2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #50157

GIFTS: Reverse CADding as an Early Challenge Pathway for First-Year Engineering Students

Prof. Kapil Gangwar, Wentworth Institute of Technology

Kapil Gangwar is an assistant professor of mechanical engineering at Wentworth Institute of Technology with a background in materials, mechanics and manufacturing.

GIFTS: Reverse CADding as an Early Challenge Pathway for First-Year Engineering Students

Abstract

This Great Ideas for Teaching Students (GIFTS) paper presents Reverse CADding as a scalable, early-engagement activity for first-year engineering students, particularly those entering with prior experience in CAD, machining, or fabrication. While first-year undergraduate curricula across engineering schools emphasize foundational theory, some students arrive technically prepared and seek deeper challenges not always available in required courses. Reverse CADding provides a voluntary, hands-on pathway implemented through the Society of Manufacturing Engineers (SME) chapter and, at our school, a no-prerequisite Introduction to Manufacturing Processes elective. Through this GIFTS activity, students measure physical components with precision tools, develop sketches, create SOLIDWORKS models, generate engineering drawings, and reflect on manufacturability and design intent. This activity is framed around the KEEN Entrepreneurial Mindset Learning (EML) 3Cs: curiosity, connections, and creating value. Early indicators show increased SME attendance and sustained engagement, especially among first-year students. Reverse CADding offers an adaptable model for cultivating early engineering identity, technical confidence, and manufacturing awareness among first-year students [1].

1. Introduction: Early Technical Challenge in the First Year

This GIFTS paper describes Reverse CADding as an early challenge pathway for first-year engineering students who seek more advanced, hands-on engagement than typical first-year curriculum provides. First-year programs are necessarily structured and foundational, emphasizing mathematics, physics, and introductory design. Within this structure, some incoming students arrive with substantial prior experience in CAD, machining, robotics, or fabrication and might feel under-challenged when coursework and co-curricular activities are tuned mainly for novices [2]. Reverse engineering is a recurring element in upper-level graphics, manufacturing, and capstone courses, yet students often encounter it late and in constrained, assignment-driven formats. To address this gap, Reverse CADding was positioned in a voluntary co-curricular setting (the SME chapter) and reinforced in a no-prerequisite Introduction to Manufacturing Processes elective [3]. The goal of this activity is to plant an early conceptual "seed" around reverse engineering and manufacturability that students carry into later coursework, while giving advanced first-year students space and choice to "hit the ground running" [4], [5]. Rather than replacing existing first-year courses, Reverse CADding is an early, scalable challenge pathway that provides structured opportunities for advanced first-year students while remaining accessible to less experienced students through scaffolded complexity. This paper outlines the context, activity structure, integration with the KEEN 3Cs, assessment approach, and evidence of first-year impact [6], [7].

2. Context and Implementation

Our institution is a mid-sized, undergraduate-focused university with a strong emphasis on hands-on engineering education. The sophomore-level Engineering Graphics course enrolls over 100 students annually and focuses on CAD proficiency and technical drawing within a structured progression; open-ended reverse engineering is not consistently included. Therefore, Reverse CADding was implemented in two first-year-accessible contexts. 1) SME chapter projects (voluntary participation) and 2) Introduction to Manufacturing Processes (no-prerequisite elective). SME participation is voluntary and interest-driven, giving students opportunities to pursue fabrication-based challenges beyond traditionally graded coursework. The collaboration with SME was motivated by the chapter's underutilized manufacturing equipment and a desire to increase student engagement beyond passive meeting demonstrations. Several first-year students with prior CAD or machining experience seek out SME participation, but common "everyone builds the same part" projects can be too basic. The Introduction to Manufacturing Processes elective enrolls students from multiple majors and levels, introduces shop safety and machine operation, and offers a natural venue for a more structured Reverse CADding task. To keep activities coherent while accommodating differing preparation levels, Reverse CADding uses a shared framework that scales in complexity:

Measure → Sketch → Model → Draw → Reflect → Fabricate (optional)

Less experienced students replicate parts provided by the instructor (for example, simple cubes or Swiss-cheese-style blocks Figures 1–3), focusing on measurement and basic modeling. More advanced first-year students may select or redesign functional components, including repairing previously failed parts. In one instance, a student refined an existing CAD model of a fractured bicycle component and attempted to fabricate an improved version using SME resources. In another instance, a first-year student designed and manufactured a custom rock-climbing hold. Although SME is open to all years, over the last two years our chapter has intentionally invited first-year students (e.g., through the campus fair) into Reverse CADding projects to connect early interest and preparation to campus manufacturing resources. The elective provides a parallel, credit-bearing context where similar tasks can expose a broader group of first-year students to reverse engineering concepts, even if they are new to CAD or do not join SME. Students who complete Reverse CADding in the first year have reported feeling more confident and intentional when they encounter similar tasks in the sophomore Engineering Graphics course.

3. Reverse CADding Activity Structure

The Reverse CADding activity is organized into four stages anchored by the shared framework. Each full cycle typically takes 3–6 hours depending on part complexity and student preparation—suitable for a single extended lab session or spread across two to three SME meetings. One of the representative artifacts used in this activity was a coordinate measuring machine (CMM) calibration block (Figure 4 and Figure 5), chosen for its geometric precision and clear dimensional features.

- **Measurement:** Students examine physical parts and use precision tools such as calipers, micrometers, dial indicators, depth gauges, and protractors to capture key geometric and dimensional relationships. Emphasis is placed on tool selection, measurement strategy, and awareness of uncertainty; in some cases, this introduces students to the concept of interchangeability.

- **Modeling and Drawing:** Students create orthographic sketches, then develop solid models in SOLIDWORKS (or CAD software of their choice) that reflect inferred design intent. Students generate engineering drawings with appropriate views, introductory tolerancing, and annotations that support manufacturing. Mentors (advisors, technicians, and SME officers) encourage students to consider modeling order and feature strategy in relation to machining sequences and fixturing.

- **Manufacturability Reflection:** Students complete short reflections addressing inferred design intent, likely manufacturing processes and process sequences, constraints imposed by available equipment, and potential improvements related to cost, efficiency, or robustness.

- **Fabrication (SME or course-based):** Where feasible, students fabricate artifacts such as aluminum cubes, Turner-style cubes, engraved nameplates, or climbing grips using manual mills, lathes, or CNC machines. Comparing manufactured parts to their CAD models and drawings reinforces how virtual design decisions manifest in physical form [8].

This structure can be implemented as a brief lab module in the elective or as a longer project in SME, without changing the core logic.

4. Integration of the KEEN Entrepreneurial Mindset (3Cs) [9]

Reverse CADding is framed using the KEEN Entrepreneurial Mindset Learning (EML) 3Cs framework—curiosity, connections, and creating value—which encourages students to approach engineering problems with an entrepreneurial perspective.

- **Curiosity (C1):** Students are prompted to ask why the part is designed as it is: which features are essential, which might be legacy or convenience choices, and how geometry relates to function.

- **Connections (C2):** Students connect measurement data to modeling strategy, tool access, machining constraints, and process planning. In SME, they also connect their work to future graphics and manufacturing courses, seeing Reverse CADding as preparation rather than an isolated activity.

- **Creating Value (C3):** Reflection prompts students to propose design changes that could reduce machining steps, lower material waste, improve strength, or simplify assembly. In the example of the bicycle component, the student considered how an improved replacement adds value by extending service life. This C receives particular emphasis, with rubric criteria tied directly to the feasibility and specificity of proposed improvements.

5. Evidence of Impact and Assessment Approach

Formal IRB-based data collection has not been conducted yet; however, early indicators and rubric-guided assessment provide initial evidence of impact on first-year engagement and confidence.

5.1 Engagement indicators

We noticed that the SME meeting attendance increased to approximately 90% after Reverse CADding was introduced as a recurring project theme. First-year students continued participating in SME and using manufacturing facilities after completing initial Reverse CADding activities. In the Introduction to Manufacturing Processes elective, students reported higher interest and engagement during Reverse CADding and Turner-style cube activities than during more scripted modeling exercises. A first-year student who developed advanced manufacturing skills through SME activities was selected as a work-study assistant for Introduction to Manufacturing Processes and mentored peers during lab sessions. Because SME participation is voluntary, high attendance and repeated involvement suggest genuine interest rather than compliance. Students frequently describe Reverse CADding as an opportunity to "do real engineering" earlier than expected and to position themselves as makers within the program [2].

5.2 Assessment rubric

A concise rubric supports formative and summative assessment. Typical criteria include: 1) Accuracy of a CAD model relative to the physical part, 2) Depth of design intent analysis, 3) Strength of manufacturability insight, 4) Appropriateness and precision of measurement techniques and 5) Creativity and feasibility of improvement proposals (aligned with Creating Value, C3). The rubric is introduced at project launch and used throughout the activity—not just at the end—in feedback conversations by advisors, technicians, and/or SME officers. Feedback is delivered conversationally at each stage (e.g., "What influenced your modeling order here?" or "How might this tolerance affect your machining plan?"), emphasizing iteration and craftsmanship rather than a single graded submission. Written rubric comments are provided on completed drawing packages in the elective, with an opportunity for students to revise. Future plans include tracking rubric score trends across semesters and comparing CAD accuracy and manufacturability insight before and after Reverse CADding is introduced. Both engagement patterns and rubric-guided observations suggest that Reverse CADding supports early engineering identity formation, especially among first-year students who arrive with stronger preparation and seek meaningful ways to apply it.

6. Discussion and Adaptability

Reverse CADding addresses a common first-year challenge: balancing shared foundational instruction with differentiated challenges for more technically prepared students. By placing reverse engineering in a voluntary SME environment and a no-prerequisite manufacturing elective, the activity provides, 1) A structured challenge pathway for advanced first-year students, 2) A scaffolded entry point for novices, 3) An authentic context linking CAD, metrology, and manufacturing practice [10]. The framework is adaptable at institutions that have basic metrology tools and access to entry-level CAD software. Fabrication can range from manual machining to CNC or additive manufacturing, depending on available resources. The same measure–sketch–model–draw–reflect–fabricate (optional) structure can also be embedded in introductory engineering courses that already include physical prototyping. Introducing Reverse CADding during the first year establishes an early foundation for reverse engineering that students later revisit in graphics, manufacturing, and capstone courses. Students who encounter it early appear to approach subsequent technical work with greater intentionality and confidence, seeing reverse engineering as a familiar, integrated part of design practice.

7. Conclusion

Reverse CADding provides a scalable early challenge pathway that engages first-year engineering students, especially those with prior technical preparation, through structured reverse engineering and manufacturing experiences. By leveraging voluntary SME participation and a no-prerequisite manufacturing elective, the activity channels existing skills, increases voluntary engagement, and cultivates manufacturability awareness and entrepreneurial mindset before curricular constraints limit exploratory freedom. This GIFTS model illustrates how intentional early exposure to reverse engineering can strengthen first-year engagement, support engineering identity formation, and better prepare students for later CAD, graphics, and manufacturing coursework.

8. References

[1] McLanahan, A. L. R., & Melton, D. (2025, April 3). “The Habits of EM (updated)”. Engineering Unleashed. Retrieved from https://engineeringunleashed.com/card/101. Accessed: April 29, 2026.

[2] D. Harcharik and J. Davishahl, GIFTS: Sharing Stories and Building Belonging in a First-Year Engineering Course. 2024. doi: 10.18260/1-2--47504.

[3] Wentworth Institute of Technology, “Manufacturing Minor,” 2025–2026 Academic Catalog. Accessed: April 29, 2026. [Online]. Available: https://catalog.wit.edu/

[4] K. Adhikari, “GIFTS: Intro to Civil & Environmental Engineering—First-year Engineering Course designed for Student Engagement and Belonging,” in 2025 ASEE Annual Conference & Exposition, 2025.

[5] A. D. Daniel, “Fostering an entrepreneurial mindset by using a design thinking approach in entrepreneurship education,” Industry and Higher Education, vol. 30, no. 3, pp. 215–223, Jun. 2016, doi: 10.1177/0950422216653195.

[6] R. R. Sola-Guirado, G. Guerrero-Vacas, and Ó. Rodríguez-Alabanda, “Teaching CAD/CAM/CAE tools with project-based learning in virtual distance education,” Educ. Inf. Technol. (Dordr)., vol. 27, no. 4, pp. 5051–5073, 2022, doi: 10.1007/s10639-021-10826-3.

[7] G. Berselli, P. Bilancia, and L. Luzi, “Project-based learning of advanced CAD/CAE tools in engineering education,” International Journal on Interactive Design and Manufacturing (IJIDeM), vol. 14, no. 3, pp. 1071–1083, 2020, doi: 10.1007/s12008-020-00687-4.

[8] Xyver, “Turner’s Cube (Manual Machine).” Accessed: April 29, 2026. [Online]. Available: https://www.instructables.com/Turners-Cube-Manual-Machine/

[9] E. Rahmi, D. Darmansyah, A. Yulastri, and C. Handrianto, “Bridging Entrepreneurship Education and Digital Transformation: A Novel Experiential Learning Model for Entrepreneurial Mindset Development,” International Journal of Learning, Teaching and Educational Research, vol. 24, no. 4, pp. 640–660, 2025.

[10] I. Fudos, “CAD/CAM Methods for Reverse Engineering: A Case Study of Re-engineering Jewelry,” Comput. Aided. Des. Appl., vol. 3, no. 6, pp. 683–700, Jan. 2006, doi: 10.1080/16864360.2006.10738422.

Appendix

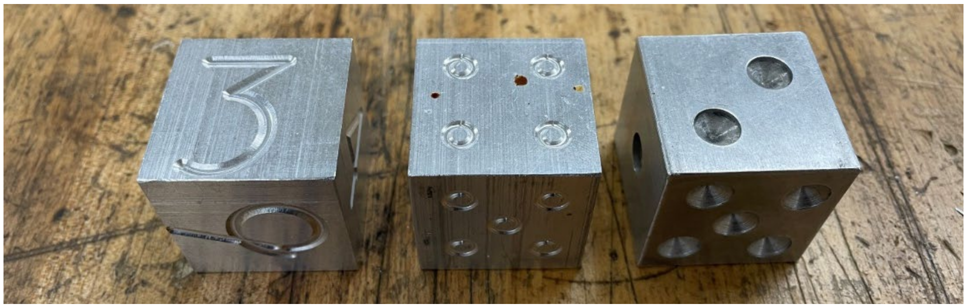

Figure 1: Some other artifacts made by students. Cubes are $\mathbf{1 \times 1 \times 1}\ \boldsymbol{in^3}$

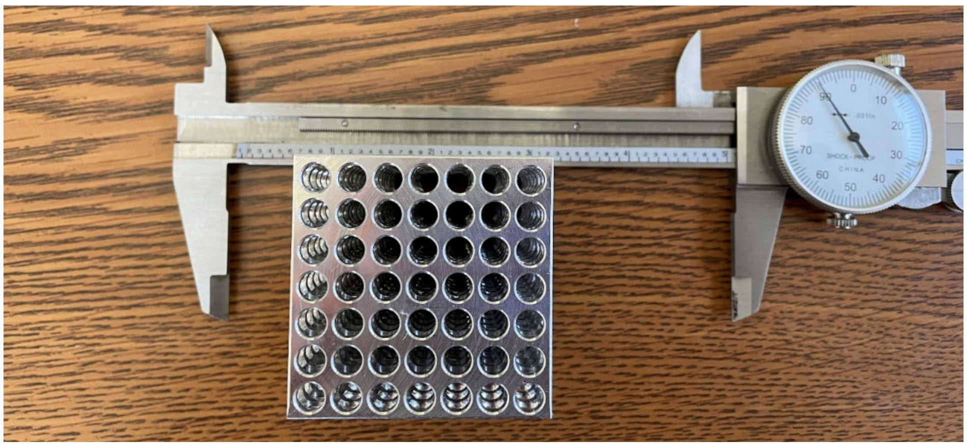

Figure 2: Swiss cheese cube model used for reverse CADding

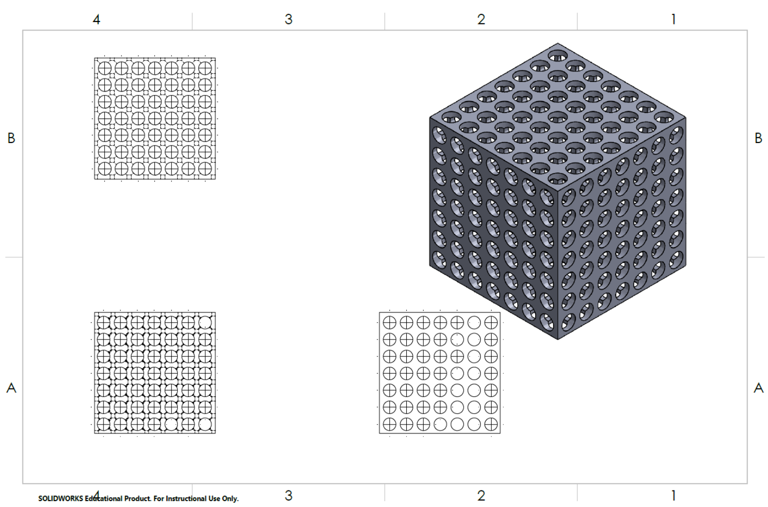

Figure 3: Finished drawing of the Swiss cheese cube model

Figure 4: CMM Block, used for reverse CADding

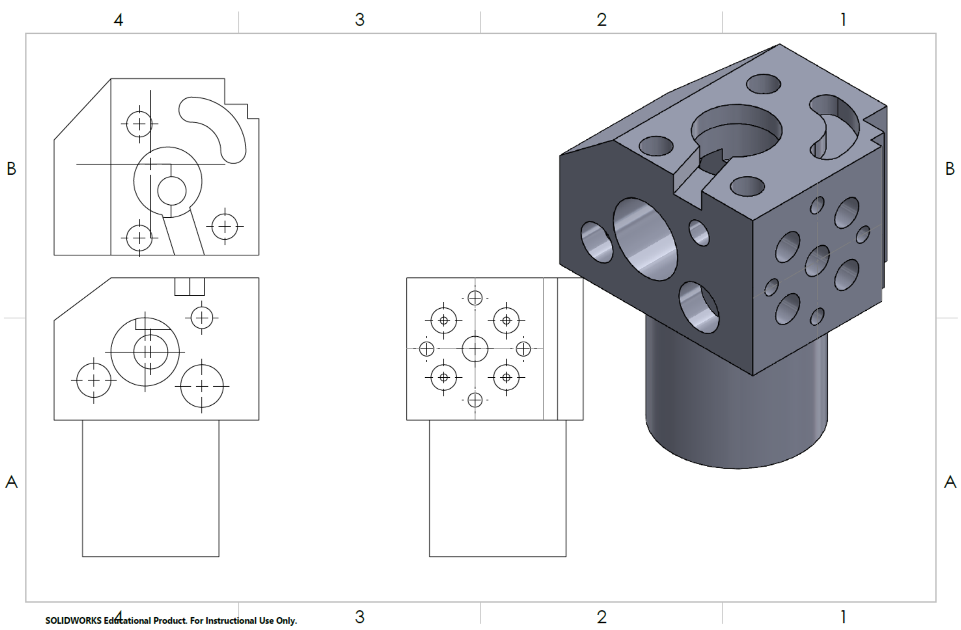

Figure 5: Finished drawing of the CMM block.

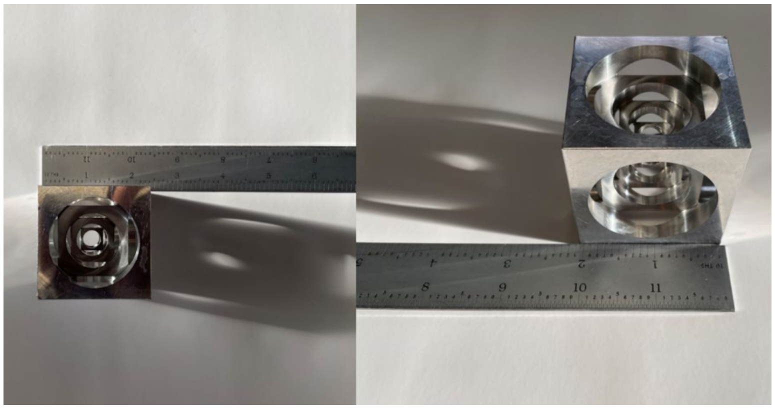

Figure 6: Turner's cube model used for reverse CADding

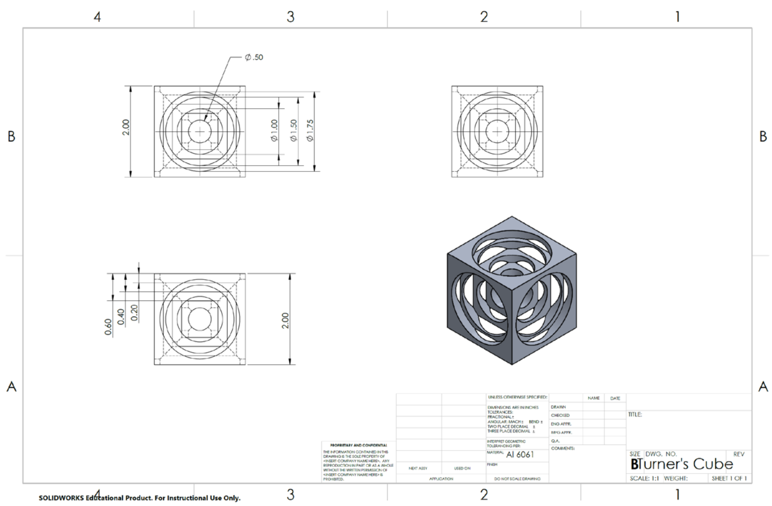

Figure 7: Finished drawing of Turner's Cube