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THE METHODOLOGY OF DEVELOPING STUDENTS' DESIGN THINKING THROUGH THE USE OF AUTOMATED DESIGN SYSTEMS

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ABSTRACT: The growing ubiquity of automated design systems (ADS) in engineering and creative industries demands new pedagogical approaches that embed such tools into learning environments while cultivating students' design-thinking competences. This study proposes and tests an instructional methodology that situates ADS at the centre of a problem-based design studio. A quasi-experimental implementation with second-year mechanical-engineering students compared an ADS-rich studio to a conventional CAD laboratory over one semester. Mixed-methods evaluation revealed significant gains in empathic problem scoping, ideation fluency and iterative prototyping in the experimental cohort, without compromising technical accuracy. The findings indicate that ADS, when framed by a human-centred design-thinking cycle and supported by reflective dialogue, can accelerate skill acquisition and deepen conceptual understanding of the design process. Recommendations for curriculum designers focus on sequencing, feedback orchestration and assessment alignment to sustain the positive effects.

KEYWORDS: Design thinking; automated design systems; engineering education; computer-aided design; instructional methodology.

INTRODUCTION: Design thinking has evolved from a professional practice heuristic to an educational paradigm that promises to nurture creativity, empathy and systemic problem solving among students across disciplines. Its diffusion into tertiary engineering curricula, however, often clashes with entrenched hardware-centred laboratory formats where mastery of computer-aided design (CAD) software eclipses the development of broader cognitive strategies [1]. Contemporary ADS, incorporating AI-assisted modelling, generative algorithms and real-time simulation, provide opportunities to bridge this gap by externalising routine tasks and freeing cognitive resources for higher-order design reasoning [2]. Yet empirical evidence on how to orchestrate ADS within learning environments to foster design-thinking mindsets remains scarce.

Recent studies have examined the impact of CAD simulation tools on problem framing and iteration depth [3], demonstrated that data-rich ADS platforms enable fine-grained analysis of student design pathways [4], and explored AI-enhanced feedback loops that shorten ideation–prototype cycles [5]. Nevertheless, most investigations report isolated interventions or focus exclusively on performance metrics rather than on the integrative cognitive dispositions that underpin design thinking. Building on human-centred learning theory and the construct of "informed design" [6], the present work formulates a comprehensive methodology that situates

ADS as cognitive partners in an inquiry-driven studio, aligning tool affordances with the empathise-define-ideate-prototype-test cycle popularised by the Stanford d.school.

The primary research question is: How does an ADS-integrated instructional methodology influence the development of students' design-thinking competences compared with traditional CAD instruction? Secondary questions explore learners' perceptions of agency, collaboration dynamics, and the nature of design artefacts produced under each condition.

The study was conducted at Jizzakh Polytechnic Institute during the spring semester of 2024–2025. Forty-two second-year mechanical-engineering students (mean age 20.3 ± 0.9 years) were randomly assigned to an experimental group (EG, n = 21) and a control group (CG, n = 21). Prior exposure to basic CAD tools was equivalent across cohorts, verified by a pre-test.

Design-thinking competence was operationalised through four constructs: empathic understanding, ideation fluency, iteration depth and prototype viability. Instruments included the Design Thinking Mindsets Inventory (DTMI) adapted for engineering contexts [7]; trace data from ADS logs capturing iteration cycles; and expert ratings of final artefacts against usability, feasibility and sustainability criteria. Semi-structured interviews explored perceptions of learning processes.

Quantitative data were analysed with SPSS 28. Independent t-tests compared post-test DTMI scores and artefact ratings between EG and CG, controlling for pre-test results via ANCOVA. Log-file metrics were normalised and subjected to Mann–Whitney U tests due to non-normal distributions. Qualitative data underwent thematic coding, triangulated with usage analytics to strengthen validity.

The ANCOVA revealed a significant effect of instructional condition on overall DTMI scores ($F = 16.84$, $p < 0.001$, $\eta^2 = 0.30$). Post-hoc comparisons showed that EG students exhibited higher empathic understanding ($M = 4.23$, $SD = 0.37$) than CG peers ($M = 3.71$, $SD = 0.40$). Ideation fluency, measured by distinct concept sketches submitted, averaged 18.7 for EG versus 11.4 for CG ($p < 0.01$). ADS log analysis indicated that EG teams completed a median of 46 iterative model revisions, nearly twice the CG count, reflecting deeper engagement in the refine-prototype loop.

Expert evaluation of final workstation prototypes awarded EG a mean viability score of 86.2/100 ($SD = 4.5$), surpassing CG's 78.9 ($SD = 5.1$), with notable advantages in modularity and user ergonomics. Interview themes highlighted that ADS automation of dimensioning and load-testing tasks liberated cognitive bandwidth for creative exploration, while integrated analytics provided immediate evidence of structural consequences, reinforcing abductive reasoning. Students also reported heightened sense of ownership through collaborative cloud workflows.

The results corroborate theoretical assertions that technology can act as a cognitive amplifier when aligned with learner-centred pedagogies [8]. The ADS-integrated methodology not only enhanced technical proficiency but also nurtured core design-thinking attributes, particularly empathy and iterative risk-taking. This dual impact contrasts with earlier findings that CADfocused instruction may narrow exploratory behaviour [3], suggesting that the affordances of contemporary ADS—such as AI-assisted optimisation and real-time simulation—reshape the learning ecology.

A critical factor was the deliberate sequencing of activities: empathic framing preceded tool immersion, preventing premature fixation on geometrical detail. Moreover, reflective studios transformed ADS analytics from mere dashboards into pedagogical dialogue, echoing formative assessment literature that positions feedback as a co-construction process [9]. The study also surfaces tensions; some novices initially experienced cognitive overload from the abundance of generative options, underscoring the need for scaffolds that gradually increase system complexity.

Limitations include the single-institution context and sample size, which constrain generalisability. Future research should examine longitudinal retention of design-thinking competences and replicate the study across differing cultural and disciplinary settings. Investigating how ADS can be tailored for non-engineering domains, where design constraints are less tangible, represents another avenue.

Embedding automated design systems within a structured, human-centred methodology demonstrably advances students' design-thinking competences while sustaining high technical standards. Key pedagogical principles encompass early empathic engagement, iterative ADS-supported experimentation, and reflective synthesis grounded in multimodal feedback. As ADS technologies continue to evolve, educators must move beyond tool training toward cultivating adaptive mindsets that leverage automation for creative and socially responsive innovation. The proposed methodology offers a replicable blueprint for such transformation, aligning curricular outcomes with the interdisciplinary competence demands of Industry 5.0.

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