

EDUCATING GENERATIVE DESIGNERS IN ENGINEERING

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PROJECT GOALS

To **define**, **implement**, and **disseminate** generative design thinking—a new form of design thinking enhanced by computational thinking—to **facilitate** the teaching and learning of **generative design**.

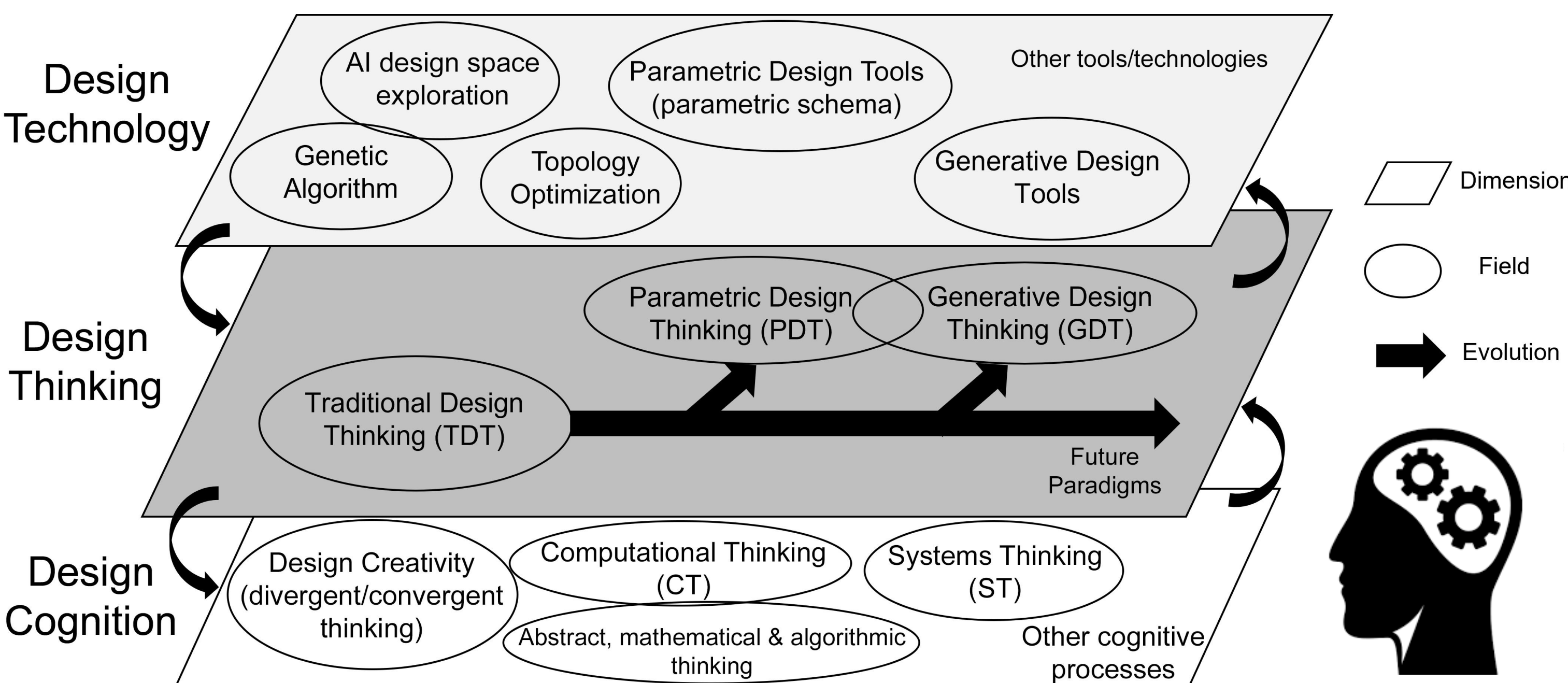
RQ1: Theoretical perspective: What are the **essential elements** of **generative design thinking** that students must acquire in order to work effectively at the human-technology frontier in engineering?

RQ2: Practical perspective: To what extent and in what ways can the project products **support the learning of generative design** as indicated by students' gains in generative design thinking?

RQ3: Affective perspective: To what extent and in what ways can **artificial intelligence** affect the **professional formation** of engineers shown by changes in interest and self-efficacy in engineering?

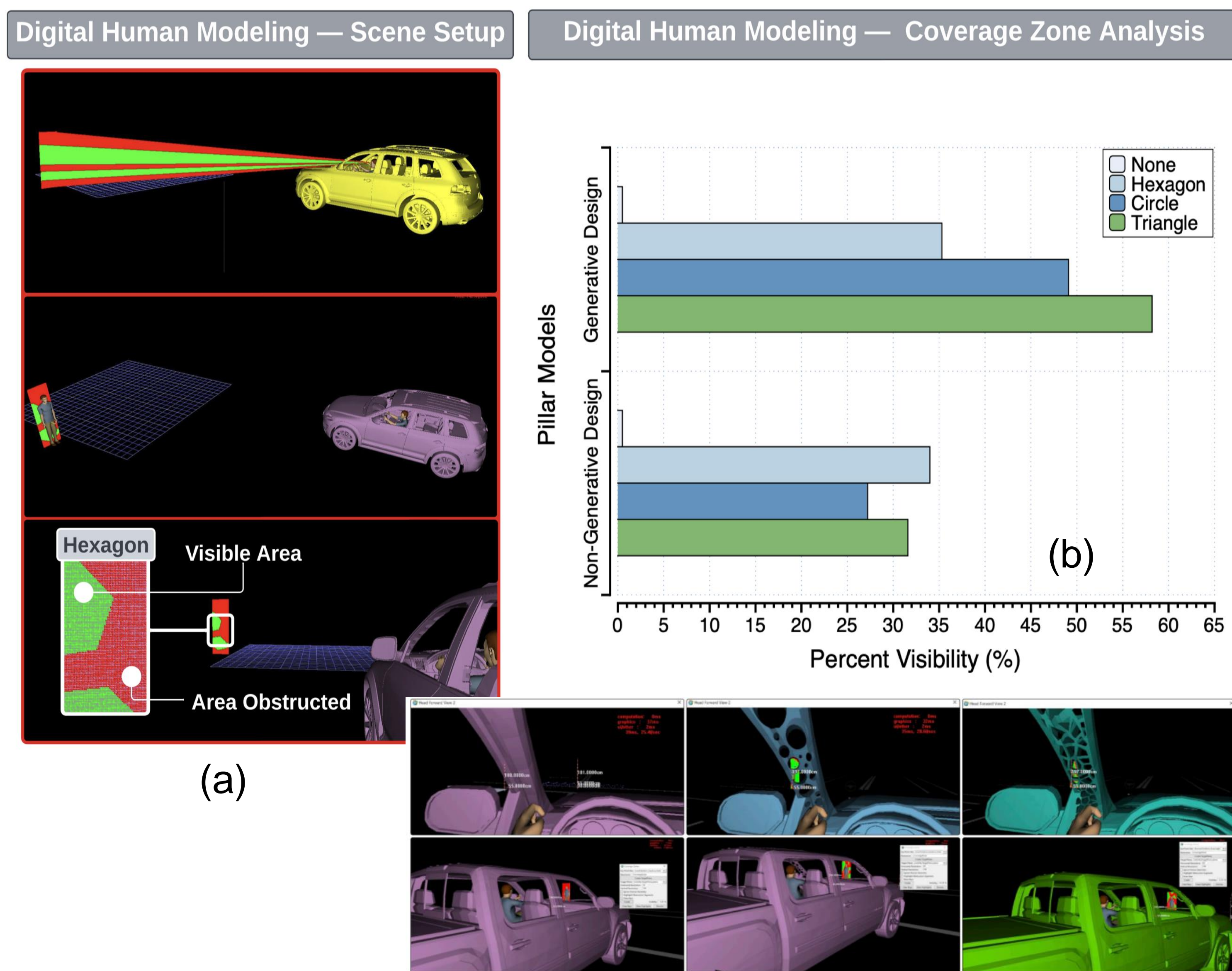
MAJOR ACTIVITIES (2022-2023)

Activity 1: Investigation on the relationships between traditional engineering design thinking, parametric design thinking, and related design thinking concepts (engineering systems thinking, computational thinking) in seeking an operational definition of Generative Design Thinking.



Evolving Design Thinking Model: With the EDT model, we will examine the influence of technology development on the formation of design thinking, the cognitive competencies associated with each design thinking concept, and the design methodologies implementing the corresponding design thinking concept. We provide an in-depth understanding of GDT and a clarification of the obscure boundaries between the many design thinking concepts.

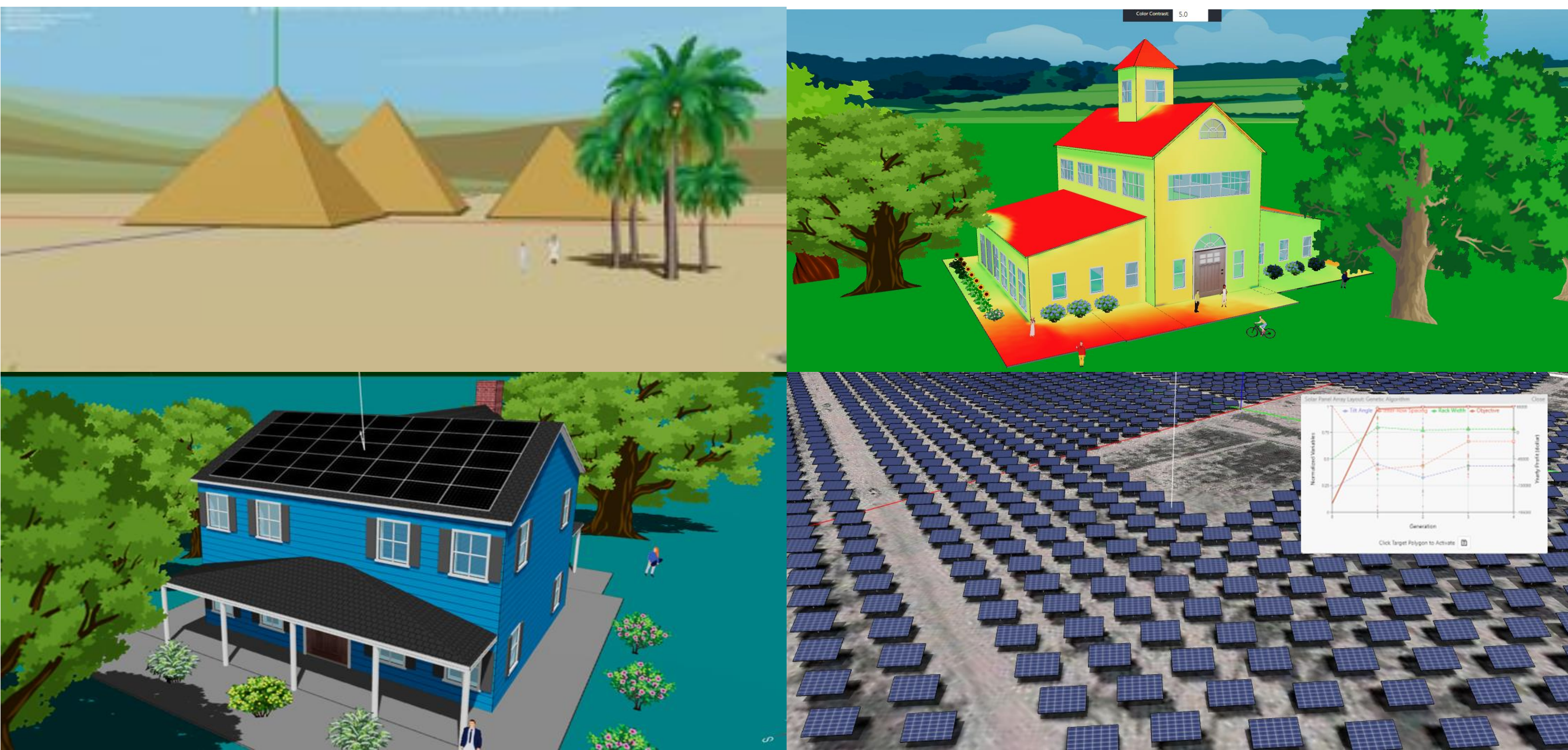
Activity 2: Injecting human factors into a generative design to optimize drivers' forward field of view (FoV) that is obscured by the A-pillars. We assess the concept of generatively designed *see-through* A-pillars and quantify vision obstructions via the Digital Human Modeling approach.



(a) Ray casting analysis conducted to quantify percent obstruction.

(b) Percent visibility differences between A-pillars concepts with non-generative and generative design models.

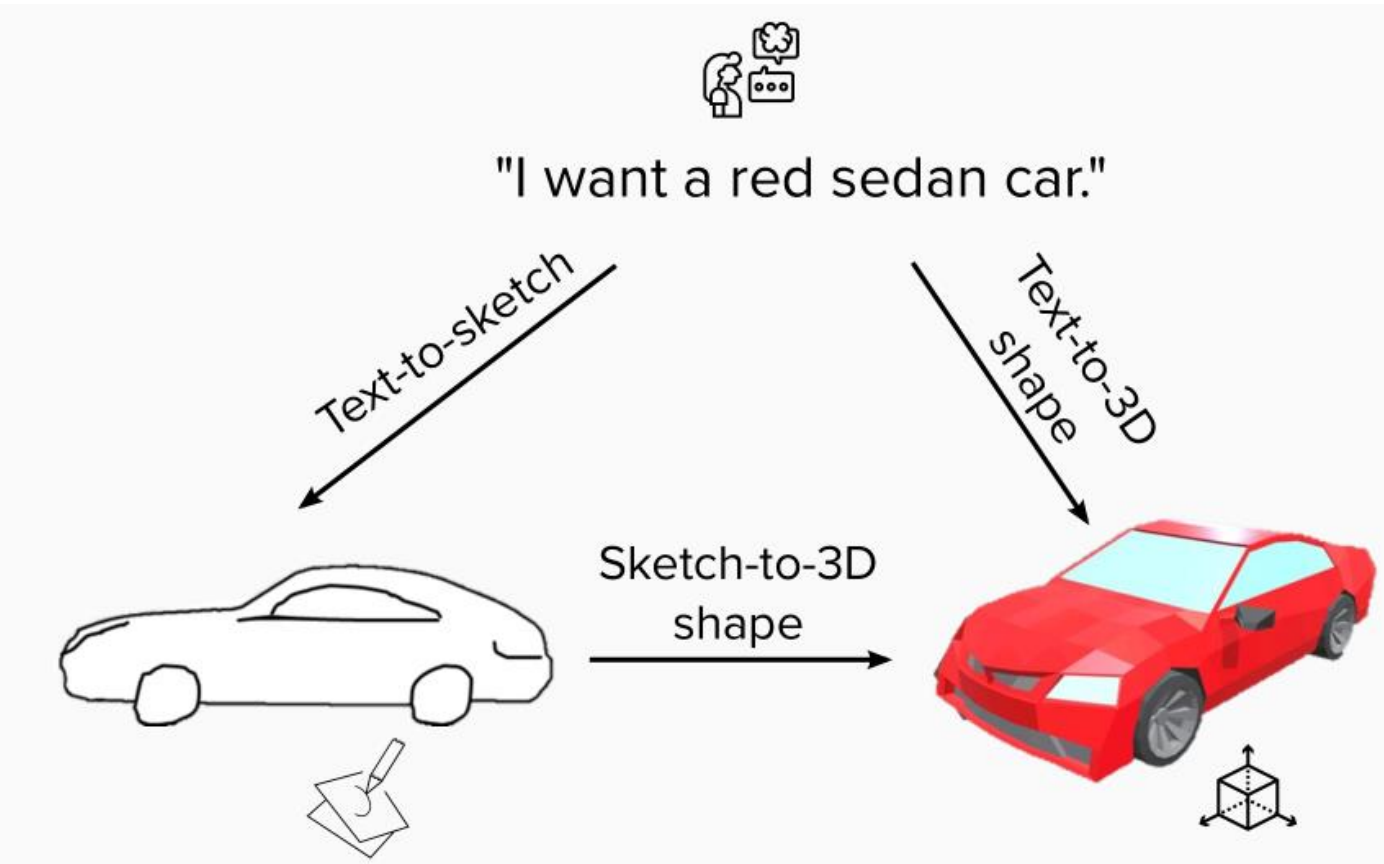
Activity 3: The design and development of Aladdin, an open-source computer-aided generative design and engineering software, with the goal to support the learning and teaching of generative design.



Aladdin is a Web-based CAD platform that is reimagining design in the age of AI by implementing generative design in the fields of architectural engineering and renewable energy engineering. It allows researchers to explore the new human-technology frontier of AI in engineering design, especially how design thinking evolves with the paradigm shift of AI-based generative design. The platform provides an alternative to commercial software that fosters independent research in engineering education.

Activity 4: Exploration of data-driven methods for the realization of generative design in support of software development.

(1) A systematic literature review on methods for deep learning of cross-modal tasks (DLCMT)



Cross-Modal Tasks	Article
Text-to-3D shape retrieval	2
Text-to-3D shape generation	6
Text-to-sketch generation	4
Sketch-to-3D retrieval	19
Sketch-to-3D generation	18
Cross-modal design integration	5

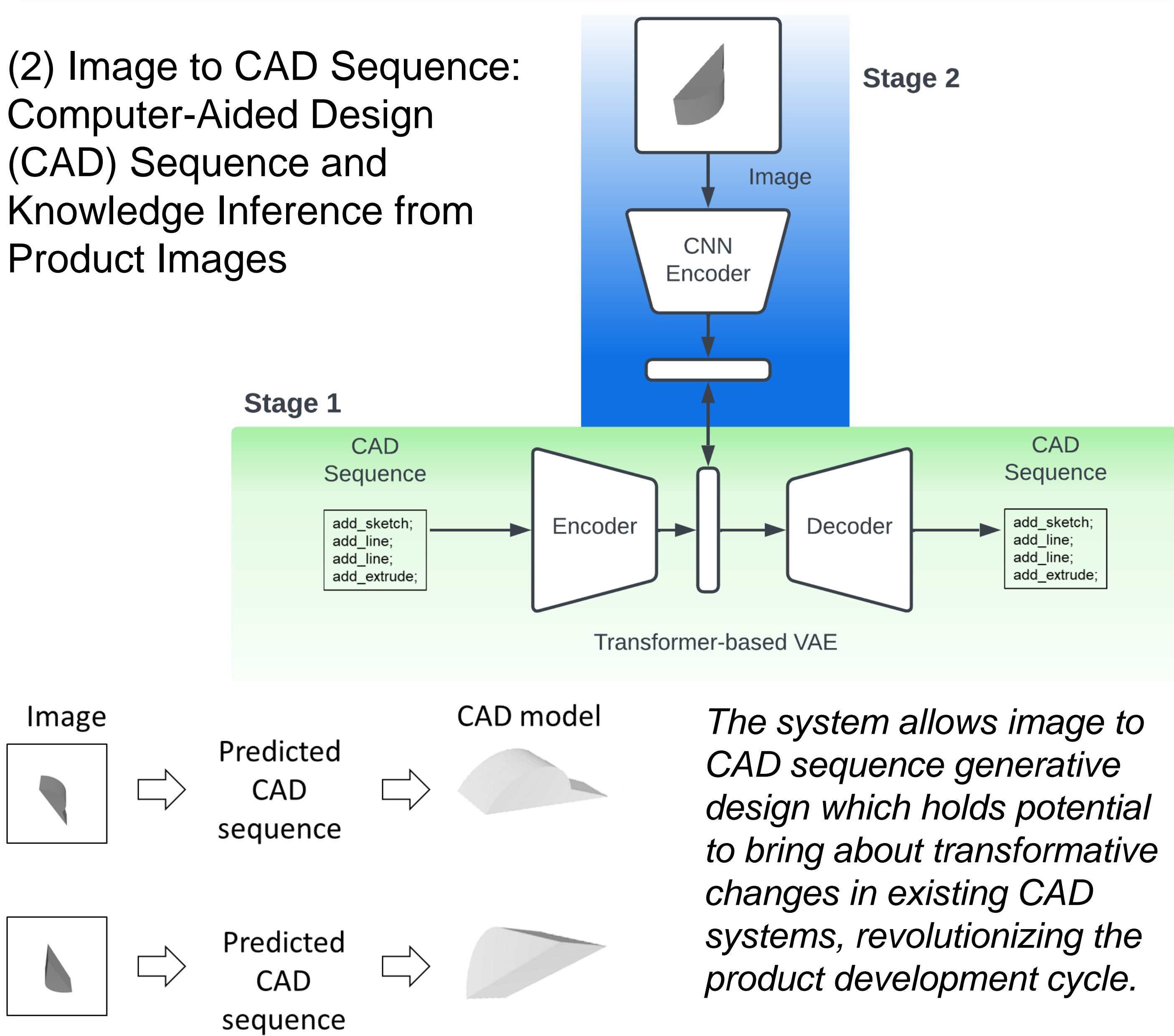
Opportunities:

- Incorporate human inputs for human-supervised generative design in design search, design creation, and design integration
- Democratization of product design
- AI-based pedagogical tools
- Immersive design environment

Challenges

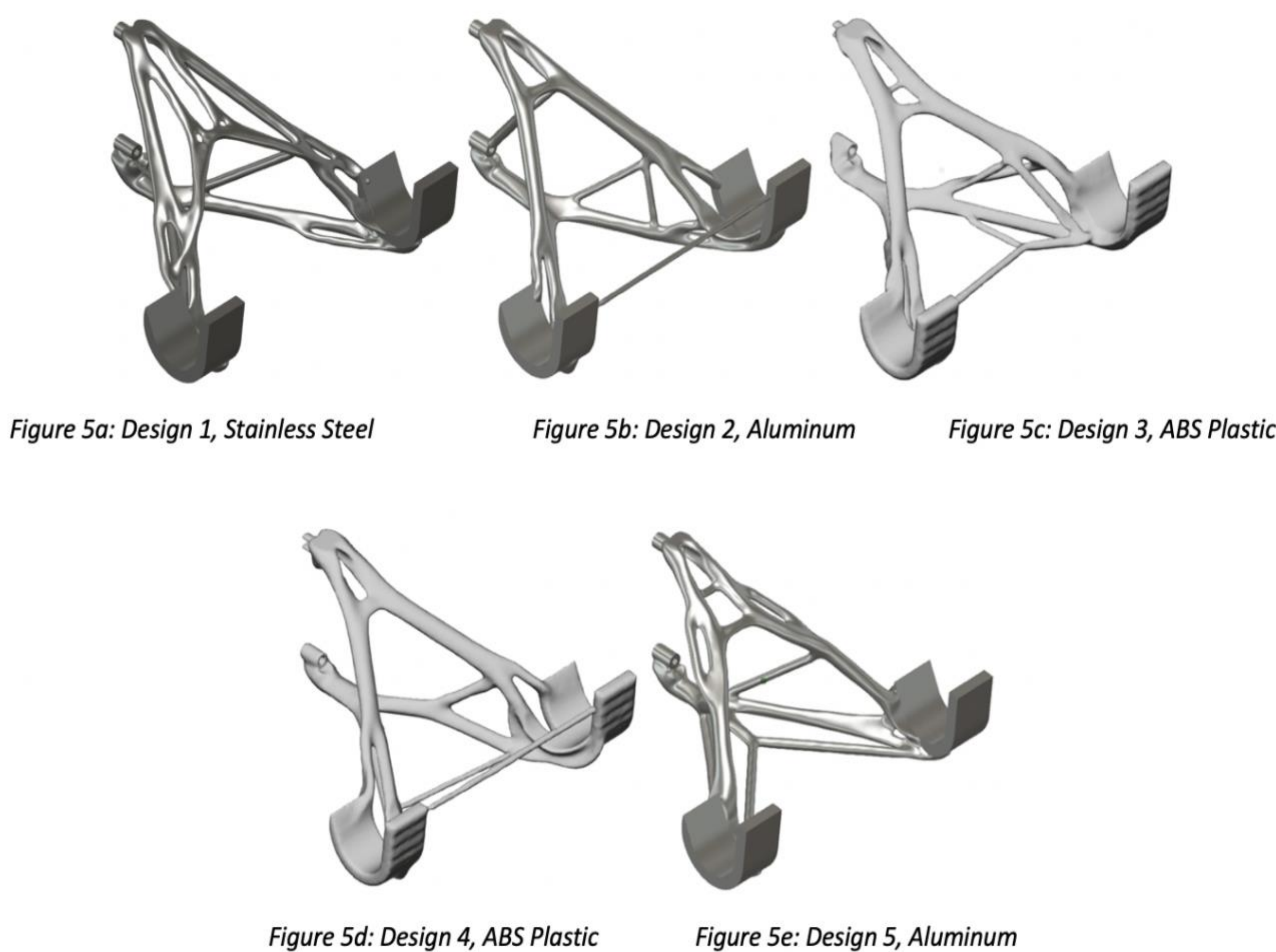
- Datasets: engineering performance and manufacturability
- Complex system design
- 3D representations
- Generalizability

(2) Image to CAD Sequence: Computer-Aided Design (CAD) Sequence and Knowledge Inference from Product Images

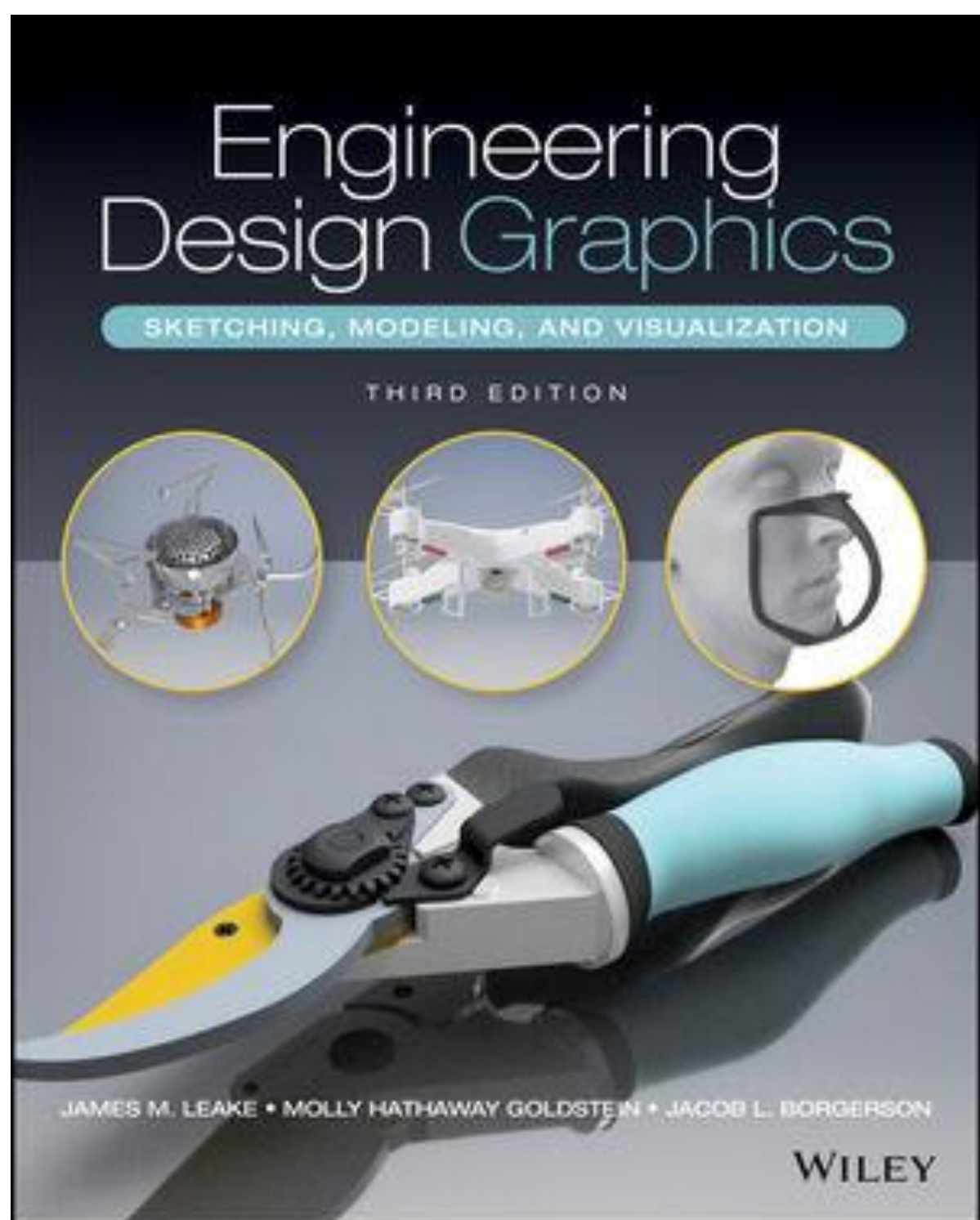


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Activity 5: Design and implementation of curriculum modules based on existing generative design technologies offered by Fusion 360 in collaboration with our industrial partner from Autodesk Inc. Data collection and analysis of students' learning data collected using the Fusion 360 based generative design lab modules.



~700 students used the materials developed in an introductory design and graphics course at UIUC.



We are broadly disseminating these GD techniques to other institutions by including them in co-PI Goldstein's engineering design graphics textbook, "Engineering Design & Graphics 3rd Edition," released in March 2022. In this book, we include a new chapter on CAD Solid Modeling to details a generative design workflow.

PUBLICATIONS

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2. H. O. Demirel, M. H. Goldstein, X. Li, & Z. Sha, "Human-Centered Generative Design Framework: An Early Design Framework to Support Concept Creation and Evaluation," International Journal of Human-Computer Interaction, 1-12. (2023).
3. X. Li, Y. Wang, Z. Sha, "Deep-Learning Methods of Cross-Modal Tasks for Conceptual Design of Product Shapes: A Review," Journal of Mechanical Design, volume 145, issue 4, pp: 041401 (20). (2023).
4. X. Li, Y. Wang, Z. Sha, "Deep Learning of Cross-Modal Tasks for Conceptual Design of Engineered Products: A Review," ASME 2022 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, St. Louis, MO, Aug. 14-17, 2022.
5. X. Li, M. H. Goldstein, O. Demirel, Z. Sha "Exploring Generative Design Thinking for Engineering Design and Design Education," 2021 ASEE Midwest Section Conference, Virtually hosted in Fayetteville, AR, Sep. 13-15, 2021.
6. M. H. Goldstein, J. Sommer, N. T. Buswell, X. Li, Z. Sha, O. Demirel, "Uncovering Generative Design Rationale in the Undergraduate Classroom," 2021 IEEE Frontiers in Education Conference (FIE), Lincoln, NE, Oct. 13-16, 2021.
7. M. Rahman, C. Xie, Z. Sha, "Design Embedding: Representation Learning of Design Thinking for Clustering Design Behaviors," ASME 2021 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Virtual Conference, Aug. 17-20, 2021.
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ACKNOWLEDGEMENT

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