Shaping Future Engineers Inquiry-Based Learning with Generation Z Curiosity and Critical Thinking

[1]Chandrakanta Mahanty, [2]Vijaya Bharathi Manjeti, [3]Suraj Aravind Bollapragada, [4]Bangaru Lakshmi Mahanthi,
[5]S. Sarojini Devi, [6]Shibani Tripathy
[1]Department of CSE, GITAM Deemed to be University, Visakhapatnam, 530045, India,
[2]Department of CSE, GITAM Deemed to be University, Visakhapatnam, 530045, India,
[3]Department of CSE, GITAM Deemed to be University, Visakhapatnam, 530045, India,
[4]Department of CSE, GITAM Deemed to be University, Visakhapatnam, 530045, India,
[5]Department of CSE, NSRIT Autonomous University Sontyam, Visakhapatnam, Affiliated to JNTU, India,
[6]Department of CSE, School of Engineering and Technology, GIET University, Odisha, India
[1] cmahanty@gitam.edu, [2] vmanjeti@gitam.edu, [3] sbollapr@gitam.edu, [4] lmahanth@gitam.edu,
[5]sarojinidevi.cse@nsrit.edu.in, [6] shibani.tripathy@giet.edu

***Abstract*— The dominant population in engineering classrooms today is Generation Z students who are highly digitally fluent, collaborative in learning styles, and interactive in their learning activities. Traditional pedagogies of lectures often fail to keep them engaged and develop higher-order thinking, while inquiry-based learning has emerged as a promising alternative. Despite the growing interest in IBL, limited empirical research has investigated how curiosity and critical thinking together influence students' perceived effectiveness of IBL in engineering education. This quantitative study used a survey approach with 500 engineering students in the age group of 18-21 years, using a 26-item Likert-scaled instrument that measured curiosity, critical thinking, IBL effectiveness, and learning preferences. The scales demonstrated strong internal consistency through Cronbach's alpha values which ranged between 0.88 and 0.95. The correlation and regression analyses revealed curiosity and critical thinking as statistically significant predictors of IBL effectiveness with r = 0.799 and 0.755, respectively, jointly explaining 64 percent of the variance, while experience with IBL accounted for an insignificant amount of variation. Student engagement and perceived learning effectiveness stem from their natural curiosity and reasoning abilities instead of their knowledge of the method. The research suggests that engineering programs should develop Generation Z students' cognitive skills through inquiry-based teaching methods which combine technology and reflection because these students need these competencies to succeed in our fast-paced world.**

***Keywords*—inquiry-based learning, Generation Z, engineering education, curiosity, critical thinking, educational effectiveness**

ICTIEE* Track— *Innovative Pedagogies and Active Learning

ICTIEE Sub-Track—Inquiry-Based Learning in Fostering Curiosity and Critical Thinking among GenZ

I. INTRODUCTION

ENGINEERING education faces unprecedented challenges as Generation Z students those born between 1997 and 2012, now dominate university classrooms. This generation of learners exhibits distinct learning styles because they have grown up surrounded by digital technologies, social media, and interactive environments (Tan et al., 2023). Traditional teaching methods are still relevant, but may not adequately prepare students for the complex problem-solving skills needed in contemporary engineering practice, or be aligned with how Generation Z prefers to learn. Gen Z is the first generation to grow up entirely surrounded by digital technology, and they now make up a large portion of higher education. They do not need to be taught how to find information; instead, they often require guidance on processing and analyzing it better. Increasingly, scholars argue that traditional lecture-based, mostly passive teaching methods do not engage these students or help them develop higher-order thinking skills (Baskoro et al., 2023). This calls for a shift toward more active learning methodologies. One such approach is IBL, which centers students in their own learning. It is an ongoing process of asking questions, seeking answers, generating solutions, and reflecting on what has been learned, mirroring how scientists and engineers work in real life. The premise of IBL is that people learn best through action and dialogue rather than by listening alone (Mayildurai et al., 2024). Mohr (2017) states that Genz students prefer learning through group work alongside immediate feedback and hands-on activities which solve actual problems. These preferences show that IBL is a good fit for how they like to learn, but we still need to do more research on how this works in engineering education.

A. Inquiry-Based Learning in Engineering Education

In IBL, students learn by working on real questions, problems, and investigations (Hmelo-Silver et al., 2007). Problem-based learning, project-based learning, and guided inquiry are just a few of the many ways to learn. All of these ways of learning stress how important it is for students to be involved, work together, and think about how they learn.

Recent studies show that IBL helps students understand, remember, and use what they learn in new situations in STEM fields (Sam et al., 2024). Constructivist theories of learning say that students learn best when they are actively involved in solving real problems instead of just passively receiving information. This method follows that idea. IBL is like what engineering students will have to do in their future jobs: solve complicated, open-ended problems by thinking outside the box.

B. The Role of Individual Differences

IBL has a lot of potentials, yet how well this works depends a great deal on the individual attributes of each of its students. Curiosity is perhaps best described as the inherent tendency to seek out new knowledge and experiences, and it is an essential element in learning and academic success (Kashdan et al., 2009). Curiosity serves as the driving force for engineering innovation while it helps students stay focused when solving difficult problems and it continues to drive their learning motivation throughout their entire career-a recognized essential factor for professional achievement. According to Facione (2011) critical thinking skills consist of three fundamental cognitive abilities which include skillful reasoning and sound decision-making and effective problem-solving. The constituent elements of critical thinking include problem analysis, evidence evaluation, assumption questioning, and solution assessment-all integral to engineering practice and arguably facilitated by IBL methods.

C. Research Questions and Objectives

This study investigated the relationships between IBL effectiveness, curiosity, critical thinking skills, and learning preferences among Generation Z engineering students. Specifically, the research addressed:

RQ1: What are the relationships between curiosity, critical thinking skills, IBL effectiveness, and learning preferences among Generation Z engineering students?

RQ2: To what extent do curiosity and critical thinking skills predict perceived IBL effectiveness?

RQ3: How does prior IBL experience influence perceptions of IBL effectiveness?

II. RELATED WORK

Generation Z, growing up in a digitally connected world, exhibits some unique cognitive and learning characteristics that shape their approach toward problem-solving and critical thinking. Promma et al. (2025) have empirically examined the influence of AI literacy on complex problem-solving skills among Thai Gen Z students majoring in accounting, identifying the mediating influences of systematic and intuitive thinking skills to argue for integrating AI literacy into curricula for workplace readiness. Rahmat et al. (2018) have presented issues regarding reading habits, approaches to cognition, and critical thinking among the Gen Z generation from various faculties within Malaysian universities. They used survey data to assess factors determining reading behavior and implications for pedagogy. Dass et al. (2021) have studied the effect of collaborative learning in enhancing learning outcomes for Gen Z students pursuing engineering studies. They have reported a better level of engagement, understanding, and academic achievement among students in core subjects related to electronics.

Premkumar et al. (2024) surveyed various studies concerned with exploring the effectiveness of Generative AI in promoting undergraduate students' critical thinking skills and bring forward both advantages and difficulties that educators face when trying to include AI resources into higher education. Pfefferova (2024) developed problem-solving tasks based on physics and targeted at enhancing critical thinking skills in Generation Z high school students and assessed these tasks within an informal learning context, considering students' preferences and cognitive profiles.

Fuentes (2020) focused on the social and technological contexts in which Generation Z architecture students develop their skills and advocated for an education that capitalizes on digital competencies but also stresses the need for embedding increased critical engagement into architectural training. Baskoro et al. (2023), in their study concerning Gen Z students of high technological proficiency and limited advanced reasoning, have suggested a pedagogical approach that combines 'traditional' pedagogies with AI tools to enhance critical thinking. Melisa et al. (2025), in a systematic analysis of the influence of ChatGPT on university students, note that the system promotes both critical thinking and independent decision-making, pointing out at the same time that AI tools should be supported by relevant instructional frameworks that maintain academic integrity and reduce overdependence on the tool.

Raitskaya and Tikhonova (2025) gathered empirical data on GenAI-human interactions. The researchers demonstrated ChatGPT's ability to improve cognitive and metacognitive abilities but educators must implement proper teaching methods to avoid students becoming overly dependent on the system. Ali et al. (2024) examined how Generation Z interacts with Generative AI technology. The authors identified educational transformation potential through creative work yet they stressed the importance of ethical considerations when teaching AI literacy through integrated critical thinking approaches in educational programs.

Al-Refaey (2024) investigated the effect of blended project-based learning on 21st-century competencies among Generation Z prospective English as a Foreign Language (EFL) teachers. Such learning led to increasing academic performance and such attitudes associated with collaborative and technology-enhanced learning. Camfield et al. (2020) explored how embedding critical empathy within student self-annotation could deconstruct stereotypes of Gen Z in higher education. This empowered metacognition, agency, and greater equitability in the assessment of learning.

Caratozzolo et al. (2019) elaborated on pedagogical interventions that used cognitive tools to enhance the critical thinking of engineering students through an integration of logical-scientific and artistic-narrative reasoning. This helped make up for the fact that technical courses don't teach people how to be nice to each other. Szabó et al. (2021) polled Gen Z students in Russia and Hungary, showing how digital literacy strongly influences motivation and, therefore, there is a need for pedagogy to keep pace with the students' learning preferences. Cickovska (2020) conducted a survey of educators with regard to understanding Gen Z in higher education and pointed out generational differences that require matched communication and teaching strategies in order to bridge expectation gaps in line with improving learning outcomes. Powell et al. (2021) detailed faculty experiences teaching Gen Z students about social justice issues via digital platforms during the COVID-19 pandemic, highlighting pedagogical adjustments that effectively engaged students amidst socio-political challenges.

The reviewed studies suggest that today's students arrive with strong digital habits that shape learning and problem solving; inquiry, collaboration, and real-world challenges spark interest and enhance reasoning. New technologies can boost learning but require guidance so that students judge for themselves rather than rely on the tools. Helping this generation succeed will involve pairing tech comfort with ongoing opportunities for critical thinking, creativity, and reflective learning. Although there is considerable research on the digital literacy of Generation Z and inquiry-based learning methods, one important gap remains: there is no reliable quantitative evidence regarding how curiosity and critical thinking together influence the effectiveness of inquiry-based learning in engineering education. Most of the previous literature is either qualitative or general in relation to higher education, without statistically modeling such cognitive factors specific to engineering contexts. Thus, this study addresses that gap by exploring the quantitative associations between curiosity and critical thinking and their relationship to perceived success in inquiry-based learning, based on evidence relevant to engineering pedagogy.

III. METHODOLOGY

Notations:

N	Total number of participants (sample size)
M	Mean of a variable
SD	Standard deviation of a variable
X_{ci}	Score of participants i on curiosity construct
X_{cti}	Score of participants i on critical thinking construct
Y_{ibli}	Score of participants i on IBL effectiveness construct
X_{lpi}	Score of participants i on learning preferences construct
α	Cronbach's alpha (internal consistency reliability)
r_{xy}	Pearson correlation coefficient between variables x and y
$\widehat{Y_{ibli}}$	Predicted IBL effectiveness score
β_0, β_1, β_2	Regression coefficients
ϵ_i	Error term for participant i
Z	Moderator variable (IBL experience level)

A. Research Design

This research investigates how the attitudes of Generation Z engineering students towards inquiry-based learning are related to their curiosity, critical thinking, and approaches to learning. Quantitative methodology was used in the current research to explore associations of curiosity and critical thinking with the effectiveness of IBL as perceived by students. The Pearson product-moment correlation coefficient was used to determine the strength of these relationships. The formula is:

$$r_{xy} = \frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum(x_i-\bar{x})^2\sum(y_i-\bar{y})^2}} \quad (1)$$

where x_i and y_i are the observed values of the two variables, and $\bar{x}$ and $\bar{y}$ are their respective means.

B. Participants

The research study included 500 university engineering students who were between 18 and 21 years old. The average age of the participants was 19.68 with an age variability of 1.03. Students learned about the study through their classes and received rewards for their participation. The gender distribution in the study matched standard engineering program demographics because it included 367 male students (73.4%) and 119 female students (23.8%) along with 11 non-binary students (2.2%) and 3 students who did not specify their gender (0.6%). The students had different levels of prior experience with IBL: 129 students had moderate experience (25.8%), 127 students had extensive experience (25.4%), 125 students had limited experience (25.0%), and 119 students had no prior experience with IBL (23.8%).

Ages included: 75 eighteen-year-olds, 146 nineteen-year-olds, 141 twenty-year-olds, and 138 twenty-one-year-olds. The total number of participants is referred to as N. These demographics have been summarized using descriptives.

The mean and standard deviation were calculated as:

$$M = \frac{1}{N}\sum_{i=1}^{N} x_i \quad (2)$$

$$SD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - M)^2} \quad (3)$$

where x_i is the score of participants i.

C. Instrumentation

Data were collected using a 26-item questionnaire measuring four primary constructs:

Curiosity and Interest (6 items, α = 0.777): Items assessed intrinsic motivation for learning, question-asking behavior, and exploration tendencies. Example item: "I enjoy learning about topics outside my major field of study."

Critical Thinking Skills (8 items, α = 0.775): Items evaluated analytical reasoning, evidence evaluation, and systematic problem-solving abilities. Example item: "I can analyze complex problems by breaking them into smaller parts."

IBL Method Effectiveness (7 items, α = 0.846): Items measured perceived effectiveness of IBL approaches. Example item: "IBL makes me more engaged in class."

Learning Preferences (5 items, α = 0.209): Items assessed preferences for various instructional approaches, including one reverse-coded item measuring preference for traditional lecture-based instruction.

All the items were 5-point Likert scales, ranging from 1 = Strongly Disagree to 5 = Strongly Agree. The internal consistency of the learning preferences scale was low, and this scale was excluded from the main analyses. Curiosity, critical thinking, and IBL effectiveness were measured using validated scales. The internal consistency of each scale was tested with Cronbach's alpha:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{j=1}^{k}\sigma_{Y_j}^2}{\sigma_X^2}\right) \qquad (4)$$

Here, k is the number of items, $\sigma_{Y_j}^2$ is the variance of item j, and σ_x^2 is the variance of the total score.

D. Data Collection and Analysis

Data collection occurred online through a google form survey. Participants provided informed consent and completed the survey anonymously.

Data were collected through structured questionnaires and analyzed in four stages.

1. Descriptive statistics were computed.
2. Pearson correlation was used to assess relationships between variables.
3. Regression analysis tested the predictive effects of curiosity and critical thinking on IBL effectiveness:

$$\widehat{Y_{ibli}} = \beta_0 + \beta_1 X_{ci} + \beta_2 X_{cti} + \epsilon_i \qquad (5)$$

where $\widehat{Y_{ibli}}$ is predicted IBL effectiveness, X_{ci} is curiosity, X_{cti} is critical thinking, β0 is the intercept, β1 and β2 are regression coefficients, and ϵ_i is the error term.

4. Finally, moderation analysis was performed to examine whether IBL experience influenced these relationships:

$$\widehat{Y_{ibli}} = \beta_0 + \beta_1 X_{ci} + \beta_2 X_{cti} + \beta_3 Z + \beta_4 (X_{ci} \times Z) + \beta_5 (X_{cti} \times Z) + \epsilon_i \qquad (6)$$

Here, Z denotes IBL experience, and the interaction terms $(X_{ci} \times Z)$ and $(X_{cti} \times Z)$ represent moderation effects.

Research methodology workflow presented in Figure 1.

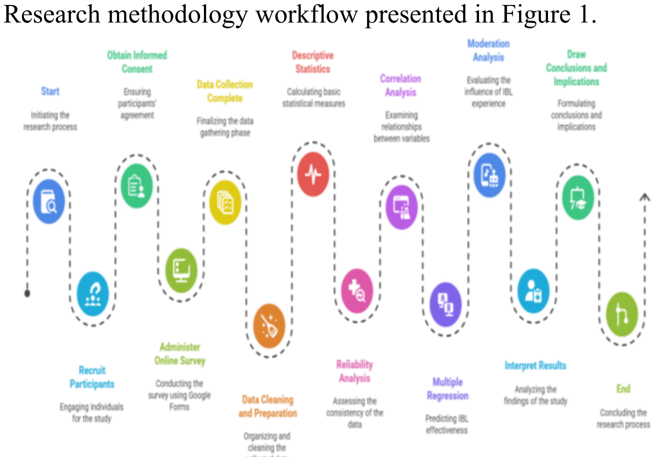

Fig. 1. Research methodology workflow

To enhance inferential validity, the analyses had been done after the assumptions concerning normality, linearity, homoscedasticity, and no multicollinearity were met. Effect sizes, including Cohen's d and partial η², were reported, including 95% confidence intervals where appropriate. Beyond theory, the reason for choosing Pearson correlations and multiple regression analyses is their precision in quantifying how much curiosity and critical thinking predict perceived IBL effectiveness beyond simple descriptive patterns.

IV. RESULTS

A. Descriptive Statistics and Reliability

Table 1 presents descriptive statistics and reliability coefficients for the primary study variables.

TABLE I
DESCRIPTIVE STATISTICS FOR STUDY VARIABLES

Scale	N	Mean	SD	Min	Max	Reliability
Curiosity & Interest	500	3.814	0.594	2.145	5.000	0.947
Critical Thinking Skills	500	3.990	0.497	2.625	5.000	0.949
IBL Method Effectiveness	500	3.919	0.597	2.286	5.000	0.950
Learning Preferences	500	3.444	0.450	2.057	4.400	0.882

B. Mean Scores Across Constructs

Fig. 2. Mean Scores Across All Four Constructs with Standard Deviations

Figure 2 shows that critical thinking had the highest mean endorsement, followed by IBL effectiveness and curiosity. Learning preferences were lower, perhaps because students were uncertain as to their best means of learning or because there was a reverse-coded item favoring traditional instruction.

C. Correlation Analysis

Strong positive correlations emerged between key variables, with the correlation matrix revealing the strength of relationships between constructs.

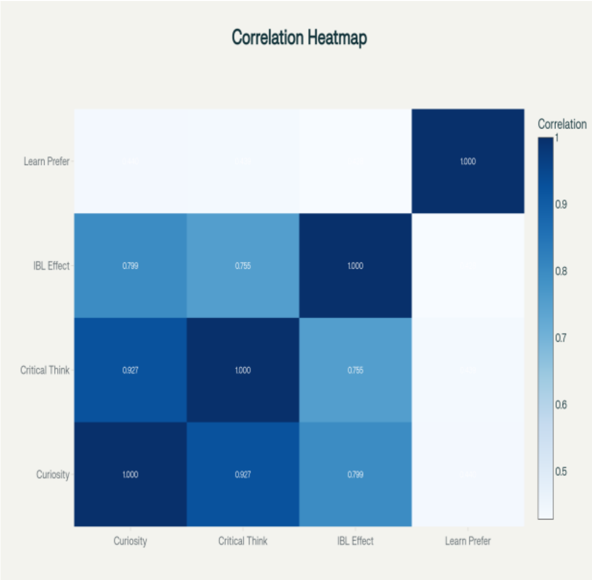

Fig. 3. Correlation heatmap

TABLE II
CORRELATION MATRIX

Variable	1	2	3	4
1. Curiosity & Interest	1.000			
2. Critical Thinking Skills	0.927***	1.000		
3. IBL Method Effectiveness	0.799***	0.755***	1.000	
4. Learning Preferences	0.440***	0.439***	0.428***	1.000

*p < 0.001

The correlation heatmap (Figure 3) visually displays these relationships, with the strongest associations between curiosity and critical thinking (r = 0.927) and curiosity and IBL effectiveness (r = 0.799).

These inter-correlations were both statistically significant and practically meaningful, as $p < 0.001$. The 95% confidence intervals for the correlations of Curiosity with IBL Effectiveness, from 0.752 to 0.836, and those of Critical Thinking with IBL Effectiveness, from 0.705 to 0.794, indicate that the results are stable and unlikely to occur from sampling fluctuation. This lends support to the view that, empirically, curiosity and critical thinking are meaningful predictors of students' perceptions of IBL effectiveness.

D. *Curiosity and IBL Effectiveness Relationship*

The scatter plot in Figure 4 depicts a strong positive linear relationship between curiosity and IBL effectiveness; that is, students with higher curiosity tend to rate IBL as more effective (r = 0.799), consistent with the notion that intrinsically motivated learners gain more from IBL methods. Prior IBL experience. When considering prior IBL experience (Figure 4), the reports of IBL effectiveness were quite consistent among groups: Extensive (M = 3.959), Moderate (M = 3.945), None (M = 3.896), and Limited (M = 3.859). The small differences that exist suggest that prior experience does not greatly affect current perceptions of IBL effectiveness.

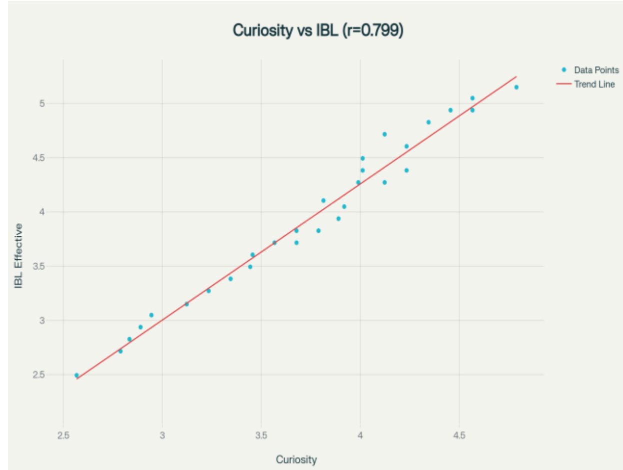

Fig. 4. Scatter Plot of Curiosity vs IBL Effectiveness (r = 0.799)

E. *Multiple Regression Analysis*

Multiple regression examined the combined predictive power of curiosity and critical thinking on IBL effectiveness:

IBL Effectiveness = 0.729 + 0.709(Curiosity) + 0.122(Critical Thinking)

Model Summary: $R^2 = 0.640$ $F(2, 497) = 441.0$, $p < 0.001$

Both curiosity ($\beta = 0.709$, $p < 0.001$) and critical thinking ($\beta = 0.122$, $p < 0.001$) emerged as significant predictors. Together, these variables explained 64% of variance in IBL effectiveness, indicating a large effect size according to Cohen's conventions.

F. *IBL Experience Analysis*

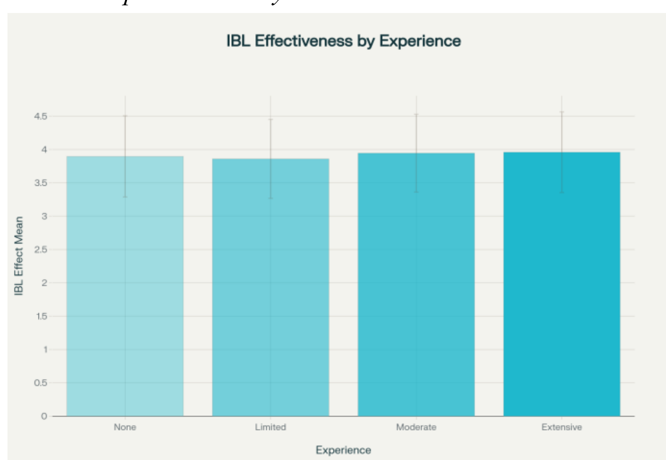

Fig. 5. IBL Effectiveness by Prior Experience Level

Analysis across prior IBL experience levels (Figure 5) showed relatively consistent IBL effectiveness ratings: Extensive (M = 3.959), Moderate (M = 3.945), None (M = 3.896), and Limited (M = 3.859). The minimal differences suggest that prior experience does not substantially influence current perceptions of IBL effectiveness.

G. *Gender Analysis*

IBL effectiveness across gender groups (Figure 6) revealed similar patterns: Non-binary (M = 4.244, n = 7), Prefer not to say (M = 3.951, n = 3), Female (M = 3.931, n = 112), and Male (M = 3.909, n = 378). While non-binary students showed the highest mean, the small sample size limits interpretability. The similar scores across male and female students suggest gender does not substantially influence IBL effectiveness perceptions.

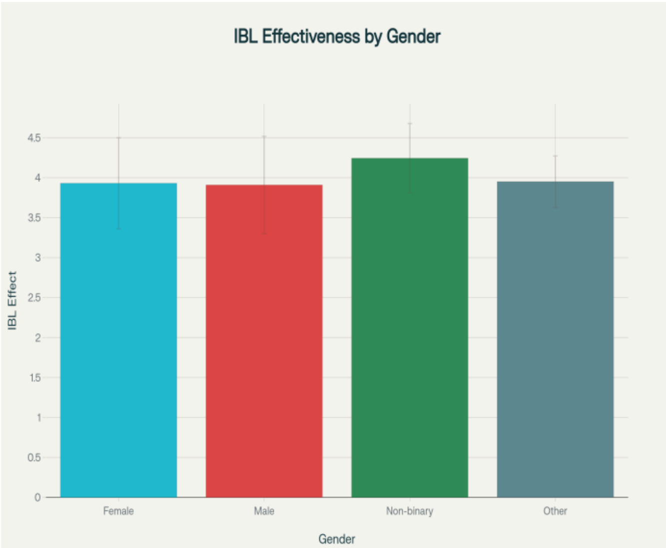

Fig. 6. IBL Effectiveness by Gender

V. DISCUSSION

A. Strong Curiosity and IBL Relationship

Data in the graph suggest that curiosity is a strong booster of IBL effectiveness, with a 0.799 correlation indicating a near-strong relationship. When students are curious about exploring unfamiliar questions, they respond best to open discovery-friendly classes. In practical terms, instructors who foster wonder via open questions engage students more and amplify the benefits of IBL. The overall model stands at $R^2 = 0.64$, indicating that much of the variation in IBL effectiveness is explained by curiosity and related factors. Standardized betas are shown as curiosity at $\beta = 0.709$, far stronger than critical thinking at $\beta = 0.122$, indicating that intrinsic motivation largely molds perceived learning gains. These robust results indicate that both curiosity and critical thinking significantly predict Gen Z IBL success. Causality between curiosity and inquiry practice cannot be established from these data, but clearly, the two reinforce each other. Building curiosity provides a sound foundation for inquiry-based teaching.

B. Critical Thinking and Inquiry Based Learning Synergy

Analysis also finds that stronger critical thinking correlates with higher IBL effectiveness ($r = 0.755$). It confirms an assumption that problem analysis, evidence weighing, and logical conclusions provide a sound basis for students to excel in self-directed inquiry: such students usually ask good questions, evaluate information, and thrive in open-ended tasks. These findings emphasize the prior development of foundational reasoning before inquiry projects. For mixed-ability classrooms, structured supports (worked examples, guiding questions, guided reflection) create opportunities for less experienced students to gain confidence and eventually be successful in inquiry.

C. Combined Predictive Power

As predictors of IBL effectiveness, taken together, curiosity and critical thinking accounted for 64 percent of the variation among students. Curiosity was the stronger predictor; critical thinking provided an additional, albeit smaller, effect. This interaction across the two factors provides evidence that both interest and reasoning skill are necessary for effectiveness with IBL. Because of this, teachers should create learning spaces that not only spark real interest but also give students the tools they need to practice good reasoning. A balanced approach that fosters both qualities is most likely to facilitate student success.

D. Experience Effects

Among the more surprising outcomes was that experience with IBL before had very little to do with the rating of its effectiveness by students. Students who had no experience with inquiry-based approaches rated it almost as highly as those with considerable experience. This suggests that familiarity and repetition are not the most important factors in the development of a positive experience and that the most important ingredients are curiosity and reasoning ability. In fact, we have shown that simply putting students through inquiry tasks again and again without fostering their curiosity and reasoning dispositions is unlikely to cause them to appreciate the value of inquiry.

E. Curriculum Design Considerations

The effectiveness of IBL in engineering programs requires practical steps for implementation. Instructors should implement straightforward assessment tools that measure student curiosity and analytical abilities to identify learners who require additional support before they start inquiry projects. Students respond better to inquiry-based learning when instructors introduce short curiosity-inducing activities including thinking puzzles alongside real-world case studies and live demonstrations. To help students learn how to do their own research better, teachers should give them short lessons on logical thinking, how to evaluate evidence, and how to solve problems step by step. Students can build their skills and confidence more effectively by starting with structured activities and then moving on to completely open-ended projects.

F. Pedagogical Strategies

Using practical teaching methods makes IBL easier to use. When starting a new topic, there should be short, interesting prompts that either challenge common beliefs or ask interesting questions. When students are working in groups, the level of support they get should depend on how ready they are. For example, some teams should be given specific questions to answer, while others should be allowed to work on their own. By putting together students with different levels of curiosity and reasoning skills, less experienced students can gain confidence by working with their peers.

G. Generation Z Considerations

The digital tools and collaborative platforms of the contemporary world they live in, have also shaped the learning expectations of the Gen Z students, having been exposed to them for the most part of their lives. Questioning-learning circumstances meet the current students' inclinations if technology employs purposeful integration ways. Digital simulations, in addition to virtual labs and networks, may attract and engage learners' interest in inquiry tasks by making them more meaningful and closer to students. This generation wants instant feedback, and short return times. Frequent check points paired with short check procedures help students stay motivated by providing an instant answer.

H. Theoretical Contributions

The study helps extend self-determination theory by demonstrating how intrinsic curiosity promotes learning in autonomy- and exploration-supportive contexts. It also relates to cognitive load theory in that it illustrates that basic reasoning skills need to be taught before problem solving. In summary, results highlight individual differences in learning and the value of considering what students know and why they are motivated to learn.

I. Implications and Recommendations for Engineering Education

This study fills a very important gap in the existing literature on engineering education and explores the relationship between curiosity, critical thinking, and perceived IBL effectiveness among Generation Z. Given the robustness of this design-n = 500, prevalidated measurement scales, and inferential analyses-some expected findings include the following:

RQ1: The correlation between the level of curiosity and the perceived effectiveness of IBL stands at 0.799 while that of critical thinking and perceived effectiveness of IBL is 0.755, indicating that students who are curious and analytically oriented regard IBL as being more effective.

RQ2: Curiosity and critical thinking jointly explain 64 percent of the variance in perceived IBL outcomes, which means that these attributes work as key predictors of IBL success.

RQ3: The relatively modest influence of prior IBL experience is outweighed by the stronger impact of intrinsic curiosity and critical thinking, which directs attention toward developing these dispositions.

Implications for engineering education: The design curriculum should be aimed at developing curiosity and reasoning through open-ended problems, guided inquiry, and case studies. Faculty should employ reflective dialogical techniques, scaffolding of reasoning, combined with feedback that supports student autonomy, congruent with the principles of Self-Determination Theory. Assessment procedures would include measures not only of mastery but also of the ability to venture into novel areas, driven by students' intrinsic curiosity. The methods proposed are in line with lifelong learning, an important precondition for innovative engineering work within an AI/ Automation environment.

J. Limitations and Future Research

Limitations include a convenience sample from one institution, which may limit generalizability; future work should use multi-institutional or randomized sampling. The Learning Preferences scale was dropped due to low reliability; future studies should refine this further. The high curiosity–critical thinking overlap suggests the need for investigation via confirmatory factor analysis or SEM. Gender comparisons were limited by small non-binary samples. These limitations notwithstanding, the findings provide a sound basis for interventions that would enhance curiosity and critical thinking with inquiry-driven projects and reflective learning. Longitudinal and experimental designs should be undertaken in future research to see the development and responses of curiosity and critical thinking to specific pedagogical interventions. Mixed-methods approaches that combine observations, analytics, and reflections, plus multi-institutional studies across disciplines and cultures, would enhance generalizability.

CONCLUSIONS

The current results confirm that curiosity and critical thinking are potent predictors of IBL effectiveness for Generation Z engineering students. Together, these dispositions explained 64% of the variance in perceived IBL outcomes, which provides strong empirical justification for integrating such dispositions into modern engineering pedagogy. It follows from the foregoing that IBL best corresponds with those learners who possess high levels of curiosity and reasoning ability, which suggests that these characteristics need to be developed if students are to engage meaningfully and learn more deeply. Though this study is based on a single-institution convenience sample and excluded the low-reliability Learning Preferences scale, such limitations do not undermine the value of the study, but instead identify possibilities for refinement in subsequent research. Consequently, educators may translate these insights into practice by incorporating curiosity-enhancing activities such as open-ended design challenges, Socratic questioning, reflective problem analysis, and technology-enabled inquiry projects. Embedding structured opportunities for critical reflection and evidence-based reasoning within coursework can further strengthen students' analytic and investigative capacities. Beyond enhancing learning outcomes, fostering curiosity and critical thinking via inquiry-centered pedagogy so equips engineering graduates with the mindset and skills required for innovation, adaptability, and lifelong learning in a rapidly changing technological world.

APPENDIX

Survey Questions:

Q_ID	Category	Question_Text
Q1	Curiosity & Interest	I enjoy learning about topics outside my major field of study
Q2	Curiosity & Interest	I often ask 'what if' or 'why' questions during class discussions
Q3	Curiosity & Interest	I seek out additional resources to explore interesting topics in depth
Q4	Curiosity & Interest	I am motivated by discovering new ideas and concepts
Q5	Curiosity & Interest	I enjoy conducting research to answer questions I have
Q6	Curiosity & Interest	I prefer understanding 'how' and 'why' rather than just 'what'
Q7	Critical Thinking Skills	I can analyze complex problems by breaking them into smaller parts
Q8	Critical	I evaluate evidence before forming

	Thinking Skills	conclusions
Q9	Critical Thinking Skills	I can identify strengths and weaknesses in different arguments
Q10	Critical Thinking Skills	I approach problems systematically using logical reasoning
Q11	Critical Thinking Skills	I question assumptions before accepting information as true
Q12	Critical Thinking Skills	I can draw valid conclusions from available information
Q13	Critical Thinking Skills	I consider multiple perspectives when analyzing issues
Q14	Critical Thinking Skills	I can evaluate the credibility and reliability of information sources
Q15	IBL Method Effectiveness	Inquiry-based learning makes me more engaged in class
Q16	IBL Method Effectiveness	I understand concepts better when I discover them through investigation
Q17	IBL Method Effectiveness	IBL methods help me develop better problem-solving skills
Q18	IBL Method Effectiveness	I feel more motivated to learn when using inquiry-based approaches
Q19	IBL Method Effectiveness	Information learned through IBL stays with me longer
Q20	IBL Method Effectiveness	I can better apply knowledge learned through inquiry methods
Q21	IBL Method Effectiveness	IBL increases my confidence in tackling complex problems
Q22	Learning Preferences	I prefer traditional lecture-based instruction (reverse coded)
Q23	Learning Preferences	I learn best through collaborative group investigations
Q24	Learning Preferences	I prefer self-directed learning opportunities
Q25	Learning Preferences	Technology enhances my learning experience
Q26	Learning Preferences	I learn best through hands-on, practical activities

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