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From Bias Awareness to Better Judgment: Storytelling as a Tool for Reflective Learning in Engineering Design Education

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Abstract

This paper develops a framework for how storytelling and storification can enhance engineering students' insight into cognitive biases in design decision-making, thereby strengthening their decision-making skills. Rooted in constructivist learning theory, the approach treats stories not as communication tools but as reflective narratives to transfer the meaning and integrate this knowledge, social interaction and active meaning making into existing mental models. Such stories and narratives can help provide a different perspective and increase awareness of cognitive biases. Therefore, this awareness can bring a new behavioral insight in ways that conventional instruction often does not. In this paper, we lay out a framework connecting construct narrative engagement, reflective processing, bias awareness, empathic framing, and adaptive judgment. Further, we articulate the hypothesized causal pathways among these constructs.

We provide initial support for this framework by drawing on preliminary qualitative responses from 235 undergraduate engineering students in design courses at a public R1 university. We developed and introduced a learning module with the objective of increasing awareness of cognitive biases and their effect in engineering design through developed stories focused on teaching students about the self-relevance effect, or our tendency to better remember and prioritize information if it is related to ourselves. Initial qualitative responses from students via reflective exercises and open-ended questionnaires illustrate how stories prompt them to question their own assumptions, recognize hidden heuristics, and reconsider "obvious" design choices. We use these responses to sketch potential links among our constructs of interest. We discuss plans for future work to refine the learning module and design future studies to test our framework. Our long-term objective is to integrate stories, bias-awareness, and engineering judgment literature into a cohesive pedagogical model. We propose that storification can act as a reflective catalyst activating narrative engagement, reflective processing, bias awareness, empathic framing, and adaptive judgment, which are key precursors to behavioral change in design reasoning.

Our preliminary findings highlight the potential of using stories in learning modules to cultivate improved understanding of cognitive biases in design, leading to more sophisticated and reflective engineering decision-making. This work aligns with the DEED thematic area of Teaching Curriculum & Pedagogy by advancing narrative-based instructional strategies that integrate psychological and design-thinking principles. By framing cognitive bias education within a storified, constructivist approach, this study contributes to the development of pedagogical models that foster metacognitive awareness and adaptive judgment among future engineers.

Keywords: Cognitive bias, Learning Modules, Judgment and Decision making, Teaching Curriculum and Pedagogy

1. Introduction

Design judgment is a central competency in engineering and design education, yet it remains difficult to explicitly teach and assess due to its context-dependent, tacit, and experience-based nature [1], [2], [3]. Designers routinely make decisions under uncertainty, incomplete information, time pressure, and social influence conditions that are well known to activate cognitive biases [4], [5]. While professional expertise develops partly through experience, design education often relies on implicit learning, leaving students unaware of how biases shape their judgments and assumptions.

Traditional pedagogical approaches in engineering design education emphasize rational analysis. Although these approaches are valuable, they frequently underemphasize reflective processes that allow learners to recognize how personal assumptions, heuristics, and values influence decision-making [6]. As a result, students may learn *what* decision was made without understanding *why* it felt reasonable at the time.

Recent research highlights the need for educational tools that support judgment development rather than purely procedural competence [7]. Storytelling when used not as communication but as reflective narrative offers a promising pathway to address this gap. Narrative structures naturally support meaning-making, self-relevance, and perspective-taking, all of which are critical for surfacing hidden assumptions and biases [8].

In this paper, we propose a theoretical framework in which storification functions as a reflective catalyst, enabling design students to recognize cognitive biases and develop adaptive judgment. The framework is empirically grounded in classroom implementation and student reflections, offering preliminary evidence for how narrative engagement can enhance design judgment and decision-making.

2. Background

2.1 Engineering judgment and decision-making

Engineering judgment refers to the formation of opinions or decisions based on experience and knowledge gained through engineering practice. Similarly, expert opinion involves beliefs or judgments offered by individuals with recognized expertise. Subjectivity is inherent in both processes[9]. Engineering judgment is critical to both engineering education and professional practice, and the ability to engage in engineering judgment is often considered central to the development of professional engineering identity[10].

Beginning in the 2019–2020 academic year, ABET explicitly incorporated the ability to "use engineering judgment to draw conclusions" as a required outcome for graduates of accredited engineering programs. While engineering judgment has long been an implicit component of engineering curricula, relatively little research has examined how the constructive theory is defined or how students develop engineering judgment during undergraduate education[11]. This gap complicates both the assessment of engineering judgment as a learning outcome and the design of pedagogical approaches intended to support its development [11].

Student work intended to foster engineering judgment often prescribes goals and objectives and requires a single decision, product, or solution evaluated by instructors. However, such evaluations frequently lack structured mechanisms for foregrounding experiential feedback or reflecting on the cognitive processes underlying decisions. As a result, the feedback loop between decision outcomes and upstream cognitive processes may remain incomplete [11].

ABET's revised student outcome positions engineering judgment as a practice that follows analysis and interpretation. Specifically, the expansion from "an ability to design and conduct experiments, as well as to analyze and interpret data" to "an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions" suggests a shift from interpretation alone toward action informed by interpretation. Notably, judgment is made explicit in the act of drawing conclusions and implicit in determining what constitutes "appropriate" experimentation. This framing links engineering judgment directly to decision-making. In this work, decision-making is defined broadly as the connected processes that link perception (i.e., ABET's interpretation of data) to action (i.e., the resulting conclusion)[11].

2.2 Cognitive biases in design decision-making

Cognitive biases are systematic deviations from normative rationality that influence judgment and decision-making [12]. In design contexts, biases such as confirmation bias, anchoring, and fixation have been extensively documented [4], [13]. Comparative studies further demonstrate that while cognitive bias is not unique to engineering, it manifests differently across professional domains [7].

Despite increased awareness, bias mitigation strategies in design education often rely on checklists or decision-support tools, which may fail to address underlying cognitive mechanisms [8], [14]. Adaptive judgment, the ability to adjust decisions in response to context, uncertainty, and feedback, require more than awareness alone. Research suggests that bias awareness is a necessary but insufficient condition for adaptive judgment; it must be accompanied by reflection, empathy, and a willingness to revise assumptions [5].

A substantial body of research identifies numerous cognitive biases relevant to engineering decision-making. These include anchoring, in which judgments are influenced by an initial reference point even if irrelevant; confirmation bias, the tendency to seek and favor information that confirms prior beliefs; and availability bias, which relies on readily recalled examples when evaluating decisions [8]. Empirical studies demonstrate that confirmation bias can significantly reduce problem-solving effectiveness in product development [14]. Additional work shows that confirmation bias affects early concept evaluation in design cognition, supporting the integration of reflective practices in engineering education to help students recognize and overcome biased reasoning [4]. Other studies link cognitive bias to reduced design quality [15], [16].

Research on heuristics further complicates this landscape. In some contexts, heuristics, simplified decision strategies that ignore part of the available information, can produce faster and more effective decisions under uncertainty than statistical or machine-learning approaches [4]. Heuristics leverage cognitive capabilities and real-world constraints, enabling quick and frugal decision-making. However, habitual patterns of thinking that are poorly grounded in evidence or logic can lead to systematic error [17]. While heuristics may serve as useful tools in situations with limited boundary conditions [18], they can also introduce decision errors when misapplied, particularly in the presence of cognitive biases common in economic and behavioral contexts [19].

Such errors may be exacerbated when attention is inappropriately focused on certain information at the expense of more relevant data [20].

Several strategies have been proposed to mitigate the negative effects of heuristics and cognitive bias, including instructional interventions that increase awareness and support the development of more adaptive intuition [19]. In this work, we focus specifically on the self-relevance effect, defined as a cognitive bias in which personally relevant information is more likely to be attended to, remembered, and prioritized [8]. This effect has particular implications for stakeholder identification and analysis in engineering design and is examined in greater detail in the methods and appendix.

2.3 Narrative engagement and reflective learning

Narrative engagement refers to the cognitive and emotional involvement of learners in stories that are meaningful, coherent, and personally relevant. Narratives organize experience temporally and causally, enabling learners to revisit decisions, reinterpret motivations, and explore alternative perspectives [8]. In educational contexts, narrative-based reflection has been shown to support self-relevance, emotional resonance, perspective-taking, and the integration of abstract concepts with lived experience. These properties make storytelling particularly well suited for engaging implicit cognitive processes that are resistant to formalization [21].

2.4 Constructivist learning theory as the foundation for this work

Constructivist learning theory holds that knowledge is not passively received but actively constructed through interaction with experience, interpretation of prior knowledge, and reflective activity [22], [23]. From this perspective, learning is inherently situated and emerges through meaningful action within social and material contexts rather than through abstract transmission of information [24]. Reflection plays a central role in this process, enabling learners to examine and revise their understanding in response to discrepancies between expectation and experience, thereby supporting conceptual change and adaptive understanding [2]. However, while constructivist approaches emphasize experiential learning, experience alone does not guarantee metacognitive awareness. Without explicit reflective scaffolding, learners may reinforce existing misconceptions and biased reasoning patterns rather than critically interrogate their assumptions [2], [25], [26].

3. Framework Development

Based on the literature, we extracted the following core constructs and designed our framework flow as shown in the figure below.

3.1 Knowledge is actively constructed, not transmitted: Constructivism posits that learners do not passively absorb information; instead, they actively construct understanding by interpreting experiences through prior knowledge, beliefs, and assumptions [23]. *Implication for design education:* Students' design judgments are shaped by pre-existing mental models, making bias awareness a learning problem not merely a technical one.

3.2 Learning is situated and context-dependent: Meaning emerges from interaction with specific tasks, social settings, and material contexts rather than from abstract instruction alone [24], [25]. *Implication:* Biases in design judgment cannot be fully addressed through decontextualized rules or checklists; they must be examined within realistic, situated scenarios such as narratives.

3.3 Reflection is essential for conceptual change: Constructivist learning requires opportunities for learners to reflect on discrepancies between expectations and outcomes. Without reflection, experiences may reinforce existing misconceptions [2], [26].
Implication: Story-based reflection provides a structured mechanism for making implicit assumptions and biases explicit.

3.4 Prior experience is both a resource and a constraint: Learners' past experiences enable understanding but can also anchor thinking and limit exploration [12], [23]. *Implication:* Narrative prompts that evoke self-relevance can surface how prior experiences contribute to confirmation bias, fixation, or overconfidence in design decisions.

3.5 Meaning making is enhanced by reflection and connection to prior knowledge and experience: Constructivism emphasizes that learning deepens when learners perceive content as personally meaningful [27]. *Implication:* Storification leverages the self-relevance effect to increase engagement with metacognitive processes, including bias recognition.

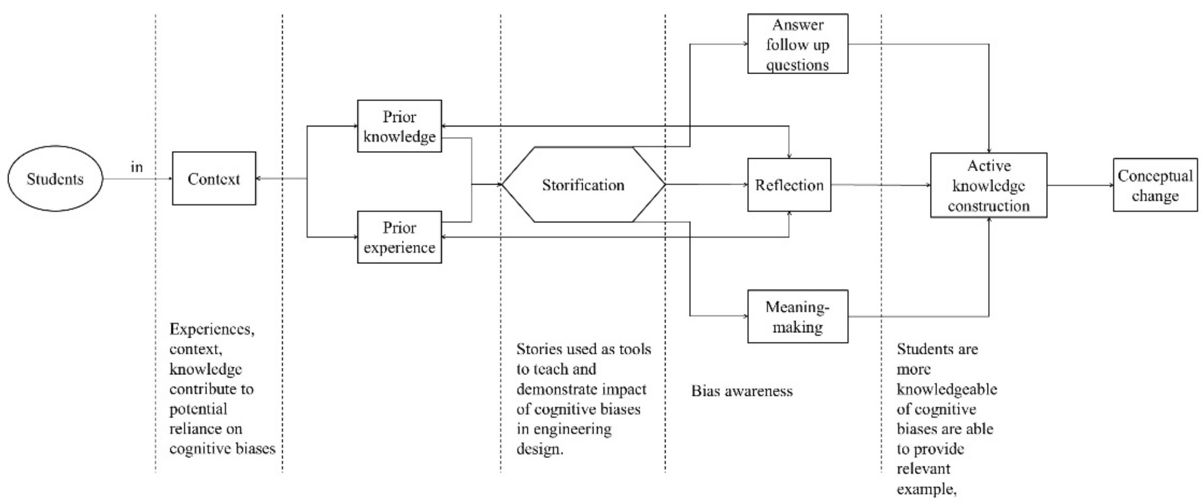

Figure 1: Students in context have prior knowledge and understanding besides prior experience, which they can reflect, answer questions and try to make meaning for the bias through storytelling and narratives. This process helps them to construct their knowledge actively and change the concept of judgment in their mindset.

4. Initial support for this framework

We conducted a study in Spring 2025 intended to teach engineering students about cognitive biases in design through narrative engagement and evaluate their learning. The authors developed a learning module to teach participants about cognitive biases, share examples of a specific bias in engineering design through narrative engagement, and evaluate student learning through multiple choice questions, open-ended questions, and design tasks. The study used an experimental design where the treatment group received the learning module before the design task and the control group received the learning module after the design task. The results of the design task are currently under analysis, so in this paper, we draw on students' qualitative responses after completing the entire study. Additional details on the learning module can be found in [28].

4.1 Sample and Participants

The study was conducted in Spring 2025 at [28]. All participants were enrolled in a design-focused mechanical design engineering course in undergrad. Students were offered extra credit for participating in the study. 295 students participated in total, and 235 students completed the study; 60 students were excluded due to incomplete responses. Data was collected via a survey on Qualtrics. A summary of participant demographics is shown in Table 1. The study was approved by the University of Arkansas Institutional Review Board under Protocol #2502587656.

Demographic category	Count	Percentage
Race		
American Indian, Native American, or Alaska native	2	0.85%
Asian	14	5.96%
Black or African American	4	1.70%
Other	8	3.40%
Prefer not to say	2	0.85%
Two or more races	12	5.11%
White or Caucasian	193	82.13%
Spanish, Hispanic, or Latino origin		
No	202	85.96%
Yes	33	14.04%
Current semester of study		
4th semester (Year 2, semester 2)	72	30.64%
5th semester (Year 3, semester 1)	8	3.40%
6th semester (Year 3, semester 2)	101	42.98%
7th semester (Year 4, semester 1)	11	4.68%
8th semester (Year 4, semester 2)	39	16.60%
Other	4	1.70%
Sex		
Female	30	12.77%
Male	203	86.38%
Non-binary - third gender	1	0.43%
Prefer not to say	1	0.43%

Table 1 Demographic information of the participants

4.2 Procedure

Participants first gave consent to participate in the study. Students then began with baseline questions to determine their prior knowledge about cognitive biases with response options "Never heard of them.", "Have heard of them but don't know about any specifically.", and "Have heard of them and know about some specific examples." Then we asked them to specify cognitive biases that they have heard of.

In the next step, they familiarized themselves with basic definitions of cognitive biases in general and specific information on the self-relevance effect which was the bias of interest in this study. Then, participants engaged with two stories about the self-relevance effect in engineering design (see the appendix for the story content). After reading the stories, participants completed several multiple-choice knowledge check questions and several open-ended questions to allow for reflection, meaning making, and integration of these new concepts with existing knowledge. Figure 2 shows an overview of the study procedure.

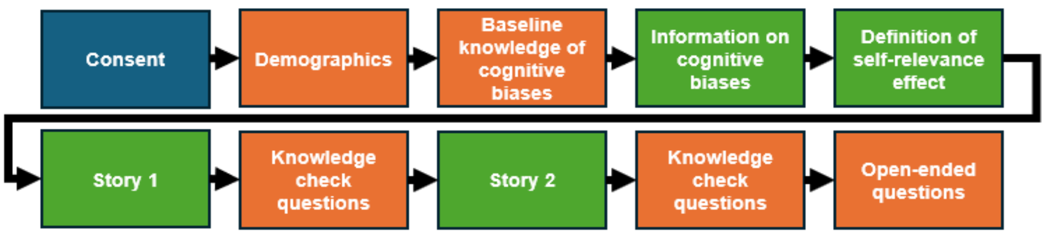

Figure 2: Overview of study procedure. Orange boxes indicate data collection, and green boxes indicate informational sections. taken from [28] with permission

5. Findings relevant to the proposed framework

First, we checked students' baseline knowledge of cognitive biases. As document in [28], the most common response was "Have heard of cognitive biases but cannot name any specifically" (66% of respondents). For participants who were able to name specific biases, confirmation bias was mentioned most often (56% of biases mentioned).

Then, we evaluated the initial effectiveness of this learning module by checking students responding to several questions about cognitive biases and engineering design. ASEE MW paper has additional details on this [28]. For the four multiple choice questions included, 74%-87% of students answered the questions correctly.

Here, we include some initial findings from participants' open-ended responses in this section. These provide an initial context from a student perspective. We plan on conducting a more complete thematic analysis of qualitative data in the future.

The first question was "Reflect on your own experience in decision-making. Can you think of and provide an example of how the "self-relevance effect" may have been involved in a decision you were part of?" The purpose of this question was to see if the students not only learned about this bias but also gained the opportunity to reflect on their own experience. Below are some illustrative responses. These responses provide initial support for the fact that reflection is based on prior knowledge and prior experience as we proposed in framework.

"For our mechanical design project, I valued the cost of production of our device since as a college student, I'm used to saving money and am money conscious."

"For many design solutions, I incorporate pieces from systems that I am already aware of because I understand how they work and when they can be used."

"In a group project we had to help find a solution to help students manage their time better. I struggle with work school balance so I pushed for features that would help track deadlines and work shifts. Looking back, I focused more on my own needs rather than the issues of my group."

"I was on a robotics project where I was one of the main people involved in design, manufacturing, and assembly. This meant that the parts of the design I worked on were focused on ease of manufacturing and assembly. However, I did not optimize for the ease of routing and mounting vital electronics inside of the system. This led to some issues during the assembly stage that had to be fixed on the fly with some off-design modifications to accommodate wire routing and electronics mounts."

The second and third open-ended questions were "What are some potential positives and negative effects when a person on a design team has a close personal connection with the design problem?". We asked this because biases often serve a purpose, and this allows students to make meaning of cognitive biases and their connection to design experiences.

Examples of <u>potential positive effects</u> that students identified included:

"The individual has a familiarity with the issue and can identify key aspects that may be overlooked by someone with limited experience."

"Someone could provide better insight into how a specific demographic is affected by a problem."

"They have skin in the game, they can understand and empathize with stakeholders."

"That team member can provide valuable information from the point of view of a user or other Stakeholder, helping to prioritize needs effectively."

Examples of <u>potential negative effects</u> that students identified included:

"They will lose sight of the 'big idea' stakeholder needs to focus on the one need that is relevant to their own experiences."

"A negative effect could be that the person could think emotionally instead of logically when trying to solve that problem"

"They may try to make a product fit their exact needs but not the overall needs of the community with the problem."

"That person may focus the design of the product too heavily on one particular feature limiting other potential features in the overall solution."

6. Discussion

Initial findings support the flow of this framework when narratives are used to reflect gained knowledge and experience effectively. Participants were able to identify relevant examples and successfully construct meaning as they interpreted their experiences through stories. Since, based on the background, it is crucial for engineering designers to learn about cognitive biases, this module can serve as a convenient template for educators to use in classroom settings. For example, during the stakeholder identification and needs assessment, instructors can incorporate this or a similar module to teach students about cognitive biases which are relevant during this phase. It may also be beneficial to build in time for students to reflect upon their learning and narrate their experience related to the topic to help them actively construct knowledge and change their perspective on the problem; this is consistent with the literature documenting the benefits of reflection and metacognition during learning [22], [29], [30].

6.1 Limitations and future work

While this study provided initial support for our proposed framework, there are several limitations to this work. First, our only participants were mechanical engineering students; future work could expand the use of this framework for students in other engineering disciplines. Second, this study considered only a single cognitive bias, the self-relevance effect. Future work could develop stories for other cognitive biases common in engineering design such as the confirmation bias, anchoring, and the availability heuristic. Finally, it might be better to extend the time of the test of this framework to see the result through time. Additional future work could include comparing traditional methods of learning and this self-narrative way of learning to investigate the effectiveness from that point of view.

7. Conclusion

This paper presents a conceptual and empirically grounded framework positioning storification as a reflective catalyst for bias awareness and adaptive judgment in design education. By activating self-relevance and reflective processing, storytelling enables learners to surface hidden assumptions and engage more thoughtfully with design decisions. The proposed framework contributes toward a cohesive pedagogical model that bridges cognitive science, design theory, and educational practice supporting the development of reflective, adaptive designers.

At the outset, the objective of this investigation was to acknowledge how the learning module would affect student awareness of cognitive biases and how it changes the perspective of the students as future engineers. This survey indicated that learning practices and stories about cognitive biases help students understand cognitive biases in engineering. In summary, this research showed that learning about a specific bias through a reflective tool can promote the active construction of knowledge and lead to change in how an individual makes engineering decisions related to a specific concept.

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Appendix

First story

A product design team was tasked with creating a secure method to fasten wheelchairs on city buses. The team, composed of engineers, designers, and project managers, was eager to gather input from various stakeholders, including wheelchair users, bus drivers, and city planners. However, during the initial meetings, the self-relevance effect began to subtly influence the team's approach. Each member tended to focus more on feedback that resonated with their personal experiences. For instance, one designer, who had a family member using a wheelchair, emphasized the importance of ease of use for the elderly, while an engineer, who frequently used public transport, prioritized the system's integration with existing bus infrastructure. As a result, the team inadvertently overlooked critical feedback from younger wheelchair users who needed a more robust and adaptable securing mechanism for their active lifestyles. As the project progressed, the impact of the self-relevance effect became more pronounced. During a stakeholder meeting, a young wheelchair user expressed concerns about the system's stability during sudden bus movements. However, since this feedback did not align with the personal experiences of the team members, it was not given the attention it deserved. Instead, the team focused on refining features that they personally found more relevant, such as the aesthetic design and ease of installation. This bias led to a final product that, while visually appealing and easy to install, failed to address the critical safety needs of all wheelchair users. The oversight became apparent only after the system was implemented, resulting in negative feedback from the very stakeholders the team aimed to serve. This experience highlighted the importance of actively mitigating cognitive biases to ensure a comprehensive and inclusive design process.

Second story

One design team was excitedly brainstorming ideas for a new product aimed at making it easier to put hair ties on for children who have thicker hair. During the stakeholder needs elicitation phase, they gathered feedback from parents, caregivers, and hairstylists. One engineer, Sarah, who had struggled with her own child's thick hair, found herself particularly drawn to comments that mirrored her own experiences. She vividly remembered a parent's frustration with hair ties that snapped easily, and another's wish for a product that could be used quickly during busy mornings. Another engineer, Tom, used to work in a rubber manufacturing facility. Tom identified the durability of the hair ties as the primary design variable to optimize. Each individual engineer developed a list of stakeholders and their needs. Tom and Sarah were surprised by the number of differences between their individual lists.