Paper ID #52804

Designing Curiosity in Engineering Education: From Momentary Spark to Motivational Drive

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Designing Curiosity in Engineering Education:
From Situational Spark to Sustained Drive

Abstract

Curiosity is increasingly recognized as a core intellectual virtue that supports adaptive problem-solving, ethical discernment, and innovation in professional engineering practice. Yet in undergraduate education, curiosity is often treated as a happy byproduct of instructional design rather than a deliberate target of professional formation. This mixed-methods article addresses the critical gap between conceptual theory and prescriptive pedagogy. We first synthesize 63 peer-reviewed articles to confirm how curiosity is defined, measured, and cultivated, using psychological models to differentiate curiosity as a momentary reaction versus a motivational drive and durable character trait. Our scoping review confirms that current engineering interventions are overwhelmingly short-term and typically promote fleeting, passive engagement through inquiry-based activities, rarely addressing the necessary development of active, sustained curiosity or its crucial relationship to adjacent virtues like intellectual humility. To address the pedagogical gap, we report on semi-structured interviews with engineering faculty to uncover the implicit strategies, or "levers," they use to promote curiosity in their classrooms. This work offers two key contributions designed for the broader ASEE audience: a pedagogical strategy for cultivating active and sustained curiosity in the engineering classroom, and a set of validated metrics, adapted from longitudinal studies, to assess the efficacy of these levers. By shifting the focus from accidental "spark" to deliberate, measurable "cultivation," this framework lays the groundwork for integrating curiosity as an essential professional competency.

1. Introduction

Curiosity, the desire to know, learn, or understand, is widely accepted as a prerequisite for success in engineering. In a profession routinely confronted with complex, ambiguous, and uncertain challenges, the ability to frame thoughtful questions and seek knowledge is paramount. Conceptual frameworks like Loewenstein's Information-Gap Theory [1] underscore that curiosity is rooted in the recognition of a knowledge deficit (or cognitive gap) that fuels the pursuit of resolution. For engineering education, this implies that teaching must not only resolve knowledge gaps but also intentionally provoke the cognitive discomfort required for curious engagement.

Despite its recognized value, curiosity in undergraduate engineering is often treated as a latent characteristic that is incidentally activated by hands-on projects, rather than a cultivable intellectual virtue that must be explicitly taught, sought, and assessed. This lack of intentionality reflects a fundamental disconnect between the robust theoretical models established in psychology (e.g., Litman's distinction between interest- and deprivation-driven curiosity [2] and Kashdan's multi-dimensional trait model [3]) and their practical, pedagogical application in the engineering classroom.The current literature, synthesized in this article, reveals a significant limitation: engineering education interventions primarily focus on promoting situational curiosity through short-term, inquiry-based activities. While effective at generating a momentary spark, these strategies rarely translate the experience into a sustained motivational drive or a durable character trait, and they almost universally lack validated, longitudinal assessment instruments. Furthermore, there is a distinct lack of inquiry into how curiosity must interact with adjacent intellectual virtues, such as intellectual humility (the willingness to acknowledge one's own cognitive limitations), which is crucial for successful knowledge-seeking behavior in complex design teams.To structure our inquiry, we synthesize three foundational psychological theories that offer a multi-level understanding of curiosity:

- Momentary Spark (Loewenstein): Defines curiosity as the situational recognition of a knowledge deficit, useful for evaluating content sequencing and trigger points in learning (Figure 1) [1].
- Motivational Drive (Litman): Distinguishes between passive, interest-driven curiosity (seeking pleasurable information, I-type) and active, deprivation-driven curiosity (motivated by discomfort and the need to resolve a gap, D-type). This helps categorize a student's motivational response to uncertainty (Figure 2) [2].
- Durable Trait (Kashdan): Frames curiosity as a stable, five-dimensional disposition tied to

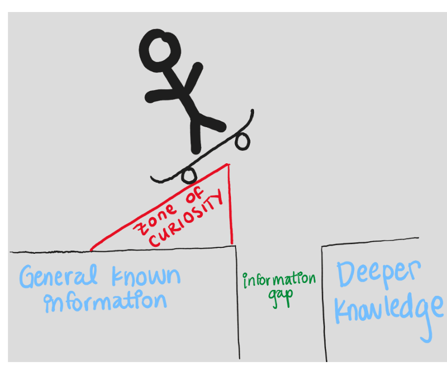

Fig 1. Loewenstein's Information Gap Theory of Curiosity

openness, ambiguity tolerance, and long-term engagement with complex problems. The five dimensions are joyous exploration, deprivation sensitivity, stress tolerance, social curiosity, and thrill-seeking. This view supports longitudinal analysis and the goal of developing curiosity as an enduring professional trait (Figure 3) [3].

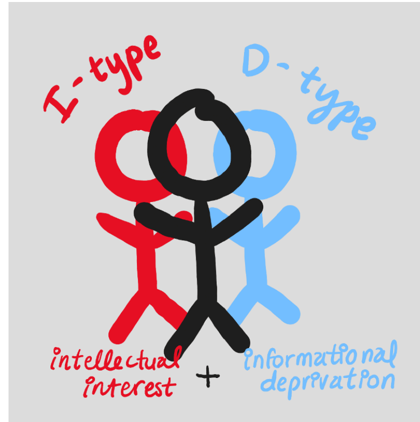

Fig 2. Litman's I-type vs. D-type curiosity model

This mixed-methods study is driven by the need to bridge this theory-practice gap by synthesizing existing knowledge and grounding it in the lived experiences of engineering educators. Specifically, we aim to answer the following research questions:

1. What are the key conceptual and methodological gaps in the current literature regarding the definition, cultivation, and assessment of curiosity in engineering education?
2. How do engineering faculty implicitly view and promote different dimensions of curiosity (e.g., active vs. passive, fleeting vs. sustained) in their classrooms?
3. Based on the synthesis and faculty data, what is a practical, prescriptive framework of instructional "levers" that engineering educators can use to cultivate and assess active, sustained curiosity?

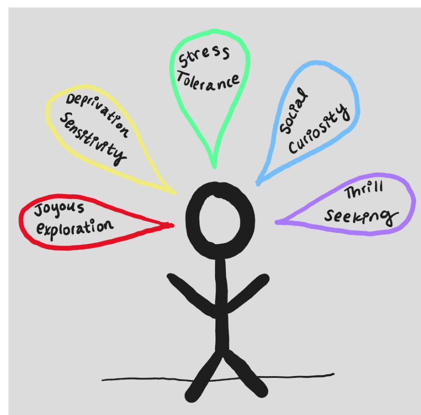

Fig 3. Kashdan's 5-dimensional model of curiosity.

By integrating the psychological spectra of curiosity with empirical faculty practice, this article culminates in the proposal of an actionable framework designed to support the intentional formation of curiosity as a fundamental professional competence.

2. Methods

This article employed a two-phase, mixed-methods approach to first define the conceptual landscape and second, to gather empirical data on instructional practices.

This article employed a sequential qualitative design consisting of a scoping literature review to first define the conceptual landscape of approaches to studying curiosity in education and next, the design of an interview to capture engineering faculty and industry perspectives on curiosity.

2.1 Phase 1: Scoping Review and Gap Analysis

We conducted a scoping review of 63 peer-reviewed articles and conference papers spanning engineering education, K-12 education, medicine, and psychology. Our structured synthesis matrix organized the literature according to:

- Conceptual Clarity: The explicit definition and theoretical framing of curiosity employed.
- Measurement Approach: The instrument or method used to quantify curiosity (or lack thereof).
- Intervention Strategy: The specific pedagogical technique utilized (e.g., PBL, flipped classroom).
- Longitudinal Tracking: Whether the study tracked changes in curiosity over a semester or longer.

A synthesis matrix highlighting key measurement strategies and pedagogical interventions, as well as their implications for different dimensions of curiosity is in Appendix A. Three established psychological models served as organizing lenses for this analysis to define the conceptual boundaries of curiosity: Loewenstein’s Information-Gap Theory, Litman’s epistemic curiosity model, and Kashdan’s Five-Dimensional Curiosity trait model. The synthesis of these models highlights the need to differentiate between active vs. passive and sustained vs. fleeting curiosity (Table 1).

Table 1. Dimensions of understanding curiosity based on psychological frameworks.

Curiosity Dimension	Psychological Basis	Pedagogical Goal
Active vs. Passive	Deprivation-driven vs. Interest-driven Curiosity	Shifting students from receiving knowledge to actively seeking knowledge to fill a self-identified gap.
Sustained vs. Fleeting	Trait Curiosity vs. State Curiosity	Developing a durable motivational pattern that persists beyond the situational context of a single course or assignment.

This review confirmed significant gaps that support the idea that engineering education research predominantly captures fleeting, passive curiosity, rarely offers explicit operational definitions, and fails to adopt existing validated trait scales for longitudinal assessment.

2.1.1 Measurement Approaches in Engineering Education

Most studies we identified in engineering education used self-report Likert-style surveys to assess trait or situational curiosity [4, 5]. A small number employed more novel approaches, such as text mining written reflections or combining multiple instruments to triangulate results [6, 7, 8, 9]. For example, CERN and ASEE papers have described methods such as analyzing students' written reflections, comparing curiosity levels across course formats, and observing how curiosity fluctuates during hands-on learning experiences [5, 10]. Few studies explicitly validated their instruments, and even fewer compared findings across multiple time points.

2.1.2 Pedagogical Interventions and Classroom Contexts

Several engineering education studies link curiosity to pedagogical strategies such as project-based learning (PBL), research experiences, real-world design problems, and biomimicry [11, 12, 13]. In these contexts, curiosity is often framed as both a means and an outcome. While interventions show promising short-term results, such as increases in student-reported curiosity after 6-week modules, they rarely assess whether these effects persist or generalize [14]. Some studies also suggest that curiosity is more evident in elective or interest-driven courses versus core curriculum.

2.1.3 Disciplinary and Longitudinal Gaps

Comparative studies in medical education reveal more mature approaches to longitudinal measurement [15, 16]. For instance, one study in Medical Teacher tracked curiosity levels across all four years of a medical curriculum using a validated scale [17]. In contrast, longitudinal tracking in engineering was absent from our sample. Additionally, engineering faculty and employer perspectives on curiosity remain underexplored. Although some studies mention curiosity as part of the entrepreneurial mindset, explicit connections to industry hiring practices or public welfare motivations are minimal [18].

2.1.4 Literature Review & Gap Analysis Discussion

This review validates that curiosity is a valued yet under-theorized construct in undergraduate engineering education. The field lacks consensus on how to define and measure curiosity, and intervention studies rarely extend beyond a single semester. Furthermore, the disconnect between classroom interventions and long-term professional outcomes weakens efforts to integrate curiosity into engineering character education. Given the importance of curiosity in fostering innovation and adaptability, engineering educators and researchers should prioritize validated longitudinal tools, study curiosity from faculty and employer perspectives, and design interventions that extend across multiple semesters or curricular stages.

The identified gaps in the study of curiosity in engineering education could be addressed by:

- Developing and validating curiosity measurement tools tailored to engineering contexts
- Conducting longitudinal studies tracking curiosity across a student's academic journey
- Investigating how faculty recognize and respond to student curiosity ("caught")
- Exploring how students actively pursue curiosity in their learning ("sought")
- Designing scalable interventions that encourage curiosity and intellectual humility ("taught") [19]
- Connecting curiosity development to broader societal impact and public welfare

These directions will help position curiosity not just as an educational buzzword, but as a measurable, teachable, and ethically relevant trait within engineering curricula.

2.2 Phase 2: Semi-Structured Faculty Interviews

To address the pedagogical gap identified in the literature, we will conduct semi-structured interviews with engineering faculty. This qualitative data is designed to capture the rich, situated context of pedagogical practice, the "art" of teaching curiosity that may not be codified in formal publications.

2.2.1 Participant Recruitment and Selection

Participants will include faculty who have demonstrated interest or prior research in teaching and learning, specifically targeting those who responded to the prior BMES conference QR code distribution, alongside faculty at the authors' institution. A diverse sample across engineering disciplines (e.g., BME, MSE, Mechanical, Civil) will be sought to ensure generalizability of instructional strategies.

2.2.2 Cognitive Interviewing for Refining Interview Questions

Prior to the full data collection, the interview protocol was systematically validated using cognitive interviewing techniques to ensure the final questions were clear, relevant, and probed the appropriate dimensions of curiosity. The primary objectives of this validation phase were to assess question comprehension (ensuring key concepts like "active vs. passive" and "intellectual humility" were interpreted as intended), evaluate cognitive processes (determining if participants could easily retrieve genuine experiences), and systematically eliminate potential biases or embedded jargon that could impact the main study's qualitative data.

A small, targeted sample of five initial participants, including three undergraduate engineering students, two engineering faculty members, and one engineering laboratory staff member were recruited for the cognitive interview. These participants will not be included in the semi-structured interviewing process. Interviewees were selected based on departmental and experiential diversity and interest in engineering education.

The cognitive interview followed a step-by-step procedure. Participants were initially provided background on the goal of the semi-structured interview, to elucidate faculty members' experiences and attitudes regarding the different dimensions of curiosity in the classroom. The initial question set (Table 2 below) was then read to the participants, one question at a time, and they were instructed to provide their feedback on how effective the questions were at probing the identified levers. Their responses were recorded as notes by the interviewer, and follow-up questioning was used in the more conversational manner of these interviews. This mimicked the targeted probing method (cite), where the interviewer uses specific, non-directive probes designed to isolate cognitive issues. For instance, a comprehension probe might ask, "What does the phrase 'pushes beyond the requirements of an assignment' mean to you in a practical sense?" or a judgment probe might test for bias: "Did the way I worded that question about curiosity's importance make you feel like you should say it's highly important?" [20, 21].

Following each session, the interviewer transcribed and immediately reviewed the feedback for common themes, which led to the protocol being iterated before the next session. This critical step eliminated identified flaws; for example, questions about abstract psychological constructs were rephrased into comparative behavioral questions (e.g., distinguishing asking for help versus seeking a solution independently). All revisions, rationales, and the specific feedback are systematically documented to ensure a transparent audit trail of the interview's development. This systematic process ensures the finalized semi-structured protocol is conceptually robust, maximizes clarity and accessibility for engineering faculty, and minimizes the risk of collecting biased data in the study.

Table 2. Initial question set prior to iteration; questions presented to cognitive interviewees.

Focus Area	Core Interview Question	Logical Follow-up (Probing for 'Levers')
Definition & Value	Do you view curiosity as an important attribute for a successful engineer? Why or why not?	*If yes:* Is curiosity something that can be taught/cultivated, or is it mostly innate? (Probes: Aristotelian vs. Innate view)
Active vs. Passive	When you promote curiosity, what is the key difference between a student who merely asks a good question and one who finds new information or resources independently?	Can you give me a specific example of an assignment that forces students to *seek* knowledge rather than just *receive* it? (Probes: Deprivation-driven/Active)
Sustained vs. Fleeting	Describe an instance where a student's curiosity was so strong it carried over to a later project, a different course, or even outside of the curriculum.	What do you do, if anything, to ensure the spark of curiosity doesn't just end when the unit or semester does? (Probes: Trait/Sustained cultivation)
Assessing & Diagnosing	How do you, as an instructor, recognize that a student is being *truly* curious, beyond simply completing the assignment?	How do you grade or provide feedback on the *act* of curiosity or knowledge-seeking itself? (Probes: Assessment)
Related Virtues	When a student runs into a problem they can't solve, how important is their ability to admit their limit or seek help?	Do you explicitly discuss intellectual traits like humility or openness with your students? How does that relate to their willingness to ask questions? (Probes: Curiosity + Humility)

2.2.3 Interview Protocol: Probing for Implicit Levers

The interview guide is built upon the protocol used in the existing ASEE literature (see Mallouk et al., 2022) but is significantly expanded to probe faculty practices against the psychological dimensions identified in the scoping review [22]. The goal is to elicit faculty's implicit understanding of the active/passive and sustained/fleeting spectrums without using the academic jargon (I-type, D-type, Trait, State). The protocol focuses on identifying the specific instructional actions the faculty take to promote curiosity.

During the cognitive interview process, a significant challenge that became evident when asking probing questions about curiosity is the ceiling effect and the associated social desirability bias. When asked directly, "Are you a curious person?" or "Do you value curiosity?", participants overwhelmingly respond in the affirmative, regardless of their actual behaviors. This "of course I am curious" response creates data that is psychometrically shallow and fails to distinguish between different dimensions of the trait. It is evident the way we ask questions is critical. Generally in the interview question set, we shift from asking about valuing curiosity to asking about exhibiting specific, difficult-to-fake behaviors. The cognitive interviewing process was designed specifically to bypass this ceiling effect.

The interviews will be audio-recorded and transcribed. Data will be analyzed using a grounded theory approach, iteratively coded for themes related to instructional strategies, implicit dimensional distinctions, and perceived barriers to curiosity cultivation. The resulting codes will be synthesized into an actionable, pedagogical framework for enabling the cultivation and study of curiosity in the engineering classroom.

Table 3. Final set of semi-structured interview questions.

Focus Area	Core Interview Questions	Follow-Ups
Definition & Value	Could you take a moment to think and identify the top three non-technical attributes you believe define a successful engineer?	*If curiosity is not mentioned:* Where does curiosity fit into this broader picture of success, and why?
Aristotelian vs. Innate	Do you believe curiosity is a trait that students mostly arrive with, can it be learned or taught, like a skill?	*If curiosity cannot be taught:* What prevents students from growing in curiosity?

		If curiosity can be taught: What are some ways curiosity can be grown in your or other classrooms?
Active vs. Passive	In what ways have you observed students exhibit curiosity? How likely do you think your students would be willing to grow a trait like curiosity? (1-5: Very unlikely, Somewhat unlikely, Neither likely or unlikely, Somewhat likely, Very likely) Can you name an assignment that incentivizes students to seek knowledge rather than receive it?	*To the last question:* Can you describe a time a student pushed beyond the requirements of the assignment out of genuine interest?
Sustained vs. Fleeting	Can you recall an instance where a student's curiosity was so strong it carried over to a later project, a different course, or perhaps an entirely new field of study?	What, if anything, did you do as an instructor to ensure that initial spark of curiosity didn't just end when the unit or semester was over?
Assessing & Diagnosing	What specific, observable behaviors or products do you use to assess or reward a student's curiosity or knowledge-seeking effort? How do you reflect those	*If has assessment strategy for curiosity:* What are any observable differences between a moderately curious student and an extremely curious one?

	behaviors in a student's grade or feedback? What effect do you believe the current assessment structure (grades, workload) has on students' curiosity?	
Related Virtues	When students run into a technical problem they can't solve (a knowledge gap), what actions or mindsets do you observe that help them deal with that uncertainty? Do you ever discuss traits like humility or open-mindedness with your students? Do you feel students are sometimes hesitant to ask questions or admit a knowledge gap?	*To 1:* In your course or other courses, what do you find to be encouraging to those actions or mindsets? *To 2:* What does that implementation look like and do you think it is received positively? *To 3:* What do you find to be the most effective way to encourage those students to admit they need help or to seek resources?
Conclusion	Is there anything else you think is important for engineering researchers to understand about how curiosity is cultivated, lost, or assessed in undergraduate education?	

3. Discussion and Future Directions

3.1 Discussion

The preliminary findings of this study underscore that while curiosity is universally sought in engineering education, it remains treated as a byproduct of educational interventions rather than a curricular priority. The identification of instructional drivers, such as hidden discoveries in labs and the integration of biomimicry in design, offers a path toward more engaged pedagogies [14, 23]. However, these drivers are only effective if supported by a robust conceptual framework that accounts for the transition from state-based interest to trait-based drive.

Our pre-analysis of the cognitive interviewing results emphasizes that how we ask determines what we learn. In conversation with engineering faculty and students, we are able to fine-tune interview questions to probe the levers most implicated in students' true curiosity outcomes. By focusing on behavioral indicators like a student's willingness to admit a knowledge gap (intellectual humility) or their propensity to seek information outside the course scope, we can measure curiosity with greater precision.

3.2 Future Directions

Future research will focus on the full-scale implementation of the semi-structured interviews to populate the pedagogical framework. The resulting data will be coded to identify the role of engaged pedagogies, longitudinal assessment, and institutional levers. Studying pedagogies will involve further exploring how specific interventions, like project-based learning, can be optimized to foster D-type (deprivation) curiosity rather than simple I-type (interest) interest. To establish a longitudinal assessment of curiosity, a semester or quarterly measurement system can be developed, mirroring the longitudinal tracking seen in medical education [24]. An example of an institutional lever would be investigating how departmental cultures can reevaluate grading structures that may discourage students from taking the intellectual risks associated with curiosity. The coding results from the interviews will be synthesized into an actionable pedagogical framework designed to catalyze and evaluate the intentional development of curiosity within engineering curricula.

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Appendix A: Scoping Literature Review

Focus Area	Key Source(s)	Methodology	Actionable Finding
Measurement & Assessment	Seliya et al. [6]	Text Mining / NLP	Curiosity can be quantitatively assessed through linguistic markers in written assignments.
Measurement & Assessment	Hartini et al. [4]	Longitudinal Likert	Curiosity peaks in the 2nd year; suggests a "sophomore slump" in student drive.
Measurement & Assessment	Sternszus [17]	Cross-disciplinary	Medical education provides a more robust blueprint for 4-year curiosity tracking.
Pedagogical Levers	Gerhart & Melton [14]	Inquiry-Based	"Hidden discoveries" in labs force students to transition from I-type to D-type curiosity.
Pedagogical Levers	Vigeant et al. [11]	Design Projects	Working for "real" clients significantly increases engagement and ambiguity tolerance.
Pedagogical Levers	Zhang et al. [22]	Biomimicry / PBL	Bio-inspired design triggers "joyous exploration," a core dimension of Kashdan's model.
Pedagogical Levers	Jackson & Ward [23]	1st Year Electronics	Curiosity-based learning increases retention in foundational engineering courses.