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USING GENERATIVE AI IN FIRST-YEAR MECHANICAL DESIGN

Abstract: *This paper explores the capabilities and limitations of free AI (Artificial Intelligence) tools in enhancing instructional practices and student comprehension in courses involving CAD software. Notebook LM, Chat GPT, and open educational resources (OER) are employed as learning tools within a classroom-ready framework for teaching CAD (computer-aided design) software to first-year undergraduate mechanical engineering students. Although AI cannot directly perform modelling tasks within design software, it proves to be a good tool within a procedural framework and delivers good results when used this way; its use can enhance concept explanation beyond static manuals, reduce instructor workload, support struggling students, improve design thinking, and increase the accessibility of design software for undergraduate learners.*

Key words: *Artificial Intelligence, Mechanical Design Engineering, OER, CAD, Intelligent Tutoring Systems*

1. INTRODUCTION

"Technical Drawing and CAD" is a core discipline that teaches first-year Mechanical Engineering students how to read, create, and communicate engineering designs visually and precisely, first by hand and then using computer software- while playing a key role in developing technical thinking and graphical skills vital to engineering, and enhancing students' spatial reasoning and problem-solving abilities. To enhance the effectiveness of teaching this discipline, this case study presents modern educational technologies such as OER (Open Educational Resources), MOOCs (Massive Open Online Courses), and AI (Artificial Intelligence), and evaluates their impact on the learning process.

OERs allow education to become more accessible for all learners, and educators have new opportunities to enhance their teaching practices [1]. The MIT Open CourseWare (OCW) initiative, launched in 2001, represented a major step toward open access in education by making most of the institutions course materials available online at no cost globally [2]. OER for engineering drawing and CAD include: MIT OpenCourseWare and NPTEL courses, which provide structured instructional materials, as well as open textbooks from LibreTexts and the Open Textbook Library. In addition, practice-oriented resources from Autodesk Education and SOLIDWORKS Education support the development of applied CAD skills, while repositories such as OER Commons and MERLOT (Multimedia Educational Resource for Learning and Online Teaching) offer supplementary teaching and learning materials.

AI offers a potential revolution in engineering design as it is foreseen to totally change human-centred traditional engineering design approaches [3]. AI is often afforded the ability to save humans time by performing laborious and repetitive tasks and managing complexity [4].

This paper presents the results of applying artificial intelligence (AI) in a first-year mechanical engineering "CAD" course, where it is used initially as a tool for instructional content development and subsequently as a tutor.

2. AI AS A TEACHING TOOL

The rapid advancement of information technologies, especially artificial intelligence (AI), is reshaping contemporary education, with AI algorithms and educational robots increasingly integrated into learning management and instructional systems to support diverse educational activities [5], [6].

Artificial intelligence (AI) provides a wide range of tools and applications with the potential to transform teaching and learning processes [7]. In educational contexts, AI technologies can be structured along a continuum of pedagogical autonomy. At the lowest level, AI support tools—such as Gamma, NotebookLM, and Slido—facilitate content creation, knowledge interaction, and student engagement without directly controlling the instructional process. At an intermediate level, AI-enhanced systems incorporate these tools within learning management environments to provide partial automation and support. At the highest level, AI assumes the role of an educator, autonomously guiding and evaluating student learning, as exemplified by intelligent tutoring systems.

3. AI AS A TUTOR

Recent studies indicate that large language model (LLM)-based systems, such as ChatGPT and Claude can function as components of intelligent learning systems (ILS), supporting personalized learning, interactive problem-solving, and adaptive feedback [8], [9], [10]. In this context, these systems act as intelligent tutors, providing real-time guidance, explanations, and formative feedback to enable individualized learning experiences.

4. CASE STUDY: AI FOR TEACHING CAD LABORATORY

4.1. Study, aim and scope

This study investigates the educational potential of AI-based systems in a CAD laboratory involving first-year undergraduate students at the Mechanical Engineering Faculty of Politehnica University of Timisoara, Romania, where AI tools, MOOCs, and OERs were integrated. The analysis includes tools such as NotebookLM, Slido, Gamma, and conversational systems including ChatGPT and Claude, with a focus on student interaction and instructional support

4.2. AI as a teaching tool

The instructional process was structured into five stages, combining AI-supported content delivery, guided instruction, and formative evaluation (Table 1).

Table 1

Laboratory workflow and educational outcomes

Laboratory workflow	**Educational outcome**
1. Introduction lecture (10 minutes)	**Introduction of the design task and presentation of session objectives, outlining fundamental concepts and the topic covered.** • Students view instructional video content generated using NotebookLM.
2. Presentation (10 minutes)	**Overview of key features to be explored in subsequent activities.** • Students view presentation materials generated using Gamma.
3. Guided practice (30 minutes)	**Development of conceptual understanding through observation, note-taking, and questioning.** • The instructor demonstrates the design process step-by-step, highlighting best practices, common errors, and decision-making strategies.
4. Independent practice (90 minutes)	**Application of knowledge in practical and problem-solving contexts.** • Students complete design tasks independently, applying tools, techniques, and concepts to create or modify designs and make relevant decisions.
5. Evaluation (10 minutes)	**Formative assessment through real-time monitoring of student understanding and engagement.** • A short quiz is administered using Slido.

4.3. AI as a tutor

In this study, AI systems such as ChatGPT and Claude, were used as intelligent tutors, providing real-time guidance, explanations, and feedback during CAD laboratory activities. These systems supported personalized and self-directed learning, while requiring instructor supervision to ensure accuracy and pedagogical validity.

Students were task to model the 3D

As illustrated in Figure 1, students were tasked with completing a partially constrained CAD sketch. In this context, the AI systems assisted in identifying missing constraints and guiding students toward achieving a fully defined model, thereby enabling accurate 3D reconstruction.

The technical sketch shown in Figure 1 represents the initial design input provided to students, created in CATIA and incorporating key geometric features and dimensions.

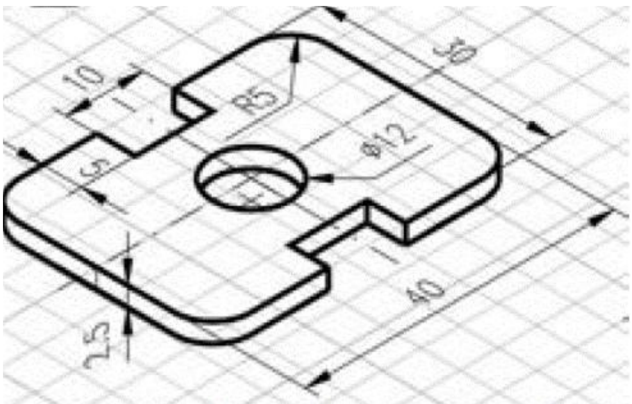

Figure 1 Input sketch provided to students as the basis for constraint-based CAD modelling.

Based on this reference, students were required to recreate the geometry in a CAD environment, resulting in the sketch illustrated in Figure 2, modelled in CATIA.

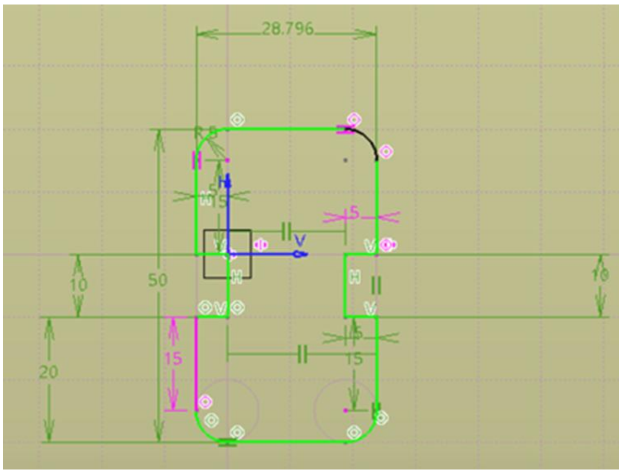

Figure 2 Partially constrained CAD sketch used in the laboratory exercise, illustrating a combination of fully constrained and under-constrained elements for constraint analysis and completion.

During this process, the initial model contained under-constrained elements that required further refinement.

In this context, ChatGPT and Claude, were used as intelligent tutors to assist students in interpreting the sketch, identifying missing constraints, and achieving a fully defined parametric model. This process ensured the correctness and stability of the geometry, enabling accurate subsequent 3D reconstruction.

The previous mentioned AI systems were asked: *What are the steps required to achieve a fully defined sketch in CATIA for subsequent 3D model generation?* The responses generated by Claude and ChatGPT are presented in Figure 3 and Figure 4, respectively.

Current Issues

The sketch is **under-constrained** — white/green elements indicate remaining degrees of freedom (DOF). Dimensions partially applied (28.796, 50, 10, 20, 15×2).

Constraints to Add

Type	Action
Anchor	Coincidence between a key corner and the origin (H/V axes)
H/V lines	Apply Horizontal/Vertical constraints to all straight edges
Coincidence	Link all open endpoints between lines and arcs
Tangency	Add Tangent constraints at arc-to-line junctions (top-right corner, bottom arc)
Dimensions	Add missing: total height, both arc radii, notch position

Procedure

1. Run **Sketch Tools → Sketch Analysis** to identify remaining DOF
2. Fix origin anchor
3. Add geometric constraints (H/V, Coincidence, Tangent)
4. Add missing dimensional constraints
5. Confirm all geometry turns **green → 0 DOF**

✅ Sketch is fully constrained when CATIA reports **"Sketch fully constrained"** — safe to proceed to 3D (Pad/Pocket).

Figure 3 Generated response of Claude

🔧 **Corrections Needed (Specific to Your Sketch)**

🔹 **1. Fix the Global Position**

❗ Problem: Sketch may still move

👉 **Action:**

- Select one corner (e.g., bottom-left)
- Apply:
  - Coincidence with **origin (0,0)**
    or
  - Horizontal + vertical distance to origin

🔹 **2. Top Horizontal Segment (28.796)**

❗ Problem: May not be fully locked vertically

👉 **Action:**

- Ensure:
  - **Horizontal constraint** is applied
- Add:
  - Vertical distance from a reference (bottom edge)

🔹 **3. Left Vertical Edge (50 height)**

❗ Problem: Could slide horizontally

👉 **Action:**

- Apply:
  - **Vertical constraint**
- Ensure:
  - Distance from origin or another edge

🔹 **4. Inner Rectangle (White Zone)**

❗ Problem: Under-constrained (position unclear)

👉 **Action:**

- Add:
  - Width + height (if missing)
  - Distance from:
    - Left edge
    - Bottom/top edge

✓ Better:

- Use **symmetry constraint** if centered

🔹 **5. Right Vertical Slot**

❗ Problem: Can move horizontally

👉 **Action:**

- Ensure:
  - Vertical lines are constrained
- Add:
  - Slot width
  - Distance from right or left edge

🔹 **6. Bottom Circles (Holes)**

❗ Problem: Likely missing full positioning

👉 **Action:**

- Add:
  - **Diameter constraint**
  - Horizontal position (distance from edge)
  - Vertical position (distance from base)

✓ Better:

- Use **symmetry between holes**

🔹 **7. Bottom Arc / Fillet**

❗ Problem: May lack tangency or radius

👉 **Action:**

- Add:
  - **Radius constraint**
  - **Tangency constraints** with adjacent lines

🔹 **8. Remove Remaining DOF (Degrees of Freedom)**

👉 Use:

Sketch → Constraint Diagnosis

👉 Then:

- Drag sketch:
  - If anything moves → still under-constrained

✅ **Final Check**

✓ All geometry → **green**

✓ No movement when dragged

✓ No warnings in constraint diagnosis

🎯 **Result**

You will obtain:

- A **fully constrained parametric sketch**
- Stable geometry
- Correct base for **3D modeling (Pad, Pocket, etc.)**

Figure 4 Generated response of ChatGPT

5. DISCUSSIONS

While analysing these responses it can be seen that Claude provides a procedural workflow for sketch construction, while ChatGPT delivers a diagnostic analysis of the current sketch state. Their effectiveness is assessed in terms of structure, accuracy, and applicability to achieving a fully constrained model (0 DOF- Degrees of freedom).

- Evaluation: Both responses are fully consistent in identifying the root causes of remaining DOF.
- Clarity:

Claude response: Clear procedural logic but limited real-time diagnosis;
Chat GPT response: High clarity in explaining why constraints are missing.

- Practical Applicability:

Claude response is optimal for reconstruction from scratch;
Chat GPT response is optimal for debugging an existing sketch.

The procedural and diagnostic approaches are complementary, not contradictory. The procedural method defines the required workflow and enforces modeling discipline, while the diagnostic method identifies unresolved constraints and remaining degrees of freedom (DOF). Together, they provide both immediate error resolution and long-term robustness, enabling the achievement of a fully constrained (0 DOF) sketch.

6. CONCLUSIONS

AI tools, including those integrated within MOOCs and OER, significantly reduce the time required for generating instructional materials and support self-paced learning; however, instructor guidance remains essential for effective knowledge transfer.

AI's inability to directly perform modeling tasks within design software does not diminish its value — when embedded in a procedural framework, it emerges as a genuinely effective tool, one that enriches concept explanation, lightens the load on instructors, assists students who are falling behind, sharpens design thinking, and makes design software far more accessible at the undergraduate level.

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