THE CDIO APPROACH TO DEVELOP AI-POWERED FEEDFORWARD SYSTEMS: THE "PROMPT MENTOR"

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ABSTRACT

This study investigates the development and implementation of Prompt Mentor, an AI-powered feedforward tool designed to support students in developing effective prompts in using and engaging critically with generative AI. The tool provides structured, iterative guidance to enhance academic reasoning and writing, and is integrated into an engineering materials course via RMIT's institutional chatbot (VAL). Prompt Mentor was developed in alignment with the CDIO educational framework and ethical standards for secure, scalable deployment within the university's learning environment. Two research questions guided the study: (1) how can Prompt Mentor be integrated into an engineering course to support prompt formulation; and (2) what pedagogical principles enhance reasoning and critical thinking through using such tools? Analysis focused on the quality of student-generated prompts, the use of AI feedback, and evidence of critical engagement in submitted assignments and reflections. Findings indicate that Prompt Mentor supported the development of prompt engineering as a teachable, iterative skill. Students demonstrated an improvement in their ability to frame specific and relevant inquiries and apply AI responses thoughtfully in their academic work. The tool functioned effectively as a feedforward mechanism, encouraging structured inquiry, self-regulated learning and increased confidence, particularly among students from non-English-speaking backgrounds. This study contributes new insights into the pedagogical design and institutional integration of generative AI in higher education. It moves beyond a technical demonstration to provide evidence of learning outcomes and transferable design principles for AI-supported academic development. Our study confirms that Prompt Mentor offers a replicable model for ethically grounded, pedagogically aligned AI tools that can address scalability and inclusivity in engineering education.

KEYWORDS

Engineering Education, Artificial Intelligence, Feedforward, CDIO framework, Standards: 1-3, 7, 8, 11.

INTRODUCTION

In September 2024, Australian International Education enrolled 1,018,799 international students. About half of these international students studied in higher education, and the majority (55%) are from non-native English-speaking backboards (NESB), such as China (22%), India (16%), Nepal (8%), Philippines (5%) and Vietnam (4%) (Department of Education, 2024). While the incoming NESB students have a minimum level of the English language proficiency, many NESB students reported challenges with reading, writing and speaking in academic contexts (Ramjan et al., 2024; Watkins et al., 2012).

In addition, all individuals, irrespective of their physical, cognitive, or mental health status and their life and work commitments, have an equal and fundamental right to education. Yet, students engaged in equitable learning, specifically those with recognized disabilities, chronic illnesses, or mental health conditions as delineated by the Disability Discrimination Act (Australian Government, 1992), alongside those encountering particular life or work circumstances, often encounter unique challenges that can impede educational experiences. As we navigate the fast-changing education environment influenced by technological advancement, it is imperative to identify and implement solutions that foster inclusivity and personalization in learning for all students. Many researchers have contended that universities are responsible for delivering education equitably (Kimpton et al., 2024; McGrath et al., 2023; Mohebbi, 2025).

Given the promising developments in artificial intelligence (AI), specifically ChatGPT, this research aims to investigate their potential and identify areas of improvement in which we can harness the power of AI tools to help students with equitable learning needs. The motivation behind Prompt Mentor is to address the challenges students face when they are studying outside classrooms and lack someone to consult with. Engineering is filled with complex problems, and students often find themselves stuck without timely guidance. Our project aimed to create a solution that leverages AI to deliver structured, personalized feedforward guidance, thereby assisting students in gaining confidence and clarity in their studies. This study was guided by the following research questions:

- How can an AI-powered feedforward tool such as Prompt Mentor be integrated into an engineering course to support students in formulating effective prompts for generative AI use?
- What pedagogical principles and design considerations are essential in developing such a tool to enhance students' reasoning and critical thinking in academic writing?

LITERATURE REVIEW

Feedforward practices

Feedforward practices in education aim to improve student learning by focusing on forward-looking feedback processes that guide students toward better performance in future tasks (Reimann et al., 2019). Unlike feedback, which has traditionally been described as information provided to students based on their past performance, the feedforward process emphasizes the importance of enabling students to improve their work (Scott et al., 2014). According to Dulfer and Akhlaghi Koopaei (2021, pp. 101-102), 'the principle of feedforward is based on developmental comments that guide students to improve work and enhance their knowledge construction rather than focusing on shortcomings of their work'.

The systematic review by Sadler et al. (2023) highlights several key aspects of feedforward practices and their implementation. They found that most feedforward practices (91%) emphasize process and design over mere delivery of feedback as a product. Educators are positioned as instructional designers, creating processes to engage learners with performance-related information actively. It is, therefore, essential to implement feedforward techniques and tools in the classroom to assist students in bridging the gaps between their current performance and their desired outcomes (Dulfer & Akhlaghi Koopaei, 2021).

Common feedforward practices among researchers are: formative assessment approach (Hine & Northeast, 2016; Reimann et al., 2019), interactive and dialogic methods (Beaumont et al., 2011; Ghazal et al., 2018; Hill & West, 2020) and integration with curriculum design (Saeed & Mohamedali, 2022). Many researchers advocate for providing comments on students' drafts before submission. For example, Ghazal et al. (2018) showed that this approach benefits all students, challenging high-achievers and guiding weaker students. Through the dialogue method, educators and students can engage in meaningful dialogue about feedback, where students are informally assessed, which can inform their final assignment (Hine & Northeast, 2016). Feedforward, when integrated into curriculum design, enhances student engagement and performance by embedding forward-looking strategies into teaching and assessment processes. Key features such as timeliness, regularity, active learner involvement, and customized feedback are essential in fostering meaningful academic development (Saeed & Mohamedali, 2022). Saeed and Mohamedali (2022) reported that when integrated systematically into curriculum design, feedforward leads to improved pass rates, higher satisfaction with feedback processes and reduced student anxiety, particularly in the early university years.

Feedforward represents a critical shift in assessment practices, emphasizing proactive and developmental support for students. However, methods for effectively implementing feedforward in large and diverse student groups, such as online or distance learning settings, require further investigation (Baker & Zuvela, 2013). The role of digital tools and AI in facilitating scalable, personalized feedforward strategies has yet to be comprehensively studied.

Technology-Enhanced Feedforward

As recent studies indicate, the integration of AI in education offers transformative potential. AI systems, such as ChatGPT, offer a scalable and efficient method for generating personalized, timely and actionable feedback tailored to students' needs, particularly in open-ended and complex assignments (Jantanukul, 2024; Monib et al., 2024).

AI tools such as ChatGPT have demonstrated the capability to produce detailed, coherent and task-focused feedback (Dai et al., 2023). The utilization of AI ensures timely and consistent feedforward, particularly in large cohorts where traditional methods encounter resource constraints (Ogunleye et al., 2024). AI has been reported to provide support for complex tasks, such as evaluating open-ended assignments, including essays and proposals, and providing comprehensive feedback across multiple domains (e.g., medical education, engineering, and humanities) (Escalante et al., 2023; Malik et al., 2023; Nguyen et al., 2024). According to Dai et al. (2023), AI can generate more readable comments with greater consistency, thereby aiding students in understanding the feedback/feedforward and motivating them to take action for improvement. AI has also shown promising results in promoting self-regulation and critical thinking through iterative feedforward that empowers learners to plan and improve their approaches (Chang et al., 2023; Mohebbi, 2025; Zhou et al., 2024).

Furthermore, AI addresses scalability by automating routine feedback/feedforward processes and supporting diverse student populations with different learning needs, including accessibility and neurodiverse needs (Giannakos et al., 2024; Kamalov et al., 2023). However, strategies must be developed to ensure AI-generated insights support sustainable learning outcomes rather than fostering dependence.

Integration of Generative AI within the CDIO Framework

Effective implementation of feedforward requires careful planning and integration into course design. The CDIO (Conceive-Design-Implement-Operate) framework, widely used in engineering education, provides a systematic approach to developing solutions by balancing theoretical knowledge and practical application (Crawley et al., 2014). In generative AI education, the CDIO framework offers a structured approach to integrating AI tools into engineering curricula while addressing ethical, pedagogical and practical challenges (Saeidlou et al., 2024). This integration aligns naturally with CDIO's emphasis on active learning and real-world engineering experiences.

Recent studies have demonstrated how strategic adaptations of generative AI, particularly ChatGPT, can align with the CDIO framework to enhance education through personalized and active learning experiences (Kimpton et al., 2024; Manna et al., 2024; Saeidlou et al., 2024). Kimpton et al. (2024) specifically evaluated how ChatGPT's capabilities can be customized to support different aspects of the CDIO standards, from technical knowledge acquisition to professional skills development. Their findings suggest that thoughtful integration of ChatGPT can enhance curriculum design by accommodating diverse learning styles and preferences, promoting inclusivity and improved learning outcomes.

Wibawa et al. (2024) further elaborate on this integration by examining how the CDIO framework can be applied to evaluate AI-generated scholarly work. Their research demonstrated that a systematic approach of CDIO can be effectively used to assess and enhance the quality of AI-generated content, particularly in academic publishing.

Implementing AI within the CDIO framework offers promising opportunities to enhance student learning outcomes through strengthened feedforward mechanisms. By examining how generative AI can support active learning, personalized feedforward and real-world problem-solving experiences, we seek to develop evidence-based guidelines for its effective integration into engineering curricula.

METHODS

In the context of this study, Prompt Mentor was designed and developed to support students in generating effective prompts to guide their engagement with generative AI tools. The system provides structured, feedforward support aimed at enhancing reasoning and critical thinking during assignment preparation.

An Overview of the Prompt Mentor: Generative AI Feedforward System into Education

The development of Prompt Mentor involved a systematic workflow designed to align with educational objectives and institutional compliance requirements (see Figure 13). Initially, the objectives for the prompts were clearly identified, preliminary prompts were drafted and tested using ChatGPT to ensure their effectiveness and appropriateness. Following this stage, the RMIT technical team developed the institutional chatbot, VAL, leveraging OpenAI's GPT-4o API (Application Programming Interface). This step was conducted in strict adherence to the

university's security and legal guidelines, ensuring all conversational data were securely stored and managed.

Subsequently, specialized prompts created specifically for Prompt Mentor were integrated into VAL to establish a coherent and interactive virtual persona. The Prompt Mentor was then incorporated into student assessments via the Canvas Learning Management System (LMS), facilitating direct student interaction within a familiar educational environment. Each interaction between students and Prompt Mentor was systematically recorded, enabling detailed tracking of conversations.

The recorded interactions served multiple educational purposes. Primarily, they provided educators with valuable data to assess students' proficiency in prompt engineering, a crucial skill in the context of generative AI tools. Additionally, these records allowed educators to conduct detailed analyses of student engagement and interaction patterns with generative AI, thereby informing further pedagogical refinements and improvements in AI integration strategies.

The workflow adopted for developing Prompt Mentor highlighted the iterative and collaborative approach essential for the successful deployment of educational technology. Each stage—from conceptualization, technical development, compliance assurance and integration within Canvas LMS—required ongoing coordination between educational experts, technology specialists and institutional compliance officers. This structured process ensured Prompt Mentor met educational goals and aligned with institutional requirements for security, data integrity and pedagogical effectiveness.

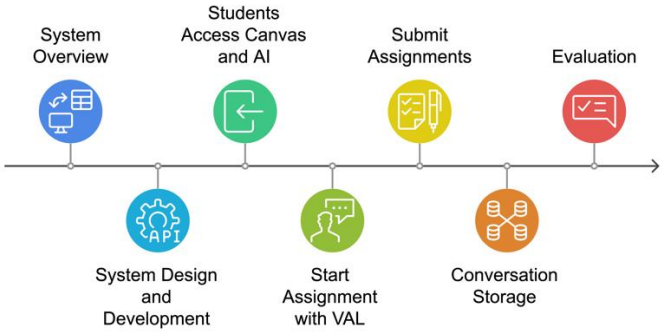

Figure 13. System overview of the Prompt Mentor System: The diagram illustrates the design and development of system prompts, student interactions facilitated through VAL, secure storage of conversations, and an evaluation framework to monitor prompt refinement and student skill development

Personalized Feedback/feedforward with Prompt Mentor

The design and development of Prompt Mentor utilized generative AI, specifically through integration with OpenAI GPT-40 large language model, to create a virtual persona capable of delivering feedback/feedforward. The process started when students input their responses or questions. Prompt Mentor then analysed the prompt, provided suggestions, and offerred an improved version. Alongside this, it provided examples to help students refine their answers (Figure 2). This interactive, AI-driven feedback/feedforward was tailored to accommodate each student's unique learning needs, making the learning experience engaging and customized.

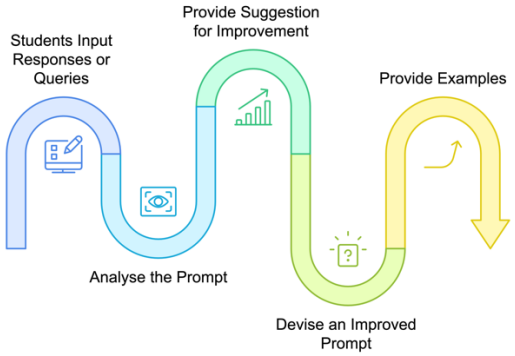

Figure 14. The process of Prompt Mentor in providing interactive responses to students

Align with CDIO Standards

The design and implementation of Prompt Mentor systematically supported all four phases of the CDIO framework. They also adhered to CDIO standards (Johan Malmqvist et al., 2019). ensuring a holistic and structured approach to engineering education. Following Standard 1, Prompt Mentor incorporated real-world contexts by addressing students' challenges when engaging independently with complex engineering concepts, thus supporting the educational experience in practical applications. The tool also supported achieving learning outcomes by enabling students to develop personal and disciplinary knowledge through structured feedback/feedforward and guidance (Standard 2).

Prompt Mentor has been integrated with the curriculum as per Standard 3, combining disciplinary knowledge with self-directed learning and problem-solving skills. It offered integrated learning experiences by embedding critical feedback/feedforward processes into the course design, which helped students connect theoretical concepts to practical applications (Standard 7). Furthermore, the active learning methods promoted by Prompt Mentor aligned with Standard 8, enabling students to actively engage with their learning process through iterative improvements guided by AI-driven personalized feedforward responses.

Finally, Standard 11 was reflected in Prompt Mentor's ability to assess and guide learning in a formative manner, focusing on technical proficiency and broader skills development. By aligning with these CDIO Standards, Prompt Mentor represented a forward-thinking approach that enhances engineering education by integrating innovative AI-driven feedforward mechanisms within a robust curriculum framework.

Case Study: Research Activity on Advanced Metallurgical Topics

The case study was embedded within the Mechanics and Materials 2 course, a core subject offered as part of the engineering curriculum at RMIT University. This course has an enrolment of approximately 250 students each semester. As part of the assessments, students were required to delve into key topics in metallurgical science and materials engineering, equipping them with the knowledge and skills necessary to design components for strength, structure integrity and real-world performance. Students were required to select and research one of five topics (Iron Ore, refining of Titanium, metallic glasses/amorphous metals, Shape Memory Alloys, or Superplasticity), summarizing their findings in a concise, structured response of 600–650 words assay.

Students were given suggested questions for each topic to aid their research, focusing on critical aspects such as material properties, fabrication methods and engineering relevance. A detailed marking rubric outlines the criteria for evaluating technical accuracy, analysis depth and communication clarity. Additionally, students have access to the Prompt Mentor tool within the VAL framework, designed to enhance their inquiry process and optimize the use of AI in developing well-formulated questions.

Qualitative Analysis of Students' Works

The qualitative analysis focused on two primary sources of textual data: (1) questions submitted by students to the Prompt Mentor AI chatbot and the corresponding responses provided by the chatbot, and (2) students' reflective statements about their interactions with the AI and the search strategies they employed. This dual analysis comprehensively understood how students engaged with AI regarding direct interaction and their broader learning processes.

This work analyzed student submissions and chatbot responses, with the aim of evaluating the language used in question formulation, the nature of the AI's responses, and the alignment of feedback/feedforward with educational goals such as critical thinking and problem-solving. In addition, the reflective statements offered deeper insights into students' perceptions of their interactions with the AI, including the effectiveness of the feedback/feedforward they received and the strategies they used to refine their questions or search for information. Common themes, challenges, and patterns in students' questioning were identified, providing valuable insights into the challenges and opportunities students encountered and contributing to broader discussions on effective AI-supported education.

RESULTS

The dataset from this study came from a random selection of ten submitted essays by students who enrolled in the Mechanics and Materials 2 course. We use gender-neutral pseudonyms to preserve anonymity while ensuring clarity when reporting individual student feedback.

The Integration of Prompt Mentor in Learning Management System (LMS)

The implementation of Prompt Mentor into the Mechanics and Materials 2 course was designed to enhance students' interaction with AI by improving their ability to ask effective and focused questions. It was embedded directly within the LMS (i.e. Canvas), where students gained access to the tool that provided immediate feedback/feedforward on their question structure, helping them refine their inquiries and better engage with AI for deeper exploration of mechanics and materials topics (Appendix 1).

Student Interactions with Prompt Mentor

The student's submitted work provided insights into how they interacted with the AI tool (e.g. Prompt Mentor) and their overall perceptions of its functionality and impact on their learning process. Student workflow revealed that AI supported their self-directed learning, where AI facilitated iterative learning by helping students reflect on their queries and refine their approach, contributing to skill development in research and problem-solving. Students progressed from vague, general prompts (e.g. "What is this topic about?") to more specific, structured queries (e.g. "What type of crystal structure does superplastic materials have?"). They also demonstrated a continuous integration of "Prompt Mentor" with other tools (e.g., ChatGPT, search engines) to validate and expand their knowledge, illustrating the AI's role in

enhancing independent learning. An example of how Jordan interacted with Prompt Mentor is shown in Figure 3.

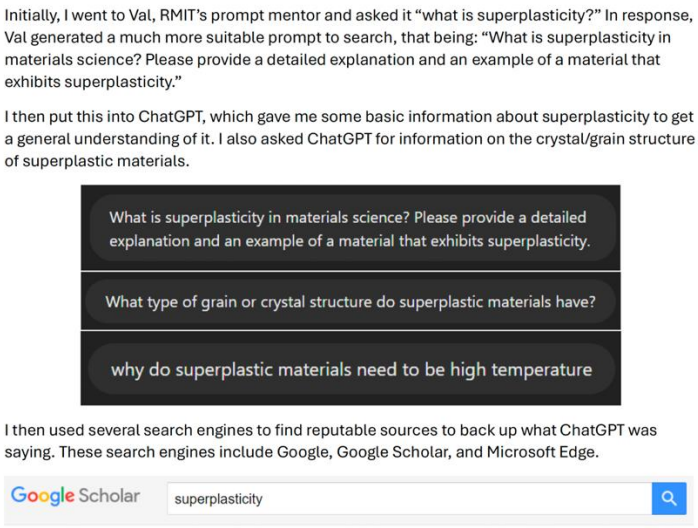

Figure 15. A student's workflow illustrating interaction with Prompt Mentor for query, refinement and integration with external tools for knowledge validation and exploration

Student Reflections

Many students have reported that "Prompt Mentor" provided valuable guidance in formulating effective questions, allowing them to explore complex problems more confidently and engage. Students noted that the tool was handy for comparing how the context level in a question affects the quality of AI-generated responses. Taylor, a student participant, reflected:

When using AI while researching the topic, it was quite easy to phrase questions for the AI, especially when using the Prompt Mentor to compare different responses to questions depending on how much context is provided. ChatGPT's model GPT-4o, even in its lite (free) version, was able to answer questions with intricate detail as well as providing examples and applications of the topic.

DISCUSSION

Implementation and Operation of Prompt Mentor to support students

Integrating Prompt Mentor within the course's digital environment ensured accessibility and ease of use, contributing to its effectiveness as a learning enhancement tool. However, implementing and operating Prompt Mentor required a multidisciplinary approach involving diverse stakeholders to ensure alignment with institutional policies and the CDIO framework. Key stakeholders included technical experts, business analysts, digital experience developers, and strategic leaders across domains such as enterprise technology, education technologies, digital learning experience, and architecture and software engineering.

Prompt Mentor relies on OpenAI's ChatGPT, which introduced controversial institutional considerations, particularly regarding intellectual property (IP), data security and the privacy of students' data. These issues were addressed through careful negotiation and compliance with university policies. The initial process also included consultative meetings with Information Technology Services and legal representatives to address IP and ownership. This

approach aligns with CDIO Standard 1, emphasizing sustainable and ethical practices, and Standard 11, ensuring secure and compliant handling of student data within learning assessment processes. These proactive measures also ensured Prompt Mentor's scalability, enabling its integration into university-wide teaching and learning. Although these activities were not student-led, they were foundational to providing a safe, scalable learning environment that supports responsible engagement with AI across the broader teaching and learning ecosystem.

Utilizing CDIO in AI-Supported Pedagogy

The CDIO framework, as developed by Crawley et al. (2014), promotes engineering education that mirrors the real-world development lifecycle of systems and products. Although the students in our study were not developing physical products, the use of Prompt Mentor facilitated cognitive processes that aligned with the intellectual demands embedded in each CDIO stage. In our study, while students were provided with a predefined problem (e.g., an engineering essay topic or assignment task), Prompt Mentor enabled them to conceive structured prompts that helped them explore and refine their approach to problem-solving. By iterating and refining their prompts based on AI feedback/feedforward, students were able to develop structured and relevant inquiries that enhanced their understanding of engineering concepts. After that, students implemented their AI-assisted inquiry strategies by integrating responses from Prompt Mentor into their writing process, using the generated suggestions to develop structured essays and assignments in engineering. The iterative nature of AI-assisted learning means students continuously interact with the tool, evaluating and refining their understanding through engagement with multiple prompts, similar to how engineers iteratively improve and maintain systems.

Hand-on Learning with AI: CDIO Pedagogy with Prompt Mentor

In our study, the adoption of CDIO framework facilitated a systematic and structured evaluation of Prompt Mentor. The framework focuses on hands-on learning and digital enhancements, ensuring that students are actively engaged while receiving meaningful AI suggestions. For example, the use of Prompt Mentor supported students in refining their questions and also encouraged reflective practices, aligning with the CDIO emphasis on iterative learning and improvement.

These findings resonate with previous research (Saeidlou et al., 2024), highlighting the connection between AI and CDIO-based pedagogy. This approach empowers each stage of the CDIO cycle through the effective integration of technology. In our study, Prompt Mentor played an essential role in the "conceive" and "design" stages by helping students evaluate their ideas and receive formative feedback/feedforward, a process crucial for developing critical thinking and problem-solving skills. Following this, students moved on to the 'implementation' stage, transforming their refined ideas into tangible outcomes, such as essays and written reports. Furthermore, integrating AI tools in the 'operate**"** stage offers significant opportunities to streamline the generation and analysis of required information. By providing students with relevant and accurate data more efficiently and in a shorter time frame, Prompt Mentor helped reduce the overall project duration while enhancing the quality of outputs.

The study also highlighted the importance of creating equitable and personalized learning environments. AI technologies like Prompt Mentor have demonstrated critical in fostering learner autonomy by enabling self-regulated and individualized learning experiences. This outcome aligns with prior findings (Hine & Northeast, 2016; Saeed & Mohamedali, 2022),

emphasizing AI's effectiveness in enhancing writing and grammar skills through personalized, instant feedback/feedforward. Such capabilities empower students to develop foundational skills while tackling complex engineering concepts.

The Prompt Mentor system was designed to support students from diverse linguistic backgrounds. By providing structured, low-risk opportunities for engagement, Prompt Mentor supported students in articulating ideas more clearly and confidently. This aligns with inclusive pedagogical practice and expands the accessibility of high-quality academic support.

Practical Implications for AI-enhanced learning

The study contributed to ongoing discussions on how AI can empower CDIO-based curricula in engineering education by highlighting opportunities and challenges. It demonstrates that AI tools like Prompt Mentor can inform best practices:

- Students benefit from structured guidance in prompt formulation, particularly in navigating open-ended, complex tasks requiring critical thinking.
- Feedforward mechanisms are more effective than post-task feedback in supporting reasoning development, as they allow students to test and refine their thinking prior to submission iteratively.
- NESB students benefited from the AI's support in articulating questions and organizing their ideas, which has implications for inclusive and adaptive learning design.
- The success of such systems depends on the technical model and their pedagogical embedding, including the timing of access, integration with assessment and opportunities for reflection.

CONCLUSION

This study contributes to the growing body of research on AI-enhanced learning by demonstrating how a purpose-built tool like Prompt Mentor can support structured inquiry, enhance student learning through active engagement and promote self-directed learning in engineering education. By integrating generative AI within a secure institutional environment and aligning with CDIO principles, the project offers a model for ethically grounded, scalable innovation.

Beyond its technical implementation, this study demonstrates significant potential in the teachability of prompt engineering, the value of feedforward design and the pedagogical conditions that foster AI-supported reasoning. Students demonstrated their ability to formulate purposeful prompts, engage with AI outputs and apply insights in academic writing—key competencies for future engineers. As engineering education continues to evolve, this work offers a research-informed strategy for integrating AI in ways that extend the CDIO framework to improve how students learn and how they think.

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APPENDIX 1

To make the most out of AI, we have developed a version of VAL, which will help you ask good questions:

Prompt Mentor

Prompto 10:18 AM

Prompt Analysis:

The prompt asks for a definition or explanation of "superplasticity."

Prompt Evaluation:

While the original prompt is clear, it lacks context and does not specify the depth or format of the information required. Adding clear instructions or asking for specific examples could enhance the response.

Example of an Improved Prompt:

"Explain the concept of superplasticity, including its applications in material science, and provide real-world examples that illustrate its importance."

Prompt Engineering Technique Used and Rationale:

The technique used is "Clear Instructions" and "Examples and Templates." By introducing these elements, the prompt encourages a more comprehensive and structured response that includes practical applications and examples, enhancing understanding.

Answer to the Original Prompt:

Superplasticity is a property of certain materials that allows them to undergo significant plastic deformation without breaking when subjected to tensile stress. This phenomenon usually occurs at elevated temperatures and low strain rates. Materials exhibiting superplasticity can elongate to several times their original length, which is advantageous in applications such as the forming of complex metal shapes and parts.

Answer to the Improved Prompt:

Superplasticity refers to the ability of certain materials to undergo extensive plastic deformation under tensile stress without fracturing, typically at high temperatures and specific strain rates. It's utilized in material science for manufacturing intricate metal forms with minimal effort. Real-world applications include the aerospace and automotive industries, where superplastic forming techniques create lightweight, durable parts. For instance, titanium alloys exhibiting superplasticity are used to form complex aircraft components with excellent strength-to-weight ratios, enhancing performance and fuel efficiency.