activities.

Motivated by the potential benefits of bridging the recognised gap, the herein proposed research seeks to improve the understanding and support the assessment of engineering designers' performance in CAD activities by investigating the underlying cognition. Researchers have acknowledged the importance of studying engineering designers' cognition during CAD activities, which is reflected in several reviews (e.g. [10]) and frameworks for studying cognitive aspects of engineering design in the CAD context (e.g. [11], [12]). However, little empirical evidence related to the cognitive aspects of CAD activities is available, so the assumptions are based on theoretical considerations [10]. Formalising, measuring, and assessing the engineering designers' performance is aggravated by the visual (information is presented visually), virtual (they are situated in virtual environments), and cognitive nature of CAD activities [1]. The cognitive complexity of CAD activities arises from the characteristics of design tasks as well as from the use of CAD systems [9], [13]. In particular, engineering designers simultaneously attend to, perceive, and interpret multiple information streams when conducting CAD activities [14]. Furthermore, they employ various cognitive abilities (e.g. spatial visualisation and mental rotation) to reach the high number of subgoals that the CAD activities are consisted of [15]. The CAD systems offer the possibility to reach these subgoals in alternative ways, thus continuously making the engineering designers evaluate the possible options and decide on how to proceed [8]. It is assumed that the execution of CAD activities, due to their cognitive complexity, imposes high demands (i.e. cognitive load) on the engineering designers' cognitive system [16]. Since engineering designers' information-processing cognitive resources are limited, their proper allocation in CAD activities is required to ensure effective and efficient performance in the virtual (CAD) environment [1].

Cognitive load has rarely been studied so far in engineering design, both theoretically and empirically [10]. Previous studies suggest that the cognitive load differs among design activities (e.g. [17] and [18]), changes depending on the type of visual design representations used to communicate design information (e.g. [19] and [20]), and relates to the experienced stress during design activities (e.g. [21] and [22]). These implications support the assumption that it is possible to influence the level of cognitive load and that the consequences of such influence may also be manifested in the engineering designers' performance. However, controlling the influence on cognitive load requires a thorough understanding of the key elements (engineering designer, CAD activity, and work environment) from which it arises. The contextualisation of these elements and the relationships between them (based on the general theoretical cognitive load model [23]) is a prerequisite for identifying the factors that may contribute to making higher cognitive demands of engineering designers during CAD activities. The theoretical model of cognitive load in CAD activities would serve as a basis for developing a method for measuring and analysing the cognitive load with the goal of assessing the levels of engineering designers' performance and identifying the factors that may be manipulated to achieve the desired level. The method for measuring and analysing cognitive load may inform (1) the planning and management of design activities and (2) the evaluation, selection, and development of CAD systems. In addition, such a method would augment the understanding of performance in engineering design activities, currently based on O'Donnell and Duffy's method [6].

Objective and hypotheses of research[2] *(suggested length: 700 characters with spaces)*

The objectives of the research are to:

1) Develop and validate a theoretical model of cognitive load in CAD activities,
2) Develop and validate a theoretical model of the engineering designer's CAD activity performance,
3) Develop and validate a method for measuring and analysing the cognitive load in CAD activities.

Hypothesis:
The method for measuring and analysing the cognitive load, based on the monitoring of psychophysiological responses, enables the assessment of the engineering designer's level of CAD activity performance.

Material, participants, methodology and plan of research *(suggested length: 6500 characters with spaces)*

The purpose of the research project is to develop support in the form of the method that enables understanding and assessing the engineering designers' performance in CAD activities. It is intended to provide such support by modelling, measuring, and analysing the cognitive load in CAD activities. The prerequisite for the method development is a thorough understanding of the cognitive load, engineering designers' performance, and the means to measure and analyse them in CAD activities. The current understanding of these phenomena and means is unsatisfactory, which asks for theoretical development prior to the prescription of the method. The guidelines for developing the understanding and support are found within the Design Research Methodology (DRM) [24] that will be used as the main research framework. The guidelines provided by the DRM will be complemented by the principles of Experimental Design Research (EDR) [25]. The research activities are organised in four main stages: research clarification, descriptive study I (that embraces literature review and preliminary empirical studies), prescriptive study (that proposes theoretical models and method) and descriptive study II (that validates the developed theoretical models and method).

Research clarification
The research clarification stage incorporates the literature reviews related to engineering designers' performance and cognitive load in CAD activities to understand the state of art and highlight the research gaps. The literature review starts with investigating these phenomena' theories, models, and concepts to build the theoretical basis for their understanding in the CAD context. In addition, dimensions through which the engineering designers' performance (e.g. efficiency and effectiveness) and cognitive load (e.g. mental load and mental effort) can be conceptualised, quantified, and categorised will be identified. The literature review will further focus on researching the available methods and tools for measuring and analysing the cognitive load and engineering designers' performance through the identified dimensions. This research will include studying the existing experimental frameworks, protocols, and guidelines

[2] The sequence of listing the objective and hypotheses depends on the area of research.

from engineering, psychology, and neuroscience. In addition, the requirements for developing the method for assessing the level of engineering designers' performance by modelling, measuring, and analysing cognitive load will be identified through the literature reviews. Finally, the research goals, the main research questions, and the hypotheses will be clarified based on the gained insights.

Descriptive study I

The descriptive study builds on the knowledge gained through the initial literature reviews conducted in the Research clarification stage. The body of knowledge will be augmented with reviews of the more specific literature, defined based on the outcomes of the first stage. In particular, the key elements, their characteristics, and the relationships among them (needed for the modelling in the further steps) will be identified. In addition to the literature reviews, preliminary empirical studies will be conducted in this stage. The findings of preliminary empirical studies will complement the initial understanding provided by the literature review. In particular, preliminary empirical studies will be conducted to augment the identification of the factors that may influence cognitive load and engineering designers' performance in CAD activities since the literature does not provide much evidence related to these topics. Furthermore, the suitability of the methods and tools for measuring the cognitive load in CAD activities will be tested and validated through preliminary experimental studies. Due to the multidimensional character and the resulting complexity of cognitive load, qualitative and quantitative research methods will be combined for its assessment [16]. In particular, the experimental studies will incorporate the subjective assessment (e.g. self-rated scales, post-task interviews, and feedback sessions), the psychophysiological measurement (e.g. electroencephalography and eye tracking), and the performance measurement (e.g. number of errors, task completion time, analysis of CAD log files) methods for measuring and analysing cognitive load. Both the engineering practitioners and the students (from the UNIZG-FMENA and POLIMI) will be considered as the study participants. The experimental studies will be conducted using the equipment available in CADLab at the University of Zagreb – Faculty of Mechanical Engineering and Naval Architecture (UNIZG-FMENA, Croatia), the Virtual Prototyping & Human Modelling Lab at Politecnico di Milano (POLIMI, Italy), and DEPICT Lab at the Luleå University of Technology (LTU, Sweden).

Prescriptive study

Insights gathered through the literature reviews and the preliminary empirical studies will allow the development of the initial theoretical models of cognitive load and engineering designers' performance in CAD activities as the form of presenting the initial understanding of the existing situation. In addition to the key elements and relationships among them, the models will encompass the identified influencing factors as well as their effects on cognitive load and engineering designers' performance. Furthermore, gathered insights and results will be presented in the form of the methods and tools' overview to present the state of art. The overview will be accompanied by the advantages and disadvantages of methods and tools, their suitability for the given CAD context, and the challenges of their application for measuring and analysing the cognitive load in CAD activities.

The models will be utilised as a basis for developing the method that should enable the assessment and potential improvement of the engineering designers' performance. The theoretical models and the means for the measurement and the analysis of cognitive load in CAD activities present the key elements of the method.

The gained understanding of the existing situation will be used in designing the detailed experimental studies to be conducted in descriptive study II. The experimental design (including the experimental setup, procedure, and methods and tools for data gathering, processing and analysis) will be guided by the existing relevant frameworks (identified in the previous stages). For example, suggestions from the tEEG [26] and the TASKS [27] frameworks on how to study cognitive and affective states in engineering design will be considered. Furthermore, the experimental design will build upon the multimodal approaches to studying CAD activities and mechanical engineers' behaviour in design, such as [28] and [12].

Descriptive study II

The experimental studies will validate the initial theoretical models and complement them with the findings related to the effects of the identified influencing factors on cognitive load and engineering designers' performance. Furthermore, they will more closely explore the relationship between the cognitive load and the engineering designers' performance in CAD activities by controlling the influencing factors and analysing their effects on performance. This relationship should serve as a basis for assessing the engineering designers' performance through the measurement and analysis of the cognitive load.

In addition, the developed method (and the theoretical models that serve as its basis) will be validated using the criteria defined by the requirements identified in the first research stage. The validation results will highlight the advantages and disadvantages of the proposed method as well as the possibilities for further elaboration. Furthermore, the initial validation of the identified influencing factors' effects should reveal if the developed method can be used to assess and improve the performance.

As a part of descriptive study II, the main research hypothesis will be confirmed or rejected by comparing the research project results with the empirical data and insights previously reported in the available literature. Depending on the validation results, the factors (out of the identified influencing ones) may be determined that, when managed, are likely to significantly impact the engineering designers' performance in CAD activities and, consequently, the engineering design process. The way of managing the identified factors may be suggested accordingly to allow the implementation of the performance improvement. Finally, the yielded insights and the gathered empirical datasets will be prepared for future analyses that will use computation intelligence techniques (e.g. deep learning neural networks) to detect, monitor, and maintain engineering designers' cognitive states in CAD activities and support the execution of the design tasks by the automation of the recurrent CAD operations and procedures.

Expected scientific contribution of proposed research *(suggested length: 500 characters with spaces)*
The scientific contribution of the proposed research is manifested through: 1) The theoretical model of cognitive load in CAD activities, 2) The theoretical model of engineering designer's performance in CAD activities, 3) The method for measuring and analysing the cognitive load in CAD activities.

List of literature cited *(no more than 30 references)*

[1] D. G. Ullman, "Toward the ideal mechanical engineering design support system," *Res. Eng. Des. - Theory, Appl. Concurr. Eng.*, vol. 13, no. 2, pp. 55–64, 2002, doi: 10.1007/s00163-001-0007-4.

[2] V. Hubka, *Principles of engineering design*, vol. 46, no. 536. Butterworth Scientific, 1980.

[3] E. Pei, I. Campbell, and M. Evans, "A taxonomic classification of visual design representations used by industrial designers and engineering designers," *Des. J.*, vol. 14, no. 1, pp. 64–91, 2011, doi: 10.2752/175630610X12877385838803.

[4] G. Goldschmidt, "Manual Sketching: Why Is It Still Relevant?," in *Philosophy of Engineering and Technology*, Springer London, 2017, pp. 77–97.

[5] C. McMahon, "Design Informatics: Supporting Engineering Design Processes with Information Technology," *J. Indian Inst. Sci.*, vol. 95, no. 4, pp. 365–377, 2015, [Online]. Available: http://journal.library.iisc.ernet.in/index.php/iisc/article/view/4585.

[6] F. J. O'Donnell and A. H. B. Duffy, *Design Performance*. Springer London, 2005.

[7] J. Gopsill, C. Snider, L. Shi, and B. Hicks, "Computer aided design user interaction as a sensor for monitoring engineers and the engineering design process," *Proc. Int. Des. Conf. Des.*, vol. DS 84, pp. 1707–1718, 2016.

[8] P. Rosso, J. Gopsill, S. Burgess, and B. Hicks, "Investigating and characterising variability in CAD modelling and its potential impact on editability: An exploratory study," *Comput. Aided. Des. Appl.*, vol. 18, no. 6, pp. 1306–1326, 2021, doi: 10.14733/cadaps.2021.1306-1326.

[9] S. Lee and J. Yan, "The impact of 3D CAD interfaces on user ideation: A comparative analysis using SketchUp and Silhouette Modeler," *Des. Stud.*, vol. 44, pp. 52–73, 2016, doi: 10.1016/j.destud.2016.02.001.

[10] L. Hay, P. Cash, and S. McKilligan, "The future of design cognition analysis," *Des. Sci.*, vol. 6, no. 20, pp. 1–26, 2020, doi: 10.1017/dsj.2020.20.

[11] M. H. Rahman, C. Schimpf, C. Xie, and Z. Sha, "A computer-aided design based research platform for design thinking studies," *J. Mech. Des.*, vol. 141, no. 12, pp. 1–12, 2019, doi: 10.1115/1.4044395.

[12] A. Sivanathan, T. Lim, J. Ritchie, R. Sung, Z. Kosmadoudi, and Y. Liu, "The application of ubiquitous multimodal synchronous data capture in CAD," *CAD Comput. Aided Des.*, vol. 59, pp. 176–191, 2015, doi: 10.1016/j.cad.2013.10.001.

[13] D. Robertson, K. Ulrich, and M. Filerman, "Cognitive complexity and CAD systems: Beyond the drafting board metaphor," Cambridge, Massachusetts, WP #3244-91-MSA, 1991.

[14] A. Dillon and M. Sweeney, "The application of cognitive psychology to CAD," *People Comput. IV*, no. January 1988, pp. 477–488, 1988, [Online]. Available: http://hdl.handle.net/10150/106215.

[15] J. J. Shah, J. Woodward, and S. M. Smith, "Applied tests of design skills-part II: visual thinking," *J. Mech. Des.*, vol. 135, no. 7, p. 071004, 2013, doi: 10.1115/1.4024228.

[16] J. Sweller, P. Ayres, and S. Kalyuga, *Cognitive Load Theory*. Springer, 2011.

[17] W. Jia, F. von Wegner, M. Zhao, and Y. Zeng, "Network oscillations imply the highest cognitive workload and lowest cognitive control during idea generation in open-ended creation tasks," *Sci. Rep.*, vol. 11, no. 1, pp. 1–24, 2021, doi: 10.1038/s41598-021-03577-1.

[18] B. Majdic, C. Cowan, J. Girdner, W. Opoku, O. Pierrakos, and E. Barrella, "Monitoring Brain Waves in an Effort to Investigate Student ' s Cognitive Load During a Variety of Problem Solving Scenarios," in *Systems and Information Engineering Design Symposium (SIEDS)*, 2017, pp. 186–191.

[19] G. B. Dadi, P. M. Goodrum, T. R. B. Taylor, and C. M. Carswell, "Cognitive Workload Demands Using 2D and 3D Spatial Engineering Information Formats," *J. Constr. Eng. Manag.*, vol. 140, no. 5, pp. 1–8, 2014, doi: 10.1061/(asce)co.1943-7862.0000827.

[20] A. M. Maier, N. Baltsen, H. Christoffersen, and H. Strrle, "Towards Diagram Understanding: A Pilot-Study Measuring Cognitive Workload Through Eye-Tracking," *Proc. Intl. Conf. Hum. Behav. Des.*, no. October, pp. 1–6, 2014.

[21] H. Nolte and C. McComb, "The cognitive experience of engineering design: an examination of first-year student stress across

principal activities of the engineering design process," *Des. Sci.*, vol. 7, no. May, 2021, doi: 10.1017/dsj.2020.32.

[22] P. Nguyen, T. A. Nguyen, and Y. Zeng, "Empirical approaches to quantifying effort, fatigue and concentration in the conceptual design process: An EEG study," *Res. Eng. Des.*, vol. 29, no. 3, pp. 393–409, 2018, doi: 10.1007/s00163-017-0273-4.

[23] H. H. Choi, J. J. G. van Merriënboer, and F. Paas, "Effects of the Physical Environment on Cognitive Load and Learning: Towards a New Model of Cognitive Load," *Educ. Psychol. Rev.*, vol. 26, no. 2, pp. 225–244, 2014, doi: 10.1007/s10648-014-9262-6.

[24] L. Blessing and A. Chakrabarti, *DRM: A Design Reseach Methodology*, no. September. 2009.

[25] P. Cash, T. Stanković, and M. Štorga, *Experimental Design Research: Approaches, Perspectives, Applications*. Springer Nature, 2016.

[26] M. Zhao, W. Jia, D. Yang, P. Nguyen, T. A. Nguyen, and Y. Zeng, "A tEEG Framework for Studying Designer ' s Cognitive and Affective States," *Des. Sci.*, vol. 6, pp. 1–47, 2020, doi: 10.1017/dsj.2020.28.

[27] J. Yang, L. Yang, H. Quan, and Y. Zeng, "Implementation Barriers: A TASKS Framework," *J. Integr. Des. Process Sci.*, vol. 25, no. X, pp. 1–14, 2021, doi: 10.3233/jid-210011.

[28] Y. Liu, J. M. Ritchie, T. Lim, Z. Kosmadoudi, A. Sivanathan, and R. C. W. Sung, "A fuzzy psycho-physiological approach to enable the understanding of an engineer's affect status during CAD activities," *CAD Comput. Aided Des.*, vol. 54, pp. 19–38, 2014, doi: 10.1016/j.cad.2013.10.007.

Total cost estimate of proposed research *(in kuna)*

350 000 HRK

Proposed sources of funding for research

Type of funding	**Title of project**	**Project leader**	**Signature**
National funding	Resources of the projects managed by the supervisor (ERASMUS, collaboration with industry)	Assoc. Prof. Stanko Škec, PhD. M.E.	
International funding	Resources of the projects managed by the supervisor (ERASMUS, collaboration with industry)	Assoc. Prof. Niccolò Becattini, PhD. M.E.	
Other types of projects	Resources of the Chair of Design and Product Development at UNIZG-FMENA (collaboration with industry, international DESIGN conference organization)	Prof. Mario Štorga, PhD. M.E.	
Self funding	Italian Government Scholarships (Application by candidate)		
	Erasmus+ Traineeship (Application by candidate)		
Session of the Ethics Committee at which consent was given to the research proposal[3]	-		

[3] Fill out only if needed

Agreement of the mentor and the doctoral candidate to request for topic approval

I declare under responsibility that I agree with the topic whose approval is requested.

Signature

Assoc. Prof. Stanko Škec, PhD. M.E.

Signature

Assoc. Prof. Niccolò Becattini, PhD. M.E.

Signature

Fanika Lukačević, mag. ing. mech.

STATEMENT

I declare under responsibility that I have not submitted a request for approval of an identical dissertation topic at any other university[4].

Zagreb, 14.12.2022.

Signature

Fanika Lukačević, mag. ing. mech.

Official stamp here

[4] Not required in case of dual doctorate (*Cotutelle de these*)