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Integrating Engineering Judgment Instruction into a Design Course for Electrical and Computer Engineering Juniors

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1.0 Introduction

Engineering judgment is a crucial, universal competency for practicing engineers. The Accreditation Board for Engineering and Technology (ABET) specifies this competency in two of its seven required student outcomes. However, engineering students have generally *not* received formal instruction on engineering judgment. Also, engineering students have generally *not* been assessed on this outcome, despite ABET's expectations. This educational gap prompted exploratory research on engineering judgment instruction and assessment in undergraduate education after first establishing a consensus-based definition for it.

Using a Delphi study with a diverse panel from academia and industry, a working definition and process model for engineering judgment were developed in the fall 2024 [1-2]. During the following spring 2025 semester, the working definition was pilot tested in Junior Design, a required course for electrical and computer engineering majors that aims to prepare them for their capstone design projects. The pilot testing involved direct, lecture-based instruction on the working definition and a follow-up exercise in which students were asked to freely apply the definition to an industry case study. Student feedback from the pilot semester informed instructional and assessment activity for the subsequent fall 2025 semester, which is the topic of this article.

During the fall 2025 semester, greater emphasis was placed on the situational context of a design opportunity or problem during the lecture-based instruction. A new worksheet scaffolded students in applying the components of the emergent engineering judgment definition to a fictitious role as a design engineer using the industry case study as a backdrop. This article will present and discuss a small dataset collected from the worksheet and implications for ongoing instruction and assessment of engineering judgment in undergraduate education.

1.1 Research Questions

For this article, we used a subset of data from the instructional worksheet to examine research questions related to students' use of engineering judgment in a fictitious design scenario during future employment. Specifically, the research questions are as follows:

1) How do students plan for skills needed in a future design assignment?
2) How do students view the role their identity might play in a future design assignment?
3) How do students incorporate societal and ethical factors into a future design assignment?
4) How do students apply critical thinking when errors are uncovered as part of a future design assignment?

2. Literature and Background

Judgment is a common term and crucial to engineering. Although there are many conceptions, notions, and ideas surrounding engineering judgment in the published literature, they had *not* been synthesized to an agreed-upon definition for engineering judgment prior to the authors' research [1-2]. Yet, a concrete definition and understanding are important to providing instruction and assessment on engineering judgment in undergraduate education.

To this end, using an 18-member Delphi study, a vetted definition and model for engineering judgment (EJ) has emerged. It contains three main components – the engineer/professional, the situational context, and critical thinking, which includes evaluation. According to this model, engineering judgment is driven by an opportunity or problem, in which the engineer applies or incorporates various knowledge, behaviors, and identity traits as well as considers the situational context to perform critical thinking. Critical thinking entails problem definition, solution identification, decision making, and evaluation, resulting in a culminating solution or decision. This process contributes to formative development of the engineer. The detailed definition is given as follows:

> **Engineering judgment** is a systematic process that supports an engineering opportunity or problem-solving effort whereby a professional applies in an ongoing manner their explicit and tacit (i.e., experiential) knowledge along with metacognition and elements of their identity to perform critical thinking. For critical thinking, the engineer also considers in an ongoing manner the situational context, including consideration of societal/social, cultural or global, environmental, ethical, health/safety, economic, and aesthetic factors as well as the existence of uncertainty, complexity, and constraints such as cost and time. During critical thinking, the engineer defines the problem or goal and possible solutions (e.g., through modeling, approximation, or assumptions) and iteratively evaluates each of these to make a decision, which may be iteratively evaluated also. In performing an evaluation, the engineer conducts testing or identifies errors, foresees potential problems, and seeks feedback or otherwise communicates in pursuing a culminating decision or solution. The process ultimately formatively impacts the engineer or professional for lifelong learning and development [1-2].

The emergent definition has undergone vetting by industry and academic reviewers and has exhibited robustness and face validity as a result. The emergent definition has been presented to 13 professionals from industry in the U.S. and abroad. Academic feedback has been obtained from faculty review panels at two R1 institutions in the U.S. as well as from ten (10) faculty from additional universities in the U.S. and abroad.

3. Methods

3.1 Instructional Methods: Lecture and Application

Before the midpoint of the semester in Junior Design, students were presented with a 45-minute lecture during class on the emergent model for engineering judgment (EJ). The instructor (i.e., first author) discussed each main component of the model – the engineer, situational context, and critical thinking – as well as the various sub-components, such as application of tacit knowledge and metacognition; consideration of contextual factors such as societal or ethical; testing and critique; and decision making. Special emphasis was placed on consideration of the situational context, including societal, cultural, ethical, health/safety, aesthetic, and environmental factors as well as uncertainty and constraints. This was done using real-world examples from the field of electrical and computer engineering, including adjusting video games to meet cultural norms, using lead-based versus lead-free solder, writing "aesthetically-pleasing" code, designing electronic toys for children that are aesthetically attractive, considering the global problem of electronic-waste, using simulation to account for uncertainty in integrated circuit board production, and Federal Communications Commission (FCC) regulations (i.e., constraints). Based on data collected during the previous pilot semester, students did *not* discuss situational context factors frequently; therefore, we aimed to scaffold students in being aware of and considering the situational context surrounding problems and opportunities. Near the end of the lecture, the instructor related a disaster case (i.e., the Northeast Blackout of 2003) to engineering judgment.

Following the lecture, students were asked to apply the engineering judgment model using an industry case study as a backdrop. This practice exercise referred to Intel's 1994 FDIV bug, which had both technical (i.e., chip design and testing) and non-technical (i.e., customer handling and fallout) aspects [3]. For this exercise, students were first provided with resources for reading about Intel's 1994 problem. A worksheet was then assigned to guide students in applying various components of the engineering judgment model to their fictitious role as an engineer working on the design and testing of the next-generation microprocessor at Intel. A sample of questions from the worksheet are presented in Table 1.

Table 1: Worksheet Questions

	Question	Applicable Component of EJ Model
1	Assume you are a newer engineer at Intel who is designing the next-generation microprocessor. (Note: although several generations have been designed since the 80486, assume you are working on the next generation of the 80486 but in the present day). You will be working on the floating-point unit (FPU). An essential part of using engineering judgment is the application of explicit knowledge. What methods, codes, and/or standards will you use for the testing of the FPU?	Application of Explicit Knowledge
2	How will you gain knowledge about the methods, codes, and/or standards for testing the FPU?	Use of Metacognition (i.e., self-regulation/planning)
3	How are you going to ensure your testing knowledge or know-how is sufficient after completing #2 above?	Use of Metacognition (i.e., self-regulation/evaluation)
4	Provide one example of how your personal identity may impact or play a role in your design work and testing.	Incorporation of Identity

	Question	Applicable Component of EJ Model
5	Provide one example of how each of the following factors may or could influence your design work. If the factor is not relevant to your work, explain why. Social/Societal, Cultural/Global, Ethical, Health/Safety, Aesthetic, Economic, Environmental, Uncertainty, Constraints, Complexity	Consideration of Situational Context
6	Assume the microprocessor has passed all of your validation and verification procedures. However, an independent tester reports an error with the FPU results. Using elements of Critical Thinking, how will you address or handle this reported problem?	Critical Thinking (includes Evaluation)

3.3 Assessment Methods

Student responses from the worksheet underwent an emergent content analysis driven by the data to answer the research questions and offer insight for ongoing instruction and assessment related to engineering judgment [4]. The small set of responses were double coded; thus, they were independently coded by two analysts, who met to discuss the codes they had assigned. When their codes differed, they reviewed the student response to reach an agreement on final codes to assign. The coding schemes used are shown in Tables 2 through 5 with the presentation of the coding results. Most questions received 13 responses, with the last question receiving 11.

4.0 Results & Discussion

A subset of results gathered from the worksheet are presented in this section based upon the research questions in section 1.1.

RQ1: *How do students plan for skills needed in a future design assignment?*

Worksheet question 2 (Table 1) challenged students to exercise metacognition by planning for how they would gain knowledge needed to test the floating-point unit (FPU) in the microprocessor they were to design as part of a future employment scenario. Metacognition is an aspect of the engineer/professional component of the model.

Not unexpectedly, nearly all (85%) stated they would use general, publicly available resources, such as information that could be accessed via the internet. However, almost 70% indicated they would access and learn specifically about IEEE standards, including IEEE 754, which governs floating point arithmetic, as shown in Table 2. Approximately half indicated they would consult with experienced or peer engineers. Formal training was mentioned, but less frequently than the other resources. This may reflect a degree of learning independence by students of today. Nearly all respondents planned to use at least two resources for their learning.

Table 2: Planning Responses

Category	Percent of responses (n=13)
General, publicly available resources	85%
IEEE standards/training, including IEEE 754	69%
Consult experienced or peer engineers	54%
Internal-to-Intel resources	46%
Formal training	31%

RQ2: *How do students view the role their identity might play in a future design assignment?*

Worksheet question 4 (Table 1) challenged students to think about how their identity might impact or play a role in the future design scenario. Identity is another feature (specific to the engineer) that is incorporated during the engineering judgment process. Most respondents associated their work ethic, professional behaviors, and values as *Identity* elements that could impact their design work (Table 3). Specifically, the following descriptors were called out in the students' responses in relation to work ethic, professional behaviors, and values: accountable, communicative, detail oriented, diligent, double-checking, honest, proactive, and reliable. This was an encouraging finding that aligned with our preliminary notion of what may be most relevant about identity for engineering judgment. Lesser percentages of respondents associated their technical competence or know-how or particular demographics as elements of their identity that might have a role in their design work and testing.

Table 3: Identity Responses

Category	Percent of responses (n=13)
Work ethic, behaviors, values	77%
Technical competence or know-how	38%
Demographics	23%

RQ3: *How do students incorporate societal and ethical context factors into a future design assignment?*

Worksheet question 5 (Table 1) challenged students to identify one example of each contextual factor (for example, societal factors) and how it might influence their design work. There are ten contextual factors identified as part of our emergent definition and model for engineering judgment. A large percentage of respondents (i.e., 85%) associated meeting product-related expectations with consideration of societal factors (Table 4). These product-related expectations included safety, quality, error-free performance, reliability, usefulness, affordability, on-time availability, and fixes to errors when needed. Nearly one-half indicated that the public's image of their work would be a societal consideration, including ensuring the public's trust and managing the public's impression. A small percentage said that communication with the public, and most notably transparency, was a societal factor that would influence their work.

Table 4: Societal Factors Responses

Category	Percent of responses (n=13)
Meeting product-related expectations	85%
Consideration/management of public's impression of them	46%
Communications with public	15%

Relative to ethical factors, over three quarters of the respondents associated error prevention and product performance with a consideration of ethical factors (Table 5). This category was related to reliable, quality, and safe products as well as rigorous and careful design and testing of them. Error communications was also discussed frequently in relation to ethical factors and entailed transparent, truthful, honest, full-disclosure communications when an error occurred.

Table 5: Ethical Factors Responses

Category	Percent of responses (n=13)
Error prevention/product performance	77%
Error communications	54%

RQ4: *How do students apply critical thinking when errors are uncovered as part of a future design assignment?*

Worksheet question 6 (Table 1) challenged students to use elements of critical thinking to address or handle an error reported by an independent tester of the FPU (floating point unit). Critical thinking is one of the main components of the emergent definition for engineering judgment. In the students' responses (n=11), every sub-component of Critical Thinking was mentioned at least twice across all of the responses. These critical thinking sub-components included identifying/defining the problem, identifying solution(s), decision making, testing/identifying errors, foreseeing problems, and communications for feedback.

Thus, students appeared to have understood and applied the engineering judgment definition to the scenario. All students (100%) mentioned testing/identifying errors and generally in more ways than one. Specifically, students mentioned both reproduction of the reported error (i.e., testing) as well as subsequent re-testing of the entire system once fixes were put in place. The following three example responses illustrate students' application of critical thinking. The first example discussed testing, foreseeing problems, and identifying solution(s).

1. *My goal would be to fix any problems caused by a veritable FPU error. First, we have to verify the bug exists. Then, if it does, I have to prevent the processor from causing any further damage. Forcing everyone to recall processors for a minor bug would be the fullest solution but may be more than what most consumers need. I wouldn't be completely silent about a minor error either since I don't know what it would affect. I would copy the results to see if I can replicate the error to rule out any scam. Then, I would announce a minor error and announce a free replacement for anyone who wants it.*

The second example response included mentions of testing, identifying/defining the problem, identifying solution(s), and communications for feedback. In this response, communication was proposed with internal leadership on the issues in the last sentence.

2. *First I will acknowledge the issue and request a reproduction of that error with all the specifications, while also acquiring the failed processor to test. I will then attempt to reproduce said issues and attempt to determine exactly what is failing. If the issue is reproducable, use equivalence checking and find the logic that fails. Additionally, I will find which components it is failing with if these issues are in realistic workloads, or specific edge cases. Lastly, after confirmining the issue, I will either find a work around if possible, compensate the customer for the issue, and communicate clearly with the public and internal leadership about the issues.*

Finally, the third example discussed testing, identifying/defining the problem, communications for feedback, identifying solution(s), decision making, and various forms of re-testing.

3. *Firstly, I would try to recreate the issue presented by the third party. Then, I will try to identify the problem. After that, I will consult with my colleagues to try and find a solution for the problem. If multiple solutions are found, one will be chosen. Then, the solution will be built and evaluated to make sure it fixed the previous problem. Finally, I will ensure my other test cases still pass after any changes I've made, then present my results to the third party and possibly the public.*

5.0 Conclusions

In this article, we presented results from an instructional worksheet intended to guide students in applying components of an emergent engineering judgment model to a fictitious, future role as a design engineer at a chip manufacturer. These results provided insight on how students planned for their required learning, viewed their identity in relation to their design work, considered societal and ethical factors as part of their design work, and approached critical thinking when an error was reported. Solid judgment is a critical, universal competency in engineering, including for design. Although this article focused on an electrical and computer engineering course, design courses across engineering can and should incorporate formal education and assessment on engineering judgment given its universal importance and ABET's requirements.

An interesting, encouraging result was that over 75% of respondents associated their work ethic, professional behaviors, and values with aspects of their Identity that could impact their design work. We have identified an opportunity to explore this particular topic more deeply as part of character education for exercising engineering judgment. The most frequent responses in relation to societal and ethical factors had a proactive nature, including meeting expectations for products (e.g., quality and reliability) as well as preventing errors and ensuring good product performance, including through careful design and testing. This was also an encouraging result that we hope to replicate during future data collection. Our enhanced emphasis on the situational context during the lecture-based instruction may have contributed to these encouraging responses for the situational context. All students mentioned testing/identifying errors in relation to critical thinking if an error were reported by a third party. This included reproduction of the error as well as subsequent re-testing of the system once fixes were made. We also hope to replicate this finding during the next round of data collection and discuss it and other encouraging responses during a debrief session with students. In general, scaffolding the students to apply specific components of the engineering judgment model using the worksheet may have contributed to the promising results found.

A limitation of the present work was the small sample of 13 students who consented to participate in the research. However, the same instruction (with a focus on consideration of the situational context) and the instructional worksheet will occur during the spring 2026 semester based on our promising results. We plan to add to our sample in the spring 2026 and produce results that can be generalized across electrical and computer engineering design courses, including capstone. However, we anticipate that findings based on a larger sample of data, in particular those related to identity and contextual considerations, will be applicable across design contexts in other engineering disciplines. Future work as part of our overall research includes ongoing collection and analysis of student reflection data related to applying the emergent engineering judgment model and definition to their course projects. A future aim is the development of a rubric to assess these reflections based on the presence of the various components of our emergent definition and model for engineering judgment.

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