EDUCATING DESIGNERS FOR GENERATIVE ENGINEERING (EDGE)

2024 Advisory Board Meeting Research Report

Click Here for the NSF Project Page

Prepared by:

Dr. Zhenghui Sha	zsha@austin.utexas.edu
Dr. Molly H. Goldstein	mhg3@illinois.edu
Dr. Onan Demirel	onan.demirel@oregonstate.edu
Dr. Charles Xie	charles@intofuture.org
Xingang Li	xingang.li@utexas.edu
John Z. Clay	jzc298@utexas.edu
Nalin Varma	nvarma@utexas.edu
Yuewan Sun	yuewansun@utexas.edu

December 13th, 2024

Project Overview

Key Personnel - Research Team

Dr. Zhenghui Sha, University of Texas at Austin, Principal Investigator

- Dr. Zhenghui Sha is an Assistant Professor in the Walker Department of Mechanical Engineering at the University of Texas (UT) at Austin. His research focuses on system science and design science as well as the intersection between these two areas, with an emphasis on design theory, human-machine interaction, swarm manufacturing, and complex sociotechnical systems.

Dr. Molly H. Goldstein, University of Illinois Urbana-Champaign, Co-Principal Investigator

- Dr. Molly H. Goldstein is a Teaching Assistant Professor in Industrial and Enterprise Systems Engineering at the University of Illinois. Her research focuses on student designer trade-off decisions through the study of their design actions and thinking. Her studies often involve educational and professional contexts with cross-disciplinary collaborations.

Dr. Onan Demirel, Oregon State University, Co-Principal Investigator

- Dr. Onan Demirel is an Assistant Professor of Mechanical Engineering at Oregon State University. His research focuses on understanding human elements in the design process, and developing multi-disciplinary design theory and methods to explore inter-dependencies and co-evolution of the human element in engineering systems. His goal is to develop computational and experimental human-centered design theory and methodology to incorporate human factors engineering principles early in the design for product development.

Dr. Charles Xie, Institute for Future Intelligence, Co-Principal Investigator

- Dr. Charles Xie is the founder, President, CEO, and Chief Scientist of the Institute of Future Intelligence. His current work is focused on evolutionary computation algorithms that can be used to create artificially intelligent design tutors embedded in CAD and CAE software. He is also the creator of Aladdin, Energy2D, iFlow, Infrared Explorer, and Quantum Explorer, and a co-developer of Infrared Street View and Telelab.

Dr. Xingang Li, University of Texas at Austin, Student Researcher

- Xingang Li is a recently graduated Ph.D. student from the System Integration and Design Informatics Laboratory, having studied under Dr. Zhenghui Sha. He will soon

join the Department of Mechanical Engineering at the University of Melbourne. His research focuses on generative design and human-AI design collaboration.

John Z. Clay, University of Texas at Austin, Research Assistant

- John Z. Clay is a post-undergraduate Research Scientist Assistant in the System Integration and Design Informatics Laboratory, working under Dr. Zhenghui Sha. His research focuses on generative design thinking and the cognitive processes underlying generative design.

Nalin Varma, University of Texas at Austin, Student Researcher

- Nalin Varma is a Ph.D. student working as a Research Assistant in the Walker Department of Mechanical Engineering at the University of Texas at Austin, studying under Dr. Zhenghui Sha. His current research seeks to understand how undergraduate engineering students navigate the stages of engineering design within the generative design paradigm.

Yuewan Sun, University of Texas at Austin, Student Researcher

- Yuewan Sun is a Ph.D. student working as a research assistant at the Walker Department of Mechanical Engineering at the University of Texas at Austin, studying under Dr. Zhenghui Sha. Her current research focuses on generative design (GD), specifically in cross-modal generative AI and Large Language Models (LLM) for engineering design.

Aiden Hall, University of Illinois Urbana-Champaign, Student Researcher

- Aiden Hall is a Master's student in Dr. Molly Goldstein's lab at UIUC. His current work investigates the use of generative design in the design process, specifically the differences in quality between AI generated designs and those created solely by humans.

Alex Brown, University of Illinois Urbana-Champaign, Student Researcher

- Alex Brown is a recently graduated Masters student from Dr. Molly Goldstein's lab at UIUC. Alex' thesis work explored the roles of different aspects of creative cognition in generative design, and was recently published in the Journal of Mechanical Design ("A study on generative design reasoning and students' divergent and convergent thinking").

Dr. Dylan Bulseco, Institute for Future Intelligence, Senior Vice President, Principal Scientist

- Dr. Dylan Bulseco is a Senior Vice President and a principal scientist at IFI. He holds a Ph.D. in Biochemistry and Biophysics from Oregon State University and has over 20 years of research experience. His current work at IFI focuses on integrating

computational science, data science, and artificial intelligence into life sciences and biotechnology in a culturally relevant and responsive way to transform biological and biomedical research and education.

Andriy Kashyrskyy, Institute for Future Intelligence,

- Andriy Kashyrskyy is a software engineer and data scientist at IFI working on supporting learning and research by linking data across experiments and providing visual analytics for scientific inquiry. He recently graduated from Minerva University with a Bachelor's Degree in computer science, arts, and humanities.

Xiaotong Ding, Institute for Future Intelligence,

- Xiaotong Ding is a Principal Software Engineer at IFI. He graduated with a Master of Science degree in computer science and a Master of Science degree in mechanical engineering, both from New Jersey Institute of Technology. He is currently working on Aladdin, AIMS, and Telelab using full-stack technology. Since joining IFI in 2021, he has been a co-author for seven peer-reviewed journal papers.

Key Personnel - Advisory Board Members

Dan Banach, Autodesk, Inc.

- Dan Banach works at Autodesk, Inc. as a Senior Technical Manager. Mr. Banach is a nationally recognized expert in Mechanical Computer-Aided Design, and has authored 25 books on the Autodesk 3D mechanical design software.

Dr. Lydia Chilton, Columbia University

- Dr. Lydia Chilton is an Assistant Professor of Computer Science at Columbia University. Dr. Chilton's research focuses on human-computer interaction within computational design, with the goal to build AI tools that enhance human productivity.

Dr. Yan Fu, Ford Motor Company

- Dr. Yan Fu is a Senior Manager in Strategy and Enterprise Analytics at Ford Motor Company. Dr. Fu's research is focused on AI and advanced optimization technologies, and her work has resulted in 2 US patents, 4 Ford Trade Secrets, and 1 Defensive Publication.

Dr. John Gero, University of North Carolina at Charlotte

- Dr. John Gero is a Research Professor in Computer Science and Architecture at the University of North Carolina at Charlotte. Dr. Gero's research spans many disciplines, including design science, design computing, AI, computer-aided design, design cognition and design neurocognition. Dr. Gero has authored over 50 books and over 750 papers throughout his career, and is a leading figure in design research.

Susan Shaw, Ford Motor Company

- Susan Shaw is a Customer Research Lead in Advanced Driver-Assistance Systems at Ford Motor Company, and was previously a Senior Engineer at the Hyundia-Kia America Technical Center, Inc. Ms. Shaw's research focuses on human-machine interface and usability of vehicle systems.

Rachel Switzky, University of Illinois Urbana-Champaign

- Rachel Switzky is an Assistant Professor at the University of Illinois Urbana-Champaign. Ms. Switzky's research focuses on human-centered design curriculum and education, and advanced AI and machine learning methods to conduct molecular research.

Goals and Research Questions

Project Goals: To define, implement, and disseminate **generative design thinking** to facilitate the teaching and learning of generative design at undergraduate levels.

- *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 AI affect the professional formation of engineers as indicated by the changes of students' interest and self-efficacy in engineering?

Work Plan

Define generative design thinking by assimilating computational thinking to augment and reshape design thinking, thereby setting up 1) a theoretical foundation for research, 2) learning goals for students, and 3) the developmental goals for the project.

Develop the open-source Aladdin software with the goal to support the learning and teaching of generative design. The focus is on supporting students as they learn basic concepts of generative design, and allowing researchers to find ways to improve this human-AI collaboration.

Develop curriculum modules in Aladdin and Fusion360 using project-based learning. To engage students, we will adopt authentic engineering projects that can be realistically solved using generative design.

Conduct educational research through collaboration with ten other participating colleges and universities. With these collaborators, we will explore the strategies and methods for integrating instructional modules and embedding the educational research into introductory engineering and CAD courses.

Collect and analyze student data using instruments such as demographic surveys, questionnaires, self-efficacy measures, design reports, screencast videos, software logs, classroom observations, and participant interviews.

Disseminate the products of this project, including an operational definition of generative design thinking, the Aladdin software, and the instructional modules.

Collaborate with the Advisory Board to evaluate and advance the project through the evaluation given by the board members.

2023 Advisory Board Meeting Insights and Suggestions

The two key suggestions that resulted from the Year 4 Advisory Board Meeting and Evaluation Report (quoted) were to:

- Focus on disseminating the project materials via collaboration with academic and industrial partners: “Continue to refine educational tools… and further integrate generative design thinking into engineering education courses or real-world applications with industry partners.”
- Consider how existing foundational generative AI software could aid project software development: “Lean into foundation models like DALLE, GPT, etc, as much as possible. They can be a great complement to the software you are currently building, and they are a fantastic teaching tool.”

By following these suggestions and the research plan outlined in the original proposal, we have conducted the following highlighted research activities in Year 5:

- Collaborated with industry leaders PTC Inc. to host the Generative Generative Design in Engineering Research and Education Workshop to disseminate project curriculum materials and Aladdin, discuss generative design and generative design thinking topics, and stimulate future collaboration with the attendees invited from academia (four-year institutions and community colleges).
- Explored the use of large language models (LLMs) for data-driven design, specifically by developing two approaches (respectively) based on GPT-4 and GPT-4V to generate 3D CAD models and evaluate their efficiency.

Please see the following section for more information on these and other Year 5 research activities.

Year 5 Research Activities

Outreach & Broader Impact

1. Hosted the **Generative Design in Engineering Research and Education Workshop** in collaboration with PTC Inc. (engineering software company) to **disseminate** project materials, **discuss** topics related to generative design, and establish future research **collaboration**.

Figure 1: The Generative Design in Engineering Research and Education Workshop attendees at PTC Inc.'s headquarters in Boston, MA, May 25th, 2024.

A major activity was the planning, organization, and hosting of the Generative Design in Engineering Research and Education Workshop with industry collaborators PTC Inc. at their headquarters in Boston, MA, from May 22nd - May 24th. Seventeen in-person attendees from eleven different institutions convened to achieve three workshop goals: first, to discuss best practices in teaching generative design and generative AI in engineering; second, to exchange ideas on the development of curriculum for teaching generative design; and, third, to promote collaboration between partners in industry and academia to stimulate cutting-edge developments in generative design research and education in engineering. An Industrial Session featured a hands-on demonstration of the

in-development GD software Onshape from PTC, and a showcase of Aladdin, a major contribution of the EDGE project. Presentations from attendees were related to generative design thinking and ethical industrial applications of generative design, and followed by two roundtable discussion sessions on 1) best practices for implementing engineering education curriculum modules and 2) research in engineering and engineering design education. See here for a formal summary of the workshop.

2. **Results dissemination** to major technical and educational conferences as well as peer-reviewed journals.

We have shared the outcomes of our project, including: the updated Aladdin software, a generative design curriculum with Aladdin design challenges, Fusion360 instructional modules developed in Year 5 and modules from previous years, engineering education research based on these curriculum materials, exploration of multimodal LLMs for 3D CAD generation, and an operational definition of generative design thinking, through major technical and educational conferences and peer-reviewed journals. Publications included "A Study on Generative Design Reasoning and Students' Divergent and Convergent Thinking," published in the flagship Journal of Mechanical Design. We also participated in the 2024 ASEE NSF Grantees Poster session to receive community feedback and display project work at one of the leading engineering education conferences. See the **Products** section on pages 16-17 for more details on the publications that have resulted from this project.

Education Research

- **Development and refinement of curriculum materials** in Aladdin and Fusion360 to teach generative design and related concepts, and conducted **human-subjects data collection** to test curriculum materials and explore generative design thinking.

Aladdin Curriculum. Last year we developed an engineering design curriculum to teach generative design and fundamental engineering design concepts via a text-based curriculum accompanied by CAD practice activities in Aladdin. In Year 5, we completed two pilot studies by conducting think-aloud sessions from students reading the curriculum and completing the activities. The results of the first pilot study which were presented in last year's Advisory Board meeting and were published in the Design Computing and Cognition (DCC) 2024 conference (please see the Products section), and a second pilot

study with the same procedure was used to guide further refinements to the curriculum in which we added text to explain basic engineering design concepts to increase accessibility to a wider range of students, and developed auxiliary teaching documents to aid the dissemination and implementation of the curriculum. A new "Teacher's Handbook" divides the curriculum into five separate Learning Goals, each of which is accompanied by a PowerPoint slideshow curated to teach the concepts in a classroom setting, and a Glossary and Index for each major concept in the curriculum. Finally, we have developed pre-recorded lectures for each Learning Goal and are implementing these materials on our website to aid collaborative educational research (see Collaboration sub-section below).

Fusion360 Curriculum. In the previous years we have worked to integrate generative design technologies into existing design courses via the development of course modules to teach generative design in Fusion360. We have continued to use these GD modules in Year 5, and nearly 1,000 students have completed the Fusion360 modules in an undergraduate course at UIUC (Engineering Design Graphics). A new study was also conducted to explore the difference in the quality of designs generated via Fusion360's generative capabilities vs. those designed with a traditional, human-driven approach. Twenty student designers were prompted to use CAD to design two objects (suspension and excavator) using either traditional design for one and generative design for the other (order was randomized; Figure 2). Analysis confirmed the initial hypothesis by uncovering a significant difference in the quality (as judged by a rubric developed by the researchers). Specifically, designs created via generative design showed a significantly higher quality on average than those designed via the traditional, human-driven process. Finally, the paper which explored divergent and convergent thinking during generative design which was submitted to the Journal of Mechanical Design last year was accepted and published in Year 5; please see the **Products** section below for all Year 5 publications.

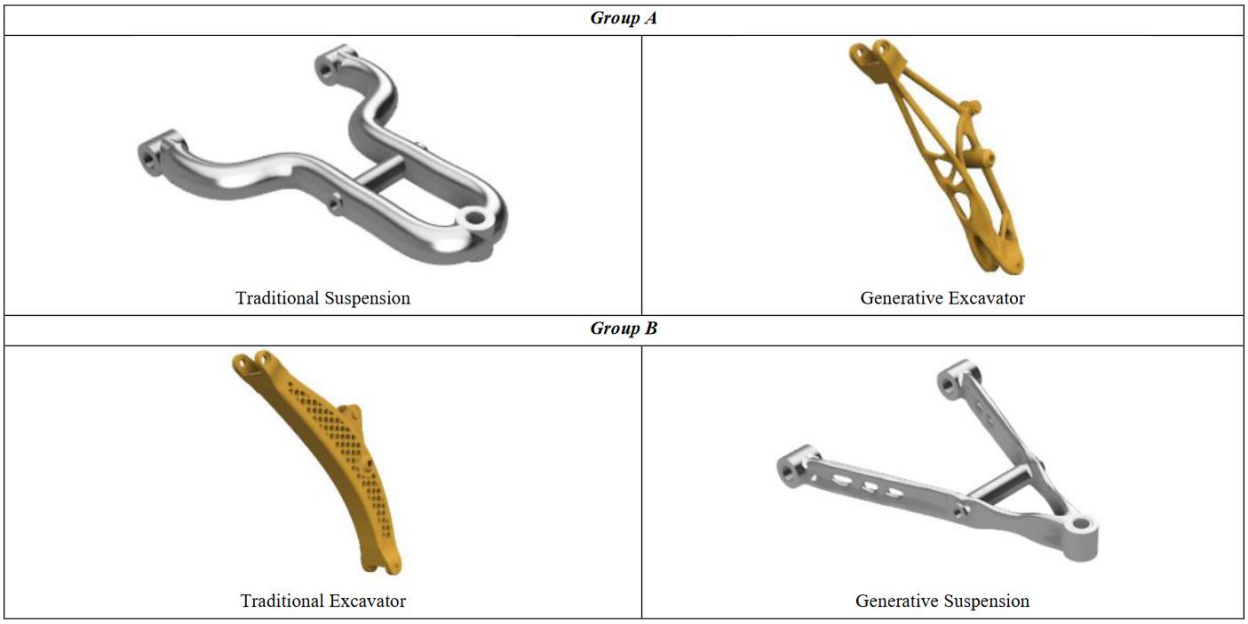

Figure 2: Student designers used Fusion360 to design two objects (suspension and excavator) using either traditional design for one and generative design for the other (order was randomized).

- Begun **cross-institutional collaboration** to conduct **educational research** using project educational materials.

This year, we have also established collaborative research relationships with GD teachers and researchers of generative design through several methods. First, we invited all attendees of the GD Workshop (Activity 1) to describe potential collaborative research plans in GD education for an opportunity to receive a $5,000 mini-seed fund grant or stipend. Two workshop attendees (Juan Zheng, Lehigh University, and David Christensen, Utah Tech University) completed this funding application and have been in communication with the EDGE team to discuss and implement their research plans for conducting human-subjects data collection to explore student designer cognition while using generative AI in engineering design (i.e., generative design thinking) in different contexts. Second, we have intentionally contacted several researchers known by project personnel to extend our collaborative network, including Aaron Hanai (Hawaii Kapiolani Community College; virtual attendee of the GD Workshop) and researchers from Texas A&M University, UC-Irvine, and Carnegie Mellon University. In total, five researchers have begun the process of collaboration by contacting their local IRB offices and/or by preparing the documents that will be used for data collection.

Generative Design Technology Development

- **Updates to and continued support of Aladdin**, an open-source computer-aided generative design and engineering software, with the goal **to support the learning and teaching of generative design**.

In Year 5, IFI continued to develop the features of the cloud-based, open-source Aladdin CAD/CAE software with generative design capabilities. One new feature is the use of project filters, which allow the user to select a subspace of the solution space to analyze designs within. In the Project's Design Gallery, a filter can be used to select those solutions that fall within certain ranges. Inspired by Autodesk's GD work in urban planning, we are also making cuboids in Aladdin stackable so that we can create city blocks more easily. Compared with buildings with roofs, windows, and walls, cuboids are approximations that may be necessary to speed up rendering and simulations, which is essential in GD considering the bottleneck of computational power.

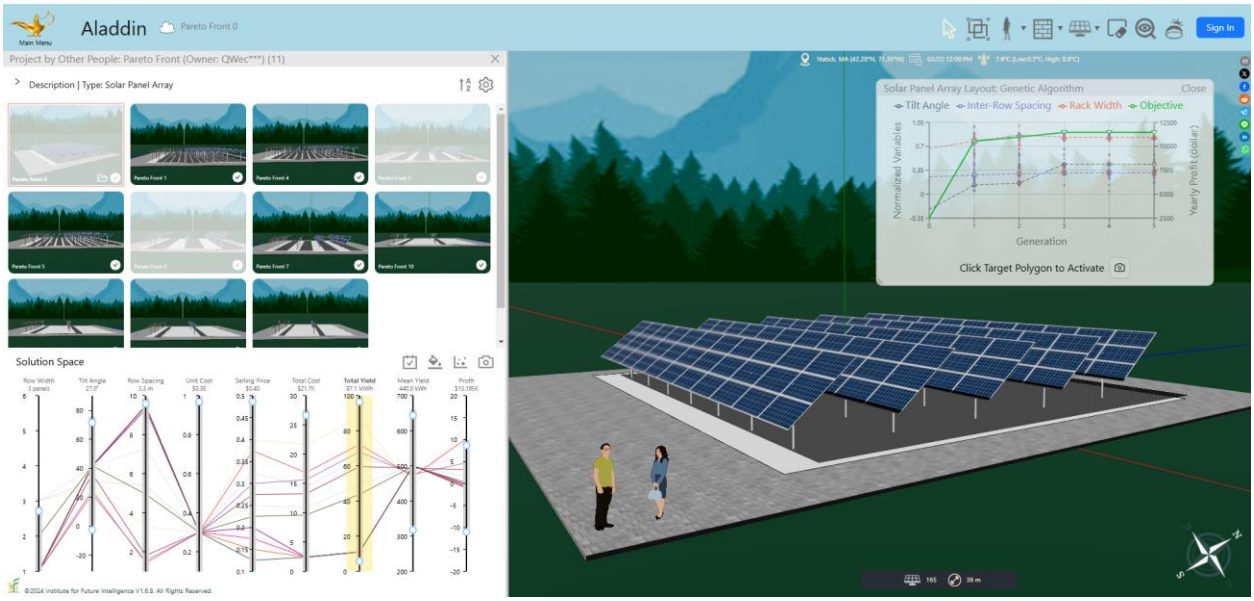

Figure 3: Aladdin's Design Gallery feature which allows users to easily view, open, edit, and compare different models.

- **Development of data-driven methods** for the realization of **generative design** in support of **software development**.

We also continued to explore data-driven generative design towards the generation of 3D CAD models in Year 5 through the use of large language models (LLMs), specifically, multimodal LLMs which can process multiple input modalities, e.g., text and images. To 1) explore how multimodal LLMs generate 3D design objects when employing different design modalities or a combination of various modalities, and 2) explore strategies to to enhance the ability of multimodal LLMs to create 3D design objects, we developed an approach to enable two LLMs (GPT-4 and GPT-4V) to generate 3D CAD models and perform experiments to evaluate their efficacy (Figure 5). GPT-4 and GPT-4V showed significant potential in the generation of 3D CAD models. We also tested four input modes for GPT-4V: text-only, text with sketch, text with image, and a combination of text, sketch, and image. GPT-4V's performance with text-only input surpassed that of the other three multimodal inputs on average, a surprising observation which challenges the common belief in multimodal machine learning that incorporating varied input modalities always improves a machine learning model's predictive accuracy due to increased information for learning and inference. The preliminary results of this study were presented at the ASME 2024 IDETC/CIE Conference. The journal version is currently under review by the Journal of Computing and Information Science in Engineering.

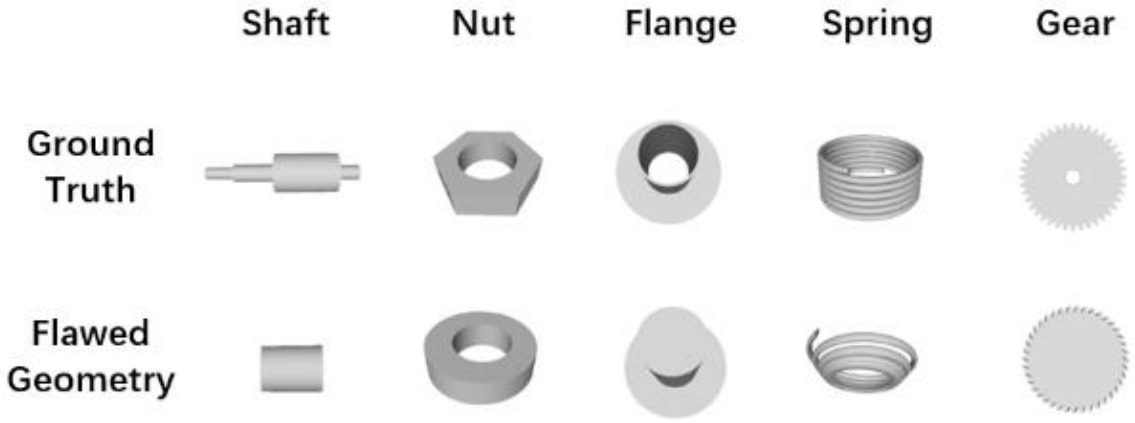

Figure 4: Examples of flawed geometry generated by the GPT-4V model.

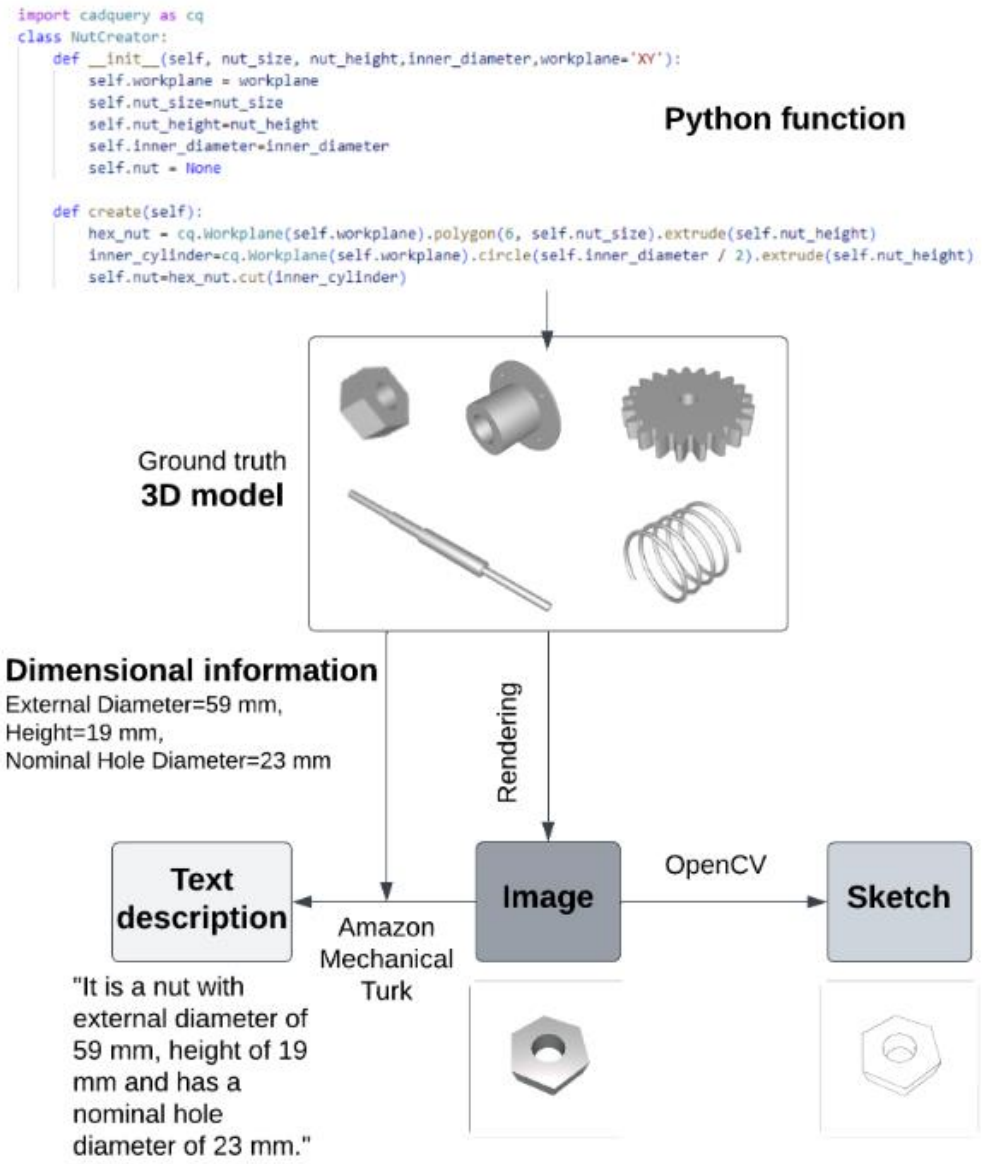

Figure 5: The data synthesis pipeline.

Key Outcomes

Outreach & Broader Impacts

- Collaborated with industry partners PTC, Inc. to host the **Generative Design in Engineering Research and Education Workshop** to **disseminate project materials**.
- **Broadened dissemination of project materials** including Aladdin and Fusion360 curriculum materials, engineering education research to explore generative design thinking, and exploration of multimodal LLMs for 3D CAD generation to major technical and educational conferences as well as peer-reviewed journals.

Education Research

- **Development and refinement of curriculum materials** in Aladdin and Fusion360 to teach generative design and related concepts.
- Conducted **human-subjects data collection** to test curriculum materials and explore generative design thinking.
- Begun **cross-institutional collaboration** to conduct **educational research** using project educational materials. Collaborating institutions include:
    a. Lehigh University
    b. Utah Tech University
    c. Hawaii Kapiolani Community College
    d. Texas A&M University
    e. Carnegie Mellon University
    f. University of California, Irvine

Generative Design Technology Development

- **Updated** the cloud-based, open-source, generative design equipped **Aladdin** to improve performance and add new features (https://intofuture.org/aladdin.html).
- **Development of data-driven methods** for the realization of **generative design** in support of **software development**.

Major Impacts

First, we focused significant efforts in Year 5 towards **disseminating project materials and insights** to create broader impacts based on the feedback from the Year 4 Advisory Board meeting and due to being in the later stages of the project. The **Generative Design in Engineering Research and Education Workshop** hosted with industry partners PTC Inc. was the key dissemination activity which allowed us to share our ideas and curriculum materials with a broader audience, and also establish relationships for collaborative educational research.

Second, the **generative design curriculum materials** developed and refined by the team have generated impacts in engineering education research and in classrooms at major universities. Specifically, we have begun **collaboration with local researchers** at UT-Austin **and external researchers** (e.g., Lehigh University and Hawaii Kapiolani Community College) to implement the Aladdin-based generative design curriculum as modules in their engineering design courses and collect data on generative design thinking from their students. In addition to Aladdin-based educational research, we have continued to develop material and conduct research via the widely-used tool Fusion360. For instance, nearly 1,000 students over the full project have completed the generative design curriculum modules developed in Fusion360, and a new study in Year 5 compared the quality of student designs generated with the help of AI vs. without.

Finally, we **explored multimodal LLMs** (GPT-4 and GPT-4V) **for 3D CAD model generation** using various input modalities (text, sketch, image). The text-only input outperformed multimodal inputs on average, but when examining category-specific results of mechanical components, multimodal inputs start to gain prominence with more complex geometries (e.g., shafts and gears) in terms of the successful parsing rate of the generated CAD programs and the geometric accuracy. From these observations, we see that the current multimodal LLMs are still limited in handling multimodal inputs when applied to LLM4CAD. However, the insights from the category-specific results indicate that multimodal LLMs have great potential benefits in real-world design scenarios characterized by complex objects although it remains challenging for them to generate complex design objects. Improving the capability of these models to process diverse input modalities and proposing strategies to improve their capability to handle complex design objects are promising research avenues.

Future Work

Note: We may refine our Year 6 work plan based on the feedback received from the AB members during this year's meeting on December 13th.

Curriculum Development and Dissemination

In the final reporting period, we will continue to test and disseminate the Aladdin-based generative design curriculum developed in Years 4 and 5. First, we will conduct a third round of pilot studies at UT-Austin (project Pl's institution) to test the efficacy of the Aladdin-based generative design curriculum by measuring student learning. Additionally, we plan to analyze and write up the data collected from the next pilot study round for a journal article that details the UT-Austin-developed design curriculum and the previous two rounds of pilot study. We are tentatively targeting the Journal of College Science Teaching and hope to submit the paper during the Fall 2024 semester.

Cross-Institutional Education Research

We will also continue the collaborations that we began in Year 5 to collect data on generative design thinking in the following institutions: Lehigh University, Utah Tech University, Texas A&M University, UC-Irvine, Carnegie Mellon University, and Hawaii Kapiolani Community College. Finally, an internal discussion is currently being held to determine future collaborators whom we will contact during the following year. We plan to use the materials developed previously, as well as the knowledge infrastructure created during the first round of collaborations, to facilitate the second round of collaborative research.

Defining Generative Design Thinking

In Year 6, we will continue investigating the essential elements of generative design thinking that students must be taught in order to work effectively at the human-technology frontier in engineering (RQ1), which will also guide the development of GD curriculums. We are currently conducting a full-length position paper featuring a systematic literature review of design thinking, design cognition, and other concepts in the EDT model to identify the key competencies that make up traditional/human-driven design thinking and parametric design thinking. We will then consider how each competency changes when adding generative Al to the engineering design process; the overall set of descriptions on how each cognitive process is executed by the designer in

generative design will result in a multi-faceted definition of GDT which is well-grounded in the field's body of research and also guide the education of these skills.

Development of Data-Driven Generative Design Approaches

In Year 6, we will advance our work in generative design by integrating Large Language Models (LLMs) and diffusion models to enhance multimodal design capabilities. Building on Year 5's progress, we aim to develop novel Al-driven design approaches that incorporate diverse inputs, such as text, sketches, and images, enabling a richer and more creative generative process. These approaches will focus on human-centered design by allowing users to guide the design generation through explicit inputs, making the Al-generated outputs more aligned with human creativity and intent. This will foster deeper exploration of design possibilities and drive innovation in conceptual and creative design.

Aladdin Software Development

We will continue to develop Aladdin in Year 6 to provide a research and education platform at the intersection between Al and design. The effort led by Co--Pl Xie from IFI will continue to optimize Aladdin and enhance its GD functionalities based on the feedback from users.

Research Dissemination and Organizing Workshops

Finally, we will continue to submit the contents of our projects to peer-reviewed conferences and journals; for example, our submission to the 2025 American Society of Engineering Education (ASEE) Conference has already been accepted and we are preparing to present our work in the NSF Grantees Poster Session. Additionally, we have plans to organize and submit a workshop proposal to the 2025 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC-CIE) on the topic of generative design education.

Year 5 Products

Journal or Juried Conference Papers

Barnaby-Brown, A. & Goldstein, M. H. Clay, J., Demirel, H. O., Li, Xi., Sha, Z. (2024). A study on generative design reasoning and students' divergent and convergent thinking. Journal of Mechanical Design, 146(3): 031405. https://doi-org/10.1115/1.4064564

J. Clay, X. Li, R. Jiang, O. Demirel, M. Goldstein, D. Zabelina, C. Xie, Z. Sha, "Engineering Design Thinking in the Age of Generative Artificial Intelligence," The 2024 ASEE Annual Conference & Exposition. June 23-26, 2024, Portland, OR. Paper and Poster Presentation.

X. Li, Y. Sun, Z. Sha, "LLM4CAD: Multi-Modal Large Language Models for 3D Computer-Aided Design Generation," ASME 2024 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Washington DC, Aug. 25-28, 2024. Paper Presentation.

E. Koolman, J. Z. Clay, X. Li, R. Jiang, M. H. Goldstein, C. Xie, H. O. Demirel, Z. Sha, "A multi-case study of traditional, parametric, and generative design thinking of engineering students," The 11th International Conference on Design Computing and Cognition (DCC 24), July 8-10, 2024, Montreal, Canada. Paper Submitted and Paper Presentation.

Hall, A. & Goldstein, M. H. (Paper Accepted). Generative vs. Traditional Computer-Aided Design: How design tools impact CAD artifact quality and designer behavior. Proceedings from the Frontiers in Education (FIE) Annual Conference, Washington, D.C., October 2024. Paper proceeding and Presentation.

Conference Abstracts, Posters, and Presentations

Z. Sha, M. Goldstein, O. Demirel, C. Xie, D. Zabelina, J. Clay, X. Li, E. Koolman, N. Varma, "Educating Generative Design in Engineering," 2024 IUSE Summit – (DEIA + STEM) x Innovation, June 16-18, 2024, Washington DC. Abstract and Poster Presentation.

Goldstein, M. H. "The Future of Design Education." Invited Talk at International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC/CIE) Design Education Conference Invited Talk August 2024. Invited Presentation.

Thesis/Dissertation

Li, Xingang. Towards Human-Centered Generative Design: Cross-Modal Synthesis for

Three-Dimensional Design Concept Generation. (2024). The University of Texas at Austin.

Other Products

The cloud-based Aladdin CAD/CAE software. Aladdin is an experimental platform for reimagining design in the coming era of AI in the context of renewable energy engineering. The power of Aladdin derives from two different sources: generative design and machine learning, with attaining explainable AI (XAI) to support human-machine collaborative intelligence as an important goal.

https://intofuture.org/aladdin.html

Design Curriculum: Educating Designers for Generative Engineering. We developed curriculum materials (text and CAD practice activities based in Aladdin) to teach the evolution of design paradigms from traditional, to parametric, and to generative design. The curriculum also includes a Teacher's Handbook consisting of a Glossary and Index, five sets of PowerPoint slides to aid teachers, and the preliminary recordings for video lectures based on these slides. https://sidilab.net/nsf-edge/edge-curriculum/

Generative Design in Engineering Research and Education Workshop

- **Webpage**: https://sidilab.net/nsf-edge/generative-design-workshop-boston-2024/
- **Summary:** https://sidilab.net/wp-content/uploads/2024/12/generative-design-in-engineering-research-and-education-workshop-summary.pdf