

EDUCATING GENERATIVE DESIGNERS IN ENGINEERING

Dr. Zhenghui Sha (PI)¹, Dr. Darya L. Zabelina (Co-PI)², Dr. Molly Goldstein (Co-PI)³, Dr. Onan Demirel (Co-PI)⁴, Dr. Charles Xie (Co-PI)⁵, John Clay¹, Alexandra Brown³, Jennifer Standridge², Xingang Li¹, Molla Rahman², Sriram Srinivasan⁴

¹ University of Texas at Austin, ² University of Arkansas, ³ University of Illinois at Urbana-Champaign, ⁴ Oregon State University, ⁵ Institute for Future Intelligence



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**.

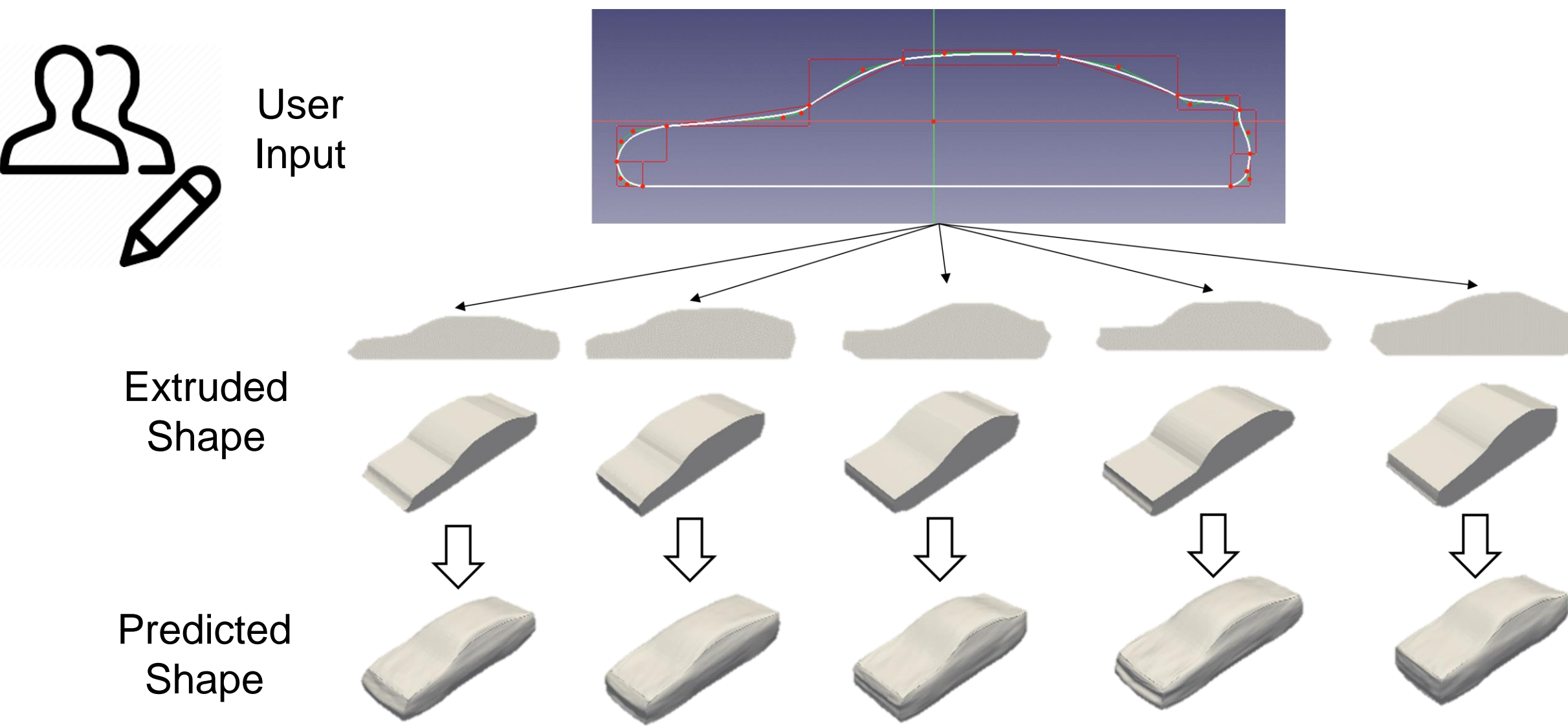
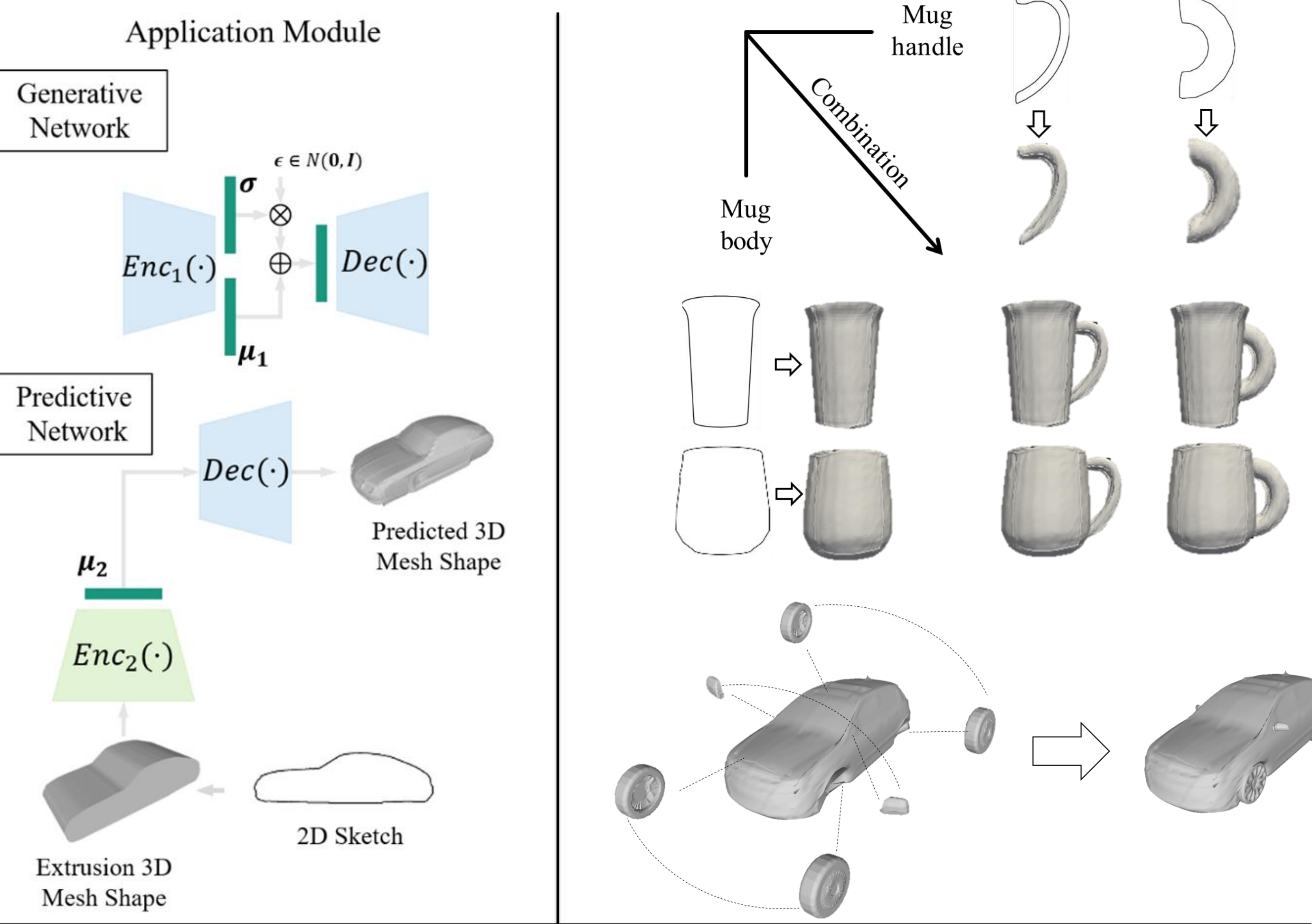
RQ1: Theoretical perspective: What are the **essential elements** of **generative design thinking** that students must acquire in order to work effectively at the human-technology frontier in engineering?

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?

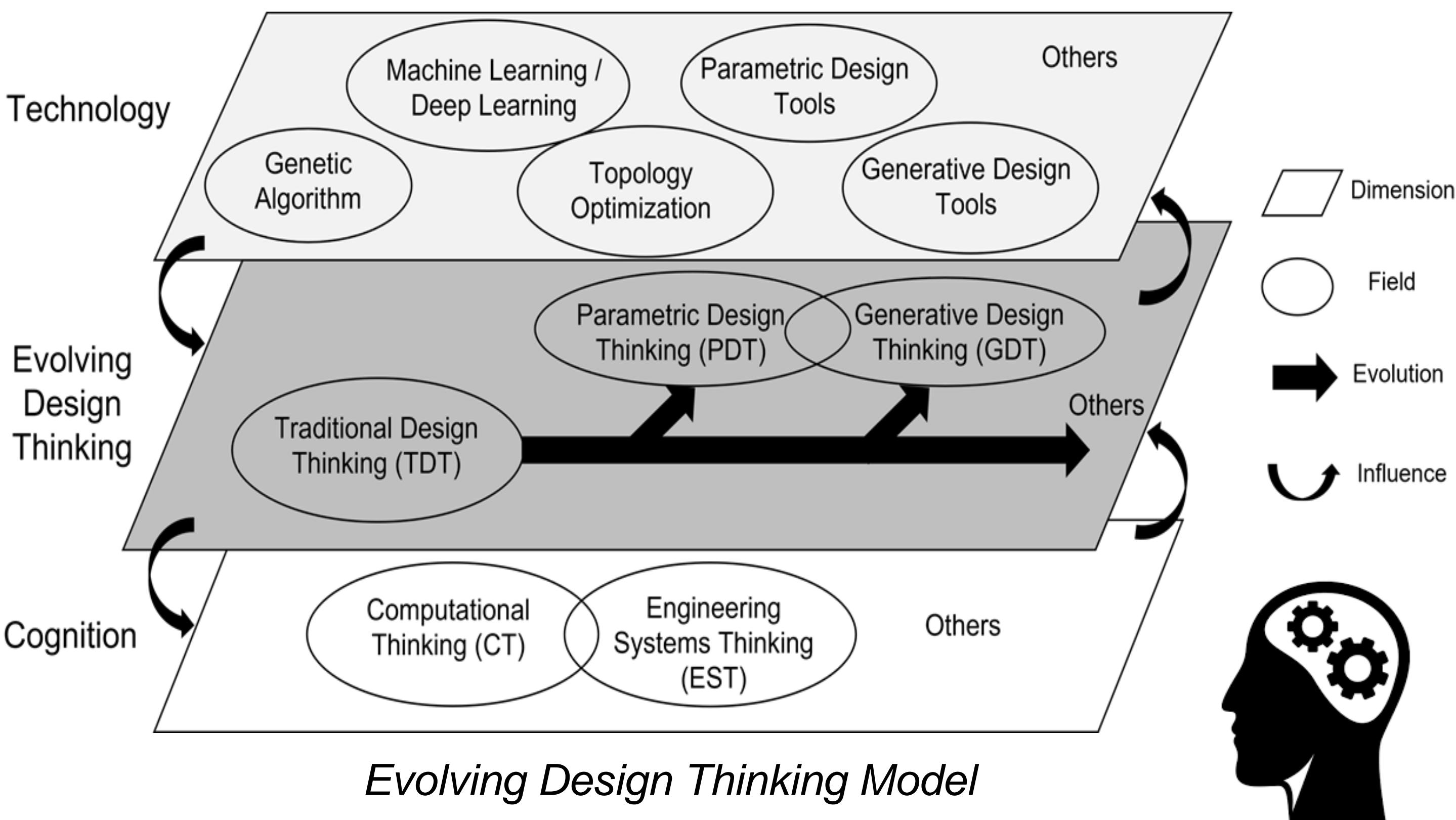
MAJOR ACTIVITIES (2019-2022)

Activity 1: Exploration of data-driven methods for the realization of generative design in support of software development.

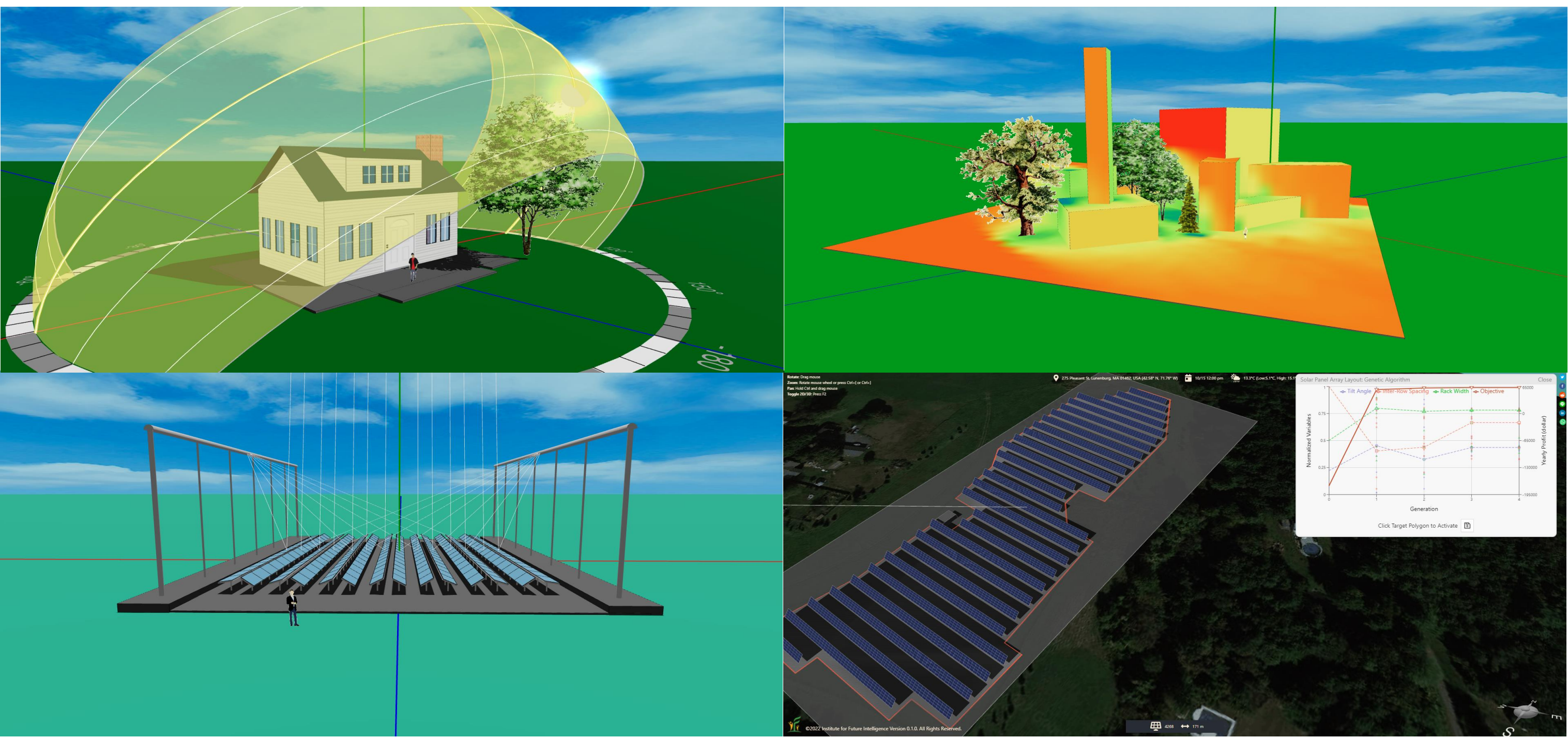


Data-driven generative design methods (part-aware generative design and sketch-to-3D design)

Activity 2: Investigation on the relationship between engineering systems thinking, parametric design thinking, computational thinking, and engineering design thinking in seeking an operational definition of generative design thinking.



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 being used to implement 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: The design and refinement of the design challenge-based human-subject experiment for the collection of design data and designers' behavioral data using Aladdin.



The computer-aided design (CAD) model that was developed. Left: a Google Maps image of the area designers worked in. Top right: A top-down view of the corresponding Aladdin model. Bottom right: Winners of the design contest receiving their prizes.

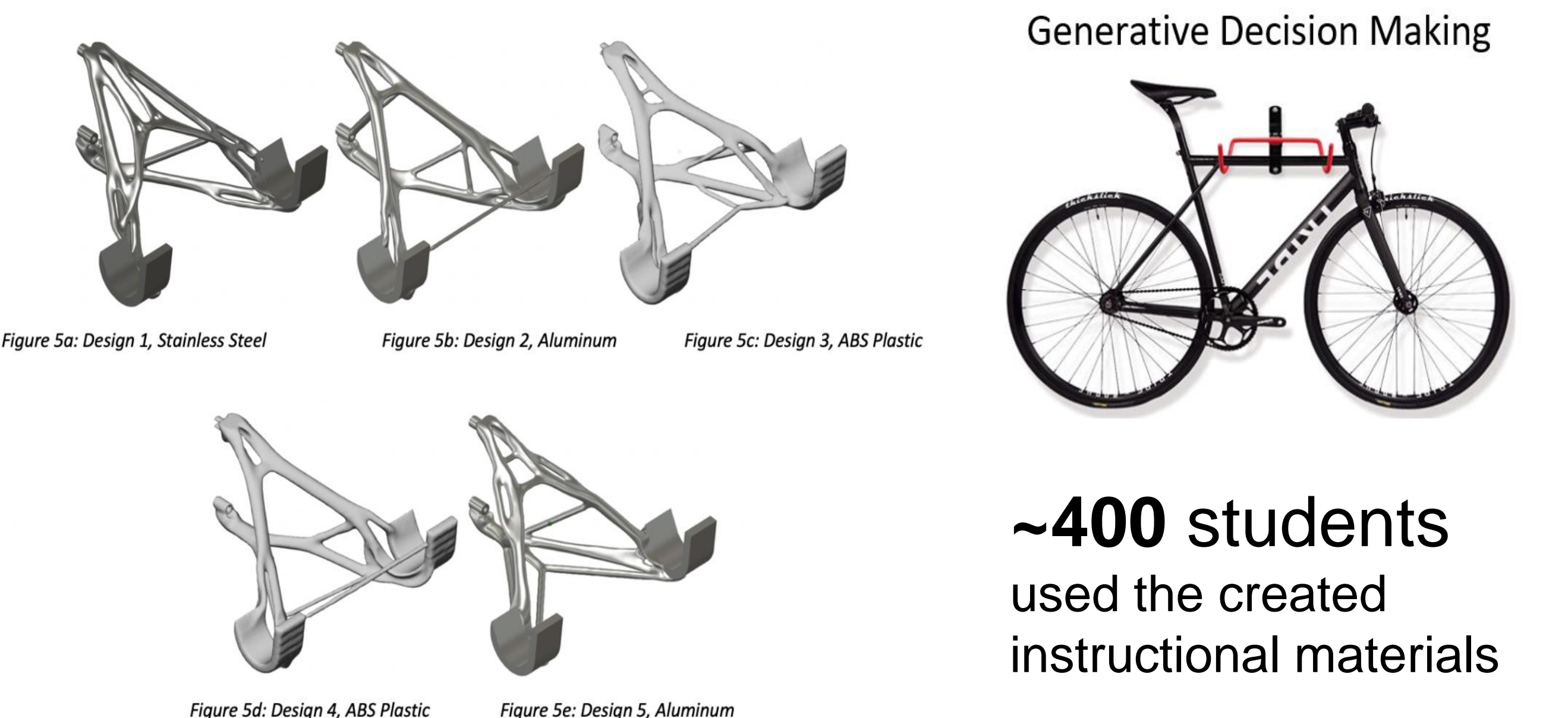
Systems Thinking Factors	Cognitive Mapping	Psychological Tests
Thinking creatively	Creativity, imagination	Alternate Uses Task; Four-Factor Imagination Scale
Understand interconnections, system synergy, & analogies	Inductive & deductive inference; analogical thinking	International Cognitive Ability Resource
Consider simultaneous factors	Working memory	KeepTrack test; n-back test
Ask good questions; understand non-engineering factors	Openness to Experience	Big Five Personality Inventory

System thinking factors were captured with validated psychological tasks to measure designer cognition.



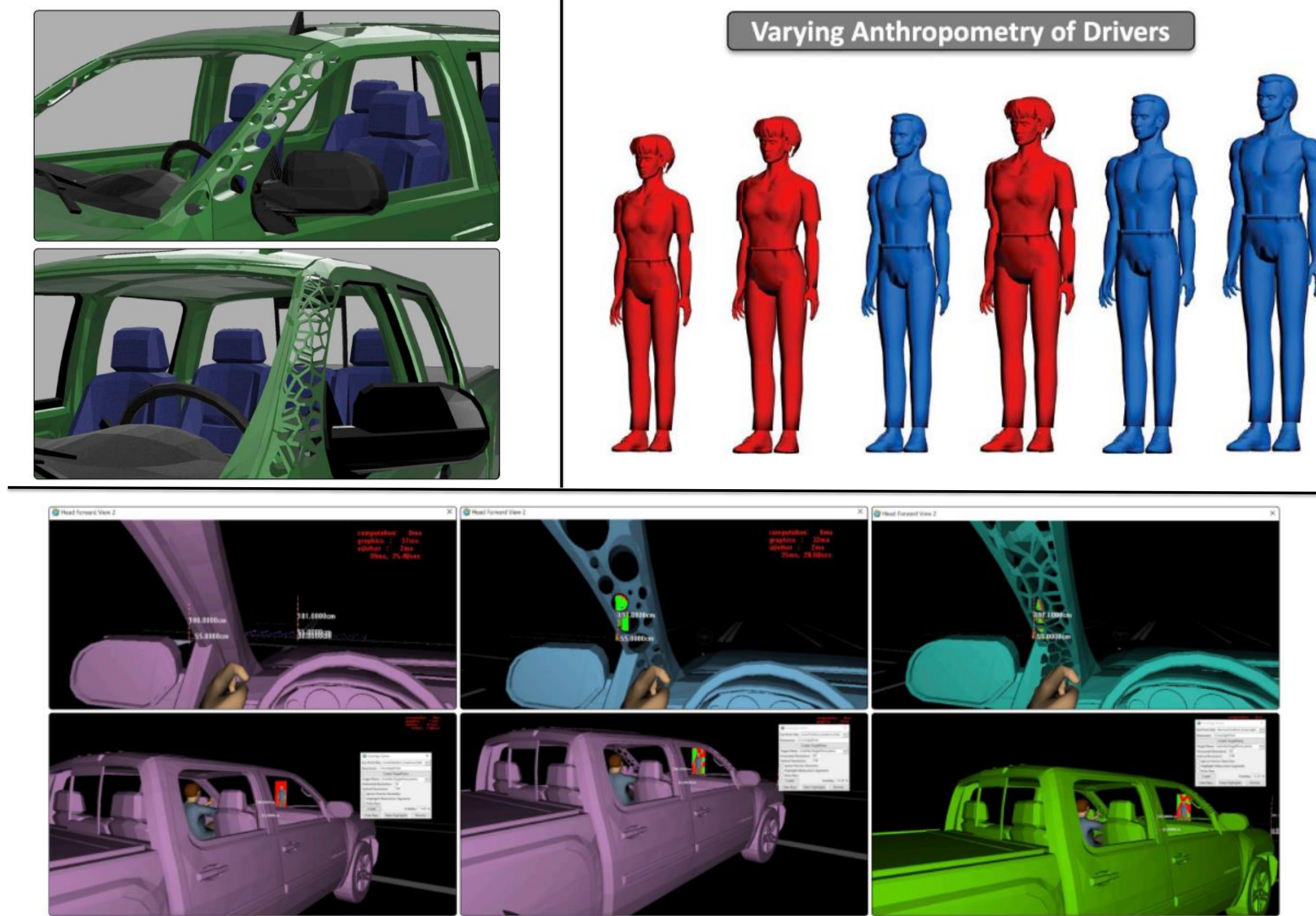
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Activity 5: Preliminary design of curriculum modules based on existing generative design technologies offered by Fusion 360 in collaboration with our industrial partner from Autodesk Inc. Data collection and analysis of students' learning data collected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



A new course material developed in an introductory design and graphics course at UIUC

Activity 6: Injecting human factors into a generative design framework 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.



Quantifying drivers' forward field of view (FoV) based on generatively designed A-pillar cut-out geometries. The circular and Voronoi cut-out geometries for a pickup/truck A-pillar were compared with the solid (benchmark) A-pillar model.

PUBLICATIONS

- 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, Missouri, Aug. 14-17, 2022.
- 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.
- 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, Nebraska, Oct. 13-16, 2021.
- J. Clay, X. Li, M. H. Rahman, D. Zabelina, C. Xie, Z. Sha, "Modeling and Profiling Student Designers' Cognitive Competencies in Computer-Aided Design," The 23rd International Conference on Engineering Design, August 16-20, 2021, Gothenburg, Sweden.
- 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.
- X. Li, C. Xie, Z. Sha, "Part-Aware Product Design Agent Using Deep Generative Network and Local Linear Embedding", The 54th Hawaii International Conference on System Science (HICSS), January 5-8, 2020, Kauai, HI.
- J. Clay, M. H. Rahman, D. Zabelina, C. Xie, Z. Sha, "The Psychological Links between Systems Thinking and Sequential Decision Making in Engineering Design", The Ninth International Conference On Design Computing and Cognition (DCC), 29 June – 1 July 2020, Atlanta, GA.

ACKNOWLEDGEMENT

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