FUTURE PROOFING COMPUTER-AIDED DESIGN EDUCATION THROUGH AI-DRIVEN E-LEARNING

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ABSTRACT

In response to the dynamic landscape of Computer-Aided Design (CAD) software and the emergence of Artificial Intelligence (AI) tools, this paper characterises a theoretical system for a Personalised AI Learning System (PALS) tailored to individual student needs. The system aims to generate personalised learning content for various CAD software as well as facilitating efficient and adaptable learning experiences. By doing so, PALS could streamline individual student learning and therefore future proof the ability to learn new software independently and frequently depending on educational needs and the commercial and technology landscape. The system is characterised as a result of literature review, student and staff surveys as well as AI experts' feedback.

Keywords: CAD, E-Learning, AI

1 HOW STUDENTS LEARN CAD AND CAD LANDSCAPE

To characterise a theoretical system for a Personalised AI Learning System (PALS), we need to understand current CAD learning methods and the potential that generative AI has in e-learning.

In the early days of CAD education, SolidWorks (Dassault Systèmes), Rhino 3D (McNeel & Associates), and Autodesk Maya dominated the CAD market. The past decade saw a proliferation in popularity of additional products such as Blender, Gravity Sketch, Onshape, and SketchUp, alongside independent rendering engines like Keyshot. Blender and Rhino's Grasshopper saw a surge in user-generated custom add-ons, enhancing features of software. This expanding and dynamic nature of CAD software landscape along with a surge in e-learning resources has altered the way students learn and tutors teach CAD.

CAD in design is not only about the quality of surfaces and model history structure but also about the ability to express design engineering ideas and be able to use it as naturally as sketching to express designs. In modern CAD education, students employ various learning methods tailored to their preferences and skill levels. Access to e-courses, tutorials, and online resources allows for self-paced learning and exploration of diverse CAD tools [1]. Instructor-led sessions and practical workshops provide structured learning experiences, complemented by guidance from instructors and real-world project applications [1]. Peer collaboration is also pivotal, enabling knowledge exchange and troubleshooting, while mentorship from CAD professionals fosters continuous improvement [2]. The challenge-based or project-based learning model promotes real-world problem-solving and critical thinking, encouraging students to take ownership of their learning [3]. Furthermore, research highlights the cognitive nature of CAD training, emphasising the separation of declarative and procedural knowledge components [4]. This understanding informs the design of effective educational tools and interfaces.

In summary, CAD education relies on independent learning facilitated by online resources, complemented by instructor guidance and peer collaboration. Mentorship remains crucial for continuous improvement, however changes in the CAD software landscape underscores the dynamic nature of CAD education and the need for adaptable learning approaches to cater to diverse student needs.

2 E-LEARNING AND GENERATIVE AI IN EDUCATION

E-learning tools are crucial in modern education, providing various learning approaches and resources like e-courses, tutorials, and online materials, along with instructor-led sessions, workshops, mentorship, peer collaboration, and challenge-based learning models [5]. Future trends in e-learning include integrating virtual and augmented reality (VR/AR), mobile learning, social media, gamification, big data, cloud e-learning, and online video [6]. These trends highlight the integration of innovative technologies to enhance the learning experience.

Generative AI technologies, such as large language models and generative models, automatically create diverse content from text prompts, advancing rapidly in complexity and accessibility [7]. These advancements leverage deep learning to generate text, graphics, audio, and video content efficiently. AI systems such as IBM's "Watson" system, is applied in medicine to aid medical students in navigating complex oncology treatment choices through evidence-based learning models [8].

Integrating interactive self-assessment graphical tools in CAD pedagogy enhances students' learning experiences [9]. Auto-assessment tools designed for CAD education, based on neutral file formats like STEP, compare students' CAD models with reference models to identify surface differences and provide valuable feedback [9]. This allows educators to gauge students' proficiency and track their learning trajectory in CAD.

Currently, ai's role in cad software primarily concentrates on design tasks such as generative design. however, its potential in educational content creation holds significant promise [9]. by enhancing the learning experience, ai can help adapt cad education to future trends, fostering student engagement and skill development. therefore, comprehending the technical challenges linked to ai implementation in cad education is vital for its effective utilisation and adaptation to evolving educational landscapes.

3 METHOD: SURVEYS TO DEFINE PALS

The study methods involved a literature review, conducting surveys among students, staff and AI experts. The literature review provided a theoretical foundation by summarising existing knowledge on CAD learning methodologies, challenges, and trends in educational technology. It informed the development of the survey questionnaire by highlighting key areas of inquiry and potential variables to explore. Additionally, it shed light on the significance of personalised learning, the role of AI in education, and emerging trends in e-learning tools, which directly influenced the conceptualisation of PALS. To gain insights into current CAD learning practices of Design Engineering students, a structured survey was disseminated among third year students on an MEng programme at a leading university. The survey included 50 students who have intermediate experience with CAD such as Fusion 360 and SolidWorks but were required to learn a new software: Rhino and Grasshopper. Student participants were asked about: the resources they use for CAD learning, examples of helpful learning experiences, challenges encountered during CAD learning, methods to adapt to the evolving landscape, familiarity with CAD software, associations between CAD software and career prospects, ease of learning various CAD software, factors contributing to ease of learning CAD software, and common methods of learning CAD. The survey results were analysed using text-to-data analysis techniques, which involved parsing and categorising responses to recognise sentiment and sort comments, thereby extracting meaningful insights to inform the characteristics of the PALS.

4 RESULTS: STUDENT CAD LEARNING EXPERIENCE

The student survey demonstrated that student CAD learning in the sampled group, comes from three main sources (Figure 1, left). 50% from online resources such as YouTube tutorials, forums, and LinkedIn Learning for CAD. 27% from collaborative learning and practice. What students gain from tutors is the ability to ask or prompt specific questions as well as learning from suggestions/demonstrations in real time. The most familiar CAD software among participants is Fusion 360, followed by SolidWorks, Blender, Rhino 3D, and AutoCAD. Participants associate SolidWorks and Fusion 360 with better career prospects, with the later considered the easiest software to learn. Factors contributing to ease of learning CAD software in students' minds include the availability of open-source add-ons and tutorials, intuitive design, simplicity, previous exposure, customisation options, and ease of transfer of files to other software.

The primary challenges encountered during CAD learning (Figure 1, right) provided insights that will feed into PALS. Firstly, students struggle to initiate their very first CAD model since there are too many unknowns. This is the step students most require tutor instruction for, so PALS needs to recognise the specific learning curve of each student, for example providing high levels of input at early stages and reducing as students' progress. In addition, students can be limited by slow access to answers as they are waiting for the next session and are unable to find the answer online. This is where it would be particularly useful for students to be able to prompt PALS for answers.

One significant challenge students brought up is CAD software setup differences and computing power limitation. Often students can be unaware that their layout of the software is different to the tutorial they are watching, for example if using a different operating system or version of the software. Secondly, 3D modelling is computationally heavy and inexperienced users often will submit a task that could require computing over ten thousand different calculations without realising it. The PALS could generate content specifically for the user's software version and operating system. Warning about potential software crashes is harder to avoid but perhaps PALS could suggest explanations as to why the software crashed based on user explanation of the steps taken. Students are aware of the evolving landscape of CAD software and adapt to it and often focus on learning new software/tools on their own.
When asked about the potential usefulness of PALS, students have made suggestions for features such as auto-creating tutorials for new software, providing suggestions for faster or more efficient methods of working, troubleshooting, or working with AI to break down constructing objects in CAD, using video or image assets and learning how to create designs

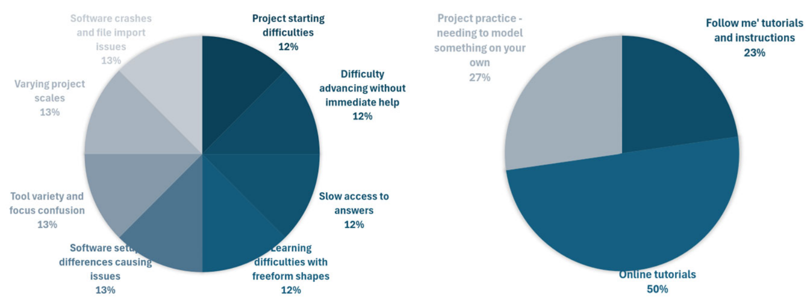

Figure 1. Sample of student survey results: ways to learn CAD (left) and types of challenges encountered when learning CAD (right)

The staff survey included Teaching Fellows who deliver CAD training to students. Their main feedback was to calibrate the feasibility of PALS. Should it be software specific, can it be an add on to existing software and how to overcome the variation in the UI of various software.
AI experts from UWE Bristol advised on the system architecture of PALS. Their feedback was positive and PALS was deemed plausible from a technical perspective.

5 CHARACTERISATIONS OF PALS

In characterisation of PALS, learnings from the student surveys together with usability factors were considered. The system comprises three modes: content generation, interactive learning, and analytics for learners and tutors. The content generation mode leverages generative AI techniques to create tailored learning materials. The interactive learning mode serves as a personalised library, recommending relevant resources and collaborative projects to inspire creativity and skill development in CAD learners. Lastly, the analytics for learners and tutors' mode provides personalised feedback to learners and comprehensive data insights to tutors, facilitating informed decision-making and instructional planning.
Generative AI systems such as PALS can employ a basic architecture comprising data input, processing, generation, and presentation layers, alongside a wrapper to manage system functionality and interactions. Data can be sourced from existing online videos and educational materials such as textbooks, user interactions, and other repositories.

5.1 Usability consideration

Critical to the PALS characterisation methodology was the evaluation of usability aspects inherent in existing CAD learning platforms. Usability can be considered to comprise of five components: learnability (initial task ease), efficiency (task speed and effectiveness), memorability (re-learning ease), errors (error frequency and recovery), and satisfaction (overall user experience) [10].

5.2 Personalised learning content generation mode

The system architecture (Figure 2) comprises several interconnected modules designed to facilitate personalised learning of CAD. The data acquisition module collects educational content from online sources such as YouTube videos, LinkedIn Learning courses, and online forums. This data is then processed and sorted based on user preferences, including the type of software, version, and operating system. Next, the content generation module utilises generative AI techniques such as natural language generation (NLG), sequence-to-sequence (Seq2Seq) models, conditional variational autoencoders (CVAEs), and template-based generation to create step-by-step tutorials tailored to the student's query and level. A user interface chatbot module provides an intuitive interface for interacting with the system, while a feedback loop module ensures continuous improvement by collecting user feedback and integrating it back into the system. This architecture enables the system to deliver personalised step-by-step instructions, explanations, code snippets, diagrams. For troubleshooting issues in real time, students can input their query or describe the issue to the system. Based on the input provided by the student, the system can diagnose the issue by comparing it with a database of common errors, troubleshooting steps, and solutions. It can also leverage machine learning algorithms to identify patterns in previous troubleshooting interactions and recommend appropriate solutions. Once the issue is identified, the system can generate step-by-step instructions, explanations, and visual aids to guide the student through the troubleshooting process. These instructions can include screenshots, diagrams, or video tutorials illustrating the necessary steps to resolve the problem.

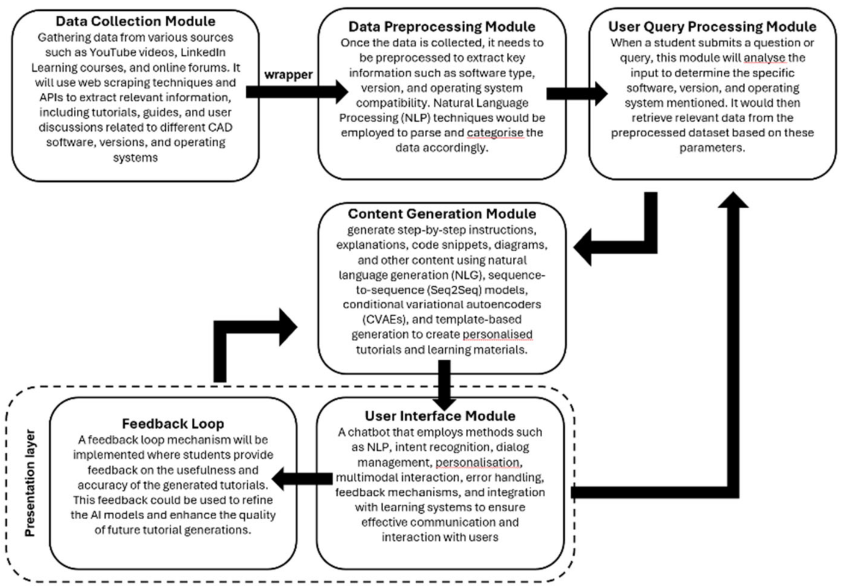

Figure 2. System architecture for the content generation mode

5.3 Interactive learning mode

In this mode, users access a personalised library of online content tailored to their software, version, and operating system set-up. It aims to inspire and challenge users by showcasing recent advancements and user-generated models. The goal is to foster learning beyond mere model creation, emphasising design skills development. Leveraging natural language processing (NLP), the system interprets user queries and retrieves relevant learning materials. It employs content filtering and recommendation systems to suggest tutorials, articles, and resources matching user needs. Additionally, web scraping and API integration access online resources and showcase user-generated content from forums and social media platforms. The mode includes an Inspiration Zone with curated designs and techniques and a Challenge Repository offering diverse design challenges. Suggestions for faster or more efficient methods of working, such as exploring the Sub-D feature in Rhino for surface control points, are also provided.

5.4 Analytics for learners and tutors' mode

PALS provides the opportunity for a considerable amount of personalised overall learning gain feedback to both learners and tutors. For students, learning does not only happen during the in-task CAD activity, but also through receiving feedback from tutors and peers following completion of activities or stages of work, and as an ongoing aggregate of student's reflection on and appreciation of gains in knowledge, skills and understanding.

This mode will gather various metrics such as engagement levels, performance on tasks, learning progress, feedback analysis, resource utilisation, collaboration patterns, retention rates, learning outcomes, comparative analysis, and predictive analytics. By collecting and analysing these data points, valuable insights into student learning experiences, areas for improvement, and tailored interventions to meet individual student needs can be effectively defined.

6 CONCLUSIONS AND FURTHER RESEARCH

PALS systems promise to revolutionise CAD education by integrating current methodologies, usability factors, and student feedback. The concept aims to cater to the changing CAD software landscape and diverse learner needs, empowering students as independent learners while offering valuable feedback to tutors for optimising teaching strategies and tracking student progress.

The PALS concept also raises several avenues for further research to enhance its effectiveness and impact in CAD education. Firstly, future studies could focus on refining the generative AI algorithms used for content generation to improve the accuracy, relevance, and diversity of learning materials produced. Additionally, exploring innovative methods for user interaction and feedback collection, such as natural language processing and sentiment analysis, could enrich the user experience and provide deeper insights into learner needs and preferences. Moreover, investigating the scalability and interoperability of PALS across different CAD software versions, operating systems, and user devices would ensure broader accessibility and usability for learners worldwide. Furthermore, longitudinal studies evaluating the long-term effectiveness and learning outcomes of PALS compared to traditional CAD education methods could provide valuable insights into impact on student learning and skill development over time.

The integration of generative AI in educational systems such as PALS raises important ethical considerations regarding the potential negative impact on students' learning experiences and core understanding of CAD and engineering principles. One significant concern is the risk that heavy reliance on generative AI-generated content may diminish students' engagement in critical thinking and independent problem-solving skills. Students may experience a similar effect to introducing GPS navigation, that reduced our own sense of orientation. By providing personalised and readily available learning materials, there is a possibility that students may become overly reliant on AI-generated solutions without fully understanding the underlying concepts or principles. This could lead to a superficial understanding of CAD and engineering principles, hindering their ability to apply theoretical knowledge to real-world problems and innovate creatively.

If AI-generated content is not adequately curated or validated by educators, there is a risk of disseminating inaccurate or biased information, potentially leading to misconceptions or reinforcing existing biases in students' learning.

To mitigate these ethical concerns, it is essential for educational institutions and developers of AI-driven systems like PALS to prioritise the promotion of critical thinking, problem-solving, and conceptual understanding alongside AI-generated content. This can be achieved by integrating opportunities for active learning, peer collaboration, and hands-on experiences into the curriculum, complementing the personalised learning materials provided by the AI system. Additionally, transparent communication about the role of AI in the learning process, including its limitations and the importance of independent inquiry, can help empower students to engage critically with AI-generated content and develop a deeper understanding of CAD and engineering principles. Overall, a balanced approach that leverages the benefits of generative AI while fostering students' autonomy and critical thinking skills is essential to ensure ethical and effective educational outcomes.

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