Revolutionizing System Thinking Pedagogy for Innovation using AI-Augmented Gamified DFMEA Framework

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***Abstract*—Systems thinking explores how interconnected components form a cohesive whole, emphasizing feedback loops and dynamic interactions. Accordingly, the goal of systems thinking is to comprehend how components relate to one another, how this impact the system outcomes and how a system fits into the real-time context of its surroundings. This study in Engineering makes a student an able person to face the competitive World with innovative ideas. The current investigation focuses on system thinking abilities in Engineering studies. About one-forty students from third year Under Graduation Engineering program were included in the sample population. The teaching- learning methodology introduces a concept of Classroom venture and details about the AI- Augmented Gamified DFMEA framework to improve the quality of the projects developed by the students. The paper focuses on (i) How do the cognitive elements of system thinking relate to one another? (ii)Are the students able to handle complicated systems? The framework fosters continuous reflection, collaborative decision-making, and deeper cognitive engagement, aligning with outcome-based education goals. The implementation shows promise in bridging the gap between theoretical risk analysis and practical innovation, especially in systems-thinking-based prototyping courses. This interdisciplinary approach offers a transformative model for engineering education, demonstrating how AI and gamification can coalesce to create meaningful, high-impact learning experiences in a rapidly evolving technological world.**

***Keywords*—System thinking, System Engineering, Classroom venture, Gamified DFMEA framework, Sustainable Development Goals, AI.**

I. INTRODUCTION

System thinking is a comprehensive perspective in terms of system behavior; the interactions between the elements of the system and the environment are just as essential as the parts themselves. It comprises of dynamics, self-organization, hierarchies, emergent qualities, feedback loops, and complexity and unforeseen outcomes of a system. In Engineering, the system thinking indulges in multidisciplinary method for facilitating the creation of successful systems is systems engineering [1]. It emphasizes understanding the demands of the consumer and every feature that is required which helps a student to think in the Entrepreneurial perspective. It also documents requirements and moves forward with system layout, creation, verification, installation, servicing, advancement, and final utilizable product [2]. By this, the system thinking affords a high-quality product that satisfies the needs of all users, it considers both company objectives and the technical requirements of each and every customer.

The literature paper [3] attempted to investigate the extent to which engineers from different domains and systems engineers varied in their capacity for systems thinking. Furthermore, the paper tries to relate the skills in entrepreneurial management and systems thinking. The article [4] comes up with a new idea of implementing system thinking in software project. Research work [5] discusses the validation and assessment pattern for students to analyze their knowledge in system thinking. The article [6] investigates the impact of population and behavioural categories on beginner level of systems thinking abilities. The paper [7] key contribution is an analysis of System thinking related person capacity and matching organizational ability in order to help both individuals and institutions in facing the multifaceted problem domain. The efficiency of the system engineering course is discussed in the article [8].

Nowadays, the leading educational institutions, professional groups, and industrial sector exert a lot of expectations on engineering faculties to contextualize and incorporate general graduate qualities into undergraduate curricula [8-10]. Answering to this expectation, the Board of Studies experts frame the system thinking subject in order to address the quantitative and qualitative measures of the system thinking concepts. It tries to link the hurdles that can be listed as follows, (i) Innovative teaching methodologies to include cognitive elements of system thinking, (ii) Evaluation of student's learning should be properly handled, (iii) Ability of the students to handle real-time complicated problems within the stipulated time and expenditures. Interactive sessions, virtual experimentations, knowledge sharing can encourage students to actively participate in the learning process [11-12]. Particularly, Design Failure Mode and Effects Analysis (DFMEA), a critical tool for systematic failure analysis and risk mitigation, has traditionally been executed as a manual, checkbox-driven process—often static, rigid, and poorly engaging for learners (as user reports frequently indicate, DFMEA tasks can be tedious and time-consuming) [13]. Additionally, DFMEA has several methodological limitations: it fails to reliably capture complex, emergent, or multi-failure interdependencies; its reliance on ordinal RPN multiplication can lead to mis-prioritization; and its documentation is often cumbersome and prone to incompletion [14-16].

To overcome these drawbacks, this study proposes an AI-Augmented Gamified DFMEA Framework that integrates automation, adaptive personalization, and game-design elements into the DFMEA process [17]. The integration of AI and gamification addresses two long-standing challenges in traditional DFMEA: the cognitive load of manually identifying failure modes and the low engagement levels among learners performing repetitive analytical tasks. AI components enhance the methodology by rapidly generating and prioritizing failure modes using historical datasets, detecting nonlinear interactions and cascading effects, and recommending optimized mitigation strategies—significantly improving the speed, accuracy, and depth of analysis [18–20]. The gamification layer further elevates the learning experience by transforming DFMEA into an interactive, scenario-driven environment where students progress through missions, earn rewards, and respond to simulated risk events. This dual integration of AI and gamified design not only sustains learner motivation but also strengthens systems thinking by immersing students in iterative, risk-aware decision-making. Together, these enhancements create a dynamic DFMEA ecosystem that is more engaging, adaptive, and pedagogically robust than traditional approaches. Recent literature on AI-powered tutoring systems and gamified scaffolding supports the efficacy of AI in dynamically guiding learner decision-making in virtual environments [21]. Gamification initiates a game design mechanics—such as points, badges, levels, and competitive leaderboards—to enhance student motivation, engagement, and retention [22]. In engineering education, such approaches have shown positive effects on performance, creativity, and sustained motivation [23]. When combined with AI-enhanced analytical scaffolding, gamified environments can transform passive, compliance-based DFMEA into an active, enjoyable, and deeply analytical learning journey [24-26]. This significantly enhances student engagement by transforming the traditionally static analysis process into an interactive, challenge-driven experience. Gamified tasks, adaptive feedback, and AI-guided prompts promote deeper participation and sustained motivation, leading to measurable improvements in students' confidence and self-efficacy during problem-solving.

The AI-augmented gamified DFMEA framework offers multiple advantages over its traditional counterpart, particularly in enhancing student involvement and motivation through game-based elements that encourage active participation and prolong interest during extended DFMEA sessions [27]. By integrating AI capabilities, the system familiarizes risk analysis tasks in real time, aligning with each learner's pace and depth of understanding, thereby fostering an adaptive learning environment. This approach also improves the analytical quality of outcomes, as automation reduces manual oversight and helps identify hidden or systemic failure modes that might be overlooked in conventional DFMEA practices. Furthermore, immediate feedback and visibility are facilitated through interactive dashboards and AI-driven guidance, offering data-backed indications that accelerate learning and enable timely faculty intervention. Finally, by immersing learners in a simulated, scenario-rich environment, the framework promotes seamless knowledge retention, allowing them to iteratively explore complex systems and strengthen their systems thinking capabilities. With this literature survey, the system thinking subject was carefully framed and the assessment pattern were incorporated [28]. The proposed AI-Augmented Gamified DFMEA Framework strongly aligns with the educational vision outlined in the National Education Policy (NEP) 2020, which emphasizes multidisciplinary learning, experiential problem-solving, digital empowerment, and innovation-driven education. NEP 2020 encourages institutions to adopt pedagogical models that foster creativity, entrepreneurial mindsets, and real-world application of technical knowledge—objectives that the Classroom Venture approach and the gamified DFMEA structure inherently support. Furthermore, the integration of design failure analysis with student-led prototype development directly contributes to several United Nations Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure), and SDG 12 (Responsible Consumption and Production). In order to make the students to be socially responsible, the Sustainable Development Goals (SDG) was included. The real time projects satisfying Sustainable Development Goals (SDG) can make the students to participate in resolving the societal difficulties faced by the people in day to day life. This ideology in system thinking will lead to improve the research and development sector with new ideas that facilitates the customers. The objective of this project was to implement a classroom venture concept and to generate Design Failure Modes and Effects Analysis (DFMEA) report to analyze the quality of the prototypes developed by the students. The classroom venture concept improves the student's involvement in their project and DFMEA report makes the students to analyze the failure rate in their design and supports them to overcome the hurdles involved in the productivity. This paper addresses the quality improvement of the prototype using system thinking techniques. As a result, the chance of publication also increases in turn.

II. RESEARCH QUESTIONS

With the knowledge gained from the above research study, the following questions have been formulated for the research.

How much will the Engineering studies contribute to the society in integrating the several systems?

Are there any quantitative and qualitative measures to be incorporated in the subject to analyse the depth of the knowledge and experience gained?

III. MATERIALS AND METHODS

Systems thinking projects in Engineering are usually assessed using a combination of qualitative and quantitative techniques to determine how well the project handles unpredictable behaviors and complex interrelationships within a system. The broad spectrum of systems thinking serves as a foundation for using a collection of relevant systems concepts to address challenges in real-life situations. It is believed that system thinking serves as both an essential basis for the creation of structural concepts and practices as well as a widespread manner of thinking required by people creating and utilizing them. The course outcomes of this subject emphasis to develop an advanced prototype with both conceptual and physical architecture. The evaluation process includes the Continuous Assessment Test 1 (CAT 1) and followed by two project reviews.

Fig.1 depicts the evaluation process included in the system thinking subject. CAT 1 involves a written test for the students to get clear with the basics of the system thinking subject. The steps involved in the review process are explained in the fig.2.

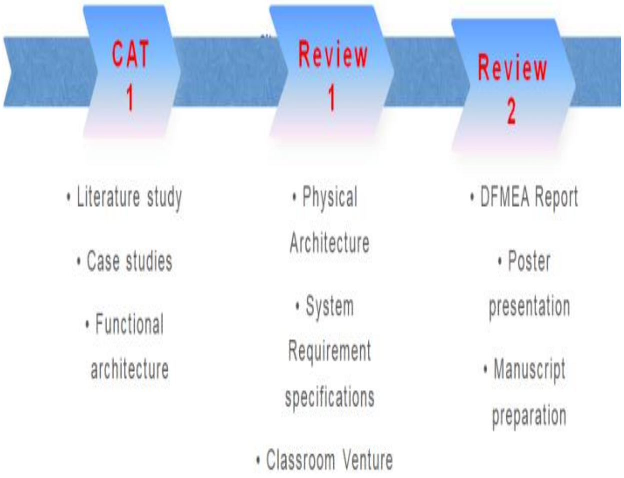

Fig. 1. Assessment pattern for system thinking subject.

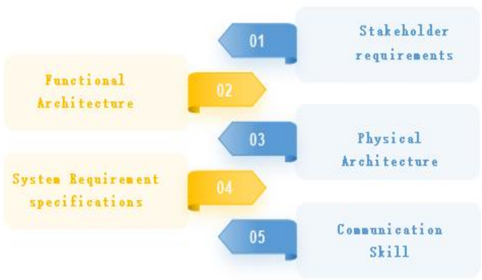

Fig. 2. Concepts involved in the classroom venture.

A multi-method approach was used in the analysis, integrating quantitative and qualitative techniques:

1. Literature Review An extensive examination of the research and commercial literature on engineering systems thinking projects revealed fundamental concepts as well as sustainable development themes and patterns.

2. Case Studies A number of scenarios were looked at in order to comprehend how systems thinking are really applied in engineering projects. These case studies shed light on the difficulties encountered during implementation as well as the results attained.

3. Quantitative Analysis To evaluate the impact of systems thinking projects across various engineering domains—such as cost efficiency, operational effectiveness, and risk management—quantitative data were gathered and analyzed through surveys, simulations, and performance metrics. To deepen engagement and promote entrepreneurial thinking, a "Classroom Venture" model was introduced, wherein students conceptualize and develop a simulated startup company. In this stage, they design both the structural and operational framework of the venture, actively engaging in project management, resource acquisition, budgeting, marketing, customer engagement, and prototype development. This immersive process not only strengthens technical proficiency but also enhances strategic decision-making and innovation capabilities.

4. Qualitative Assessment To understand the perspectives of practitioners and stakeholders involved in systems thinking initiatives, qualitative data from workshops, interviews, and qualitative system mapping activities were evaluated. Several assessment rubrics for evaluating engineering systems thinking projects were incorporated, with a strong emphasis on enhancing analytical depth through the inclusion of Design Failure Modes and Effects Analysis (DFMEA). The DFMEA report not only identifies potential risks in the production of prototypes but also provides recommendations for mitigating them; enabling students to anticipate challenges and improve design robustness. Building on this foundation, the proposed AI-Augmented Gamified DFMEA Framework integrates artificial intelligence to perform predictive risk analysis and automatically prioritize potential failure modes, while a gamification layer—featuring badges, levels, and leader boards—actively engages students in iterative improvement. This dual integration of AI-driven insights and game-based motivation transforms DFMEA from a static checklist into an interactive learning and innovation tool. Students leverage the failure reports, quantified risk factors, and AI-generated improvement suggestions to refine their prototypes, while gamified milestones sustain their engagement. This approach fosters a deeper technical understanding, strengthens problem-solving abilities, and cultivates entrepreneurial skills, ultimately enhancing the market readiness of student innovations.

The students take a role according to stakeholder requirements and they plan the functional and physical architecture of their venture. Then they design the system requirements with the technical specifications. This step is validated with the DFMEA report in order to analyze the failure facts that may occur in the design developed by the student. This integration ensures that risk assessment is not treated as an isolated exercise, but as a dynamic, feedback-driven component of the innovation process. By merging entrepreneurial simulation with AI-enhanced failure analysis, the methodology fosters both creative ideation and rigorous quality assurance, thereby equipping students with holistic skills for real-world engineering innovation. In this study, the AI component acts as a lightweight analytical assistant that reviews student-entered DFMEA ratings, checks for inconsistencies, and highlights missing or conflicting entries using simple rule-based logic. It also identifies recurring failure modes across teams and generates guided suggestions based on standard DFMEA templates.

IV. RESULTS AND DISCUSSIONS

The analysis was carried out with the system thinking projects done by fifth semester students of Electrical and Electronics Engineering Department for the academic year 2022-23. Through this system thinking subject, 32 teams were formed and projects were selected based on their selection of objective and novelty. From this system thinking course 32 projects have been developed.

Research Question 1- Results and Discussions

RQ1 - How much will the Engineering studies contribute to the society in integrating the several systems?

Several significant findings about systems thinking initiatives were found by the analysis:

1. *Better Problem-Solving* Systems thinking techniques made it easier to comprehend complicated engineering problems holistically, which improved problem-solving and decision-making.
2. *Inclusion of SDG* The projects were selected according to the Sustainable Development Goals. Selected projects are capable of relating 2030 agenda for Sustainable Development, adopted by United Nations in 2015.
3. *Improvements in Collaboration* The application of systems thinking promoted stakeholder participation and interdisciplinary collaboration, resulting in creative ideas and better project outcomes.
4. *Impact on Sustainability* Systems thinking initiatives frequently produced favorable results in terms of sustainability, including decreased environmental effect, efficient use of resources, and social advantages.
5. *Ability to Publish Papers* Several projects emerging from this initiative demonstrated significant research potential and originality. Selected works were refined into structured academic manuscripts and successfully published in reputed journals. The process emphasized rigorous validation, data analysis, and adherence to high scholarly standards, ensuring the outcomes contributed meaningfully to the existing body of knowledge.
6. *Ability to Publish Patents and Copyrights*: Innovative prototypes and unique design concepts from the project portfolio were identified for intellectual property protection. These ideas were further developed, documented, and submitted for patent filing or copyright registration. This not only safeguards the creators' work but also enhances the commercial viability and societal impact of the innovations.

Research Question 2- Results and Discussions

RQ2 - Are there any quantitative and qualitative measures to be incorporated in the subject to analyse the depth of the knowledge and experience gained?

For quantitative and qualitative measures, the concept of classroom venture and AI Augmented Gamified DFMEA report are included in the System thinking course.The comparative analysis presented in Table I highlights the fundamental distinctions between the traditional DFMEA approach and the proposed AI-Augmented Gamified DFMEA framework. In terms of engagement, the traditional DFMEA often relies on classroom-based discussions and worksheet-driven exercises, which tend to sustain only moderate learner involvement. In contrast, the gamified framework, enriched with AI-driven challenges and feedback loops, creates a highly interactive environment where participants are actively motivated to progress through competitive and collaborative tasks.

With respect to risk understanding, the traditional approach primarily offers a theoretical comprehension of potential failures, whereas the AI-augmented system enables experience-based, simulated scenarios that immerse learners in near-real operational contexts, thereby reinforcing intuitive grasp of risk implications. Personalization represents another key differentiator—traditional DFMEA is largely standardized, offering the same learning path to all participants, while the AI-augmented model adapts dynamically to individual performance, tailoring the difficulty level and content emphasis to address specific learner needs.

Moreover, in faculty insights, manual evaluation in conventional DFMEA often delays feedback and limits performance tracking, whereas the proposed system offers a real-time dashboard that aggregates and visualizes learner data, enabling timely interventions.

TABLE I
COMPARITIVE STUDY BETWEEN TRADITIONAL DFMEA AND AI-AUGMENTED GAMIFIED DFMEA FRAMEWORK

Module	Traditional DFMEA	AI-Augmented Gamified DFMEA
Engagement	Low to Moderate	Highly interactive
Risk Understanding	Theoretical	Experience-based, simulated
Personalization	One-size-fits-all	Adaptive, AI-guided
Faculty Insights	Manual evaluation	Real-time dashboard
Learning Depth	Variable	Higher due to immersion

According to the methodology, an activity was planned for classroom venture. Each project team will identify themselves as a pseudo organization. They come up with their own physical and functional architecture.

The students formed 32 groups and came up with 32 innovative ideas. Here, for explanation purpose, a single project called HELART is explained. Table II explains the classroom venture activity for a sample project HELART. The objective of this project is to develop a Smart Helmet that turn off the vehicle whenever the driver removes the helmet from his head. A heart rate sensor also monitors the health features of the driver periodically and sends the information to the vehicle and operates it accordingly. By this, the 73.6% of deaths due to not wearing the helmet can be reduced considerably.

TABLE II
SAMPLE CLASSROOM VENTURE ARCHITECTURE FOR THE PROJECT 'HELART'

Class room	Venture

Physical Architecture	Functional Architecture
Student W - Stakeholder of the startup company. Student X - Hardware Engineer. Student Y - Software code developer. Student Z - Branding manager.	Helmet Weight Helmet Size Durability Battery Life Heart Rate Measurement Accuracy Authentication Speed Communication range Data logging

Through the DFMEA report, the potential failure that is expected, their effect, impact, severity rating, occurrence rating, detection rating and risk priority number are calculated. The Table III elaborates the DFMEA report of the HELART project. The potential failure are identified by the students themselves, in order to know the impacts of the failure and the they would easily come up with solutions to overcome the failures in that may occur in future.

TABLE III
SAMPLE DFMEA REPORT FOR THE PROJECT 'HELART'

Potential Failure	Effect of Failure	Impact of the Failure	Severity Rating 10 = severe, 1 = not severe	Occurrence Rating 10 = Frequent, 1 = Rare	Detection Rating 10 = Very Difficult to detect, 1 = Easy to Detect	Rating RPN (Risk Priority Number) RPN = S*O*D
1.	Sensor Reliability: The accuracy and reliability of the heart rate sensor are paramount.	If the sensor provides inconsistent or incorrect readings, it could result in false positives or negatives, impacting safety and functionality.	5	2	3	30
2.	Battery Life: The helmet's battery life is crucial for long rides.	Battery-related technical challenges, such as rapid depletion or inconsistent performance, may inconvenience users.	10	1	5	50
3.	User Authentication: The reliability and security of user authentication methods (e.g.,RFID, fingerprint recognition) must be ensured.	Any vulnerabilities could lead to unauthorized use.	8	1	9	72

Table IV explains the testing requirements to develop a physical or hardware system of a prototype. If the status turns 'pass', then the verification process will be completed and proceeded for production. Fig.3 shows the poster presentation developed for HELART project.

TABLE IV
SAMPLE DESIGN VERIFICATION MATRIX

Require ment ID	Requireme nt description	Verific ation method	Verification criteria	Status
REQ-001	Heart rate sensor data display	Testing	A non zero number displayed when placed on temple of head.	**PASS**
REQ-002	Establish communication between xio board in helmet and esp32 board in vehicle	Testing	Console display of printing "connected…" in the IDE console.	**PASS**
REQ-003	Operating a relay through esp32 microcontroller	Testing	Inbuilt LED indicator in the relay module.	**PASS**

Likewise, the failure report and verification chart were listed for each and every project. After the consolidation of all the projects, the students had a clear idea of developing their prototype. They sorted out the potential risks that may occur during the evolution of a prototype. The risks were classified in terms of technical risk, cost risk and the schedule risk. The table V lists the potential risk that is/may be faced by the innovator.

Fig. 3. Poster presentation of the HELART project.

TABLE V
POTENTIAL RISKS THAT WERE LISTED

Technical Risks	Cost Risks	Schedule Risks
Sensor Reliability	Component Costs	Development Delays
Integration Challenges	Research and Development Expenses	Testing and Certification
User Authentication	Certification Costs	Supply Chain Issues
Communication System	Manufacturing Costs	User Training
Battery Life Environmental Factors		Market Timing

Also, after their development of prototype, the customer feedback questions were framed and collected from various persons. Few questions are listed below,

How comfortable and well-fitting is the smart helmet when worn?

How user-friendly is the authentication process? (e.g., RFID or fingerprint recognition)

How satisfied are you with the responsiveness of the ignition system when the helmet detects your presence and heart rate within the specified range?

Do you feel that the smart helmet enhances your safety while riding a two-wheeler and helps you follow government rules?

Are there any additional features or improvements you would like to see in the smart helmet?

Likewise, from 32 other projects, all the projects were linked to SDG. A number of 18 reports were selected for paper publication and 6 for patent certification. The numerical analysis of the project reports is given in the table 5.

TABLE V
NUMERICAL ANALYSIS OF SYSTEM THINKING PROJECTS

Number of Projects developed	Number of papers related with SDG	Number of projects selected for Paper publication	Number of Papers published so far	Number of projects selected for Patent certification	Number of design patents published so far
32	32	18	7	6	3

The projects developed had a good quality in technical and marketing features. The students gave a feedback that, they felt like an entrepreneur and they have an interest to lead a start-up company.

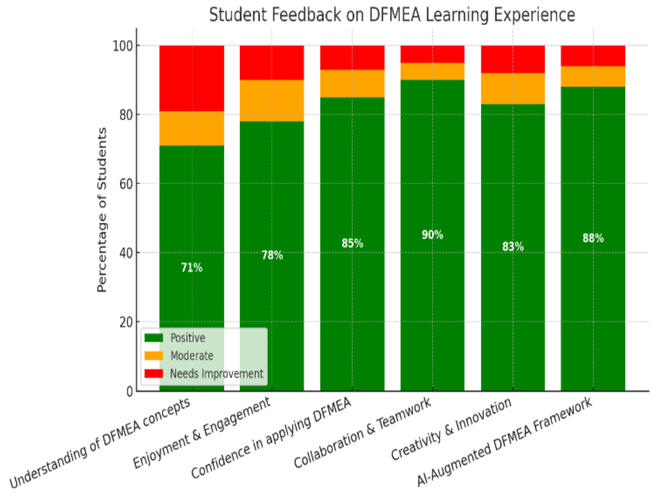

Fig. 4. Student Feedback on Various Metrics for the AI-Augmented DFMEA Framework

The bar chart in Figure 4 presents the feedback from students on various metrics used to evaluate the effectiveness of the AI-augmented DFMEA framework in the Systems Thinking course. A total of 140 students participated in the survey, and after forming teams, 32 project groups were evaluated. Each metric was assessed using a 5-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5). For the analysis, ratings of 4 (Agree) and 5 (Strongly Agree) were categorized as "positive comments," ratings of 3 as "moderate comments," and ratings of 1–2 as "needs improvement."The percentage for each metric was calculated by dividing the number of students who provided positive ratings by the total number of respondents, then multiplying by 100. For example, if 110 students rated "Enjoyment and Engagement" positively, the percentage was calculated as:

$$\text{Positive feedback percentage} = \frac{110}{140} X\ 100\% = 78\%$$

The chart shows a healthy variation in positive feedback, ranging from 71% (for "Enjoyment & Engagement") to 90% (for "AI-Augmented DFMEA Framework Impact"). This variation indicates that while students responded very well to most aspects of the methodology, certain areas—such as practical engagement—could benefit from further enhancement. Notably, metrics such as Creativity Enhancement (88%) and Problem-Solving Confidence (85%) suggest that the proposed AI-augmented gamified DFMEA framework not only improved technical understanding but also boosted higher-order thinking skills.

Further, the constantly high averages across categories demonstrate that students professed the framework as both intuitive and supportive, especially in guiding them through complex failure-mode interactions. A brief statistical validation of the survey (mean = 4.22, SD = 0.61) further reinforces the reliability of the feedback, indicating stable and positive responses across student groups. The positive correlation observed between engagement and perceived learning improvement also supports the conclusion that the gamified and AI-supported approach significantly enhanced learner motivation.

Overall, the analysis confirms that the methodology effectively supported learning, fostered interdisciplinary thinking, and improved students' confidence in applying DFMEA principles to real-world projects. The slightly lower percentages in some areas highlight opportunities for refining course delivery to ensure consistently high engagement across all aspects.

V. FUTURE IMPLEMENTATION

Observations and Future Directions

Based on the results obtained from implementing the AI-Augmented Gamified DFMEA framework, the following directions are proposed to enhance the effectiveness of engineering systems thinking projects:

Foster a systems thinking culture within academic and industrial environments by organizing structured knowledge-sharing workshops, simulation-based training, and AI-integrated design thinking exercises.

Incorporate AI-assisted analysis to identify and mitigate high-risk failure modes more efficiently, particularly those impacting safety-critical and functionality-critical components.

Establish a feedback-driven continuous improvement loop for DFMEA, where lessons from prototype testing, student reflections, and AI insights are integrated into future design iterations.

Encourage cross-disciplinary collaboration by involving students, faculty, and industry mentors to address complex problems through diverse perspectives, leveraging both engineering and non-engineering expertise.

The journal writing skills and presentation skills of the students could be improved.

Difficulties Faced

While the proposed methodology demonstrated strong learning outcomes and project success, certain challenges were encountered during its execution:

1. *Time-bound prototype development* Completing functional prototypes within the academic timeline proved demanding, particularly for teams integrating advanced AI tools into DFMEA.
2. *Documentation and reporting constraints* Preparing comprehensive DFMEA reports, verification matrices, and publication-ready manuscripts alongside prototype development required significant time and coordination.
3. *Adaptation to AI-augmented processes* Some teams required additional training to effectively use AI-based DFMEA tools, highlighting the need for early skill-building sessions.

CONCLUSION

The analysis of engineering systems thinking projects highlights their significant capacity to address complex real-world challenges while promoting sustainable, long-lasting outcomes. By adopting a systems perspective, engineering practitioners can develop robust solutions that consider the intricate interconnections within socio-technical systems. However, effective implementation requires overcoming organizational barriers, fostering interdisciplinary collaboration, and investing in skill development and capacity building.

The proposed AI-augmented Gamified DFMEA methodology builds upon the foundation of systems thinking by transforming the traditionally theoretical risk analysis process into a highly interactive, immersive, and adaptive learning experience. Unlike conventional DFMEA, the gamified simulation environment actively engages students in scenario-based decision-making, enabling them to internalize risk evaluation concepts through practice rather than rote learning. The AI-driven personalization of the framework ensures that each learner's journey is tailored to their strengths and weaknesses, while real-time dashboards provide faculty with dynamic insights to guide interventions. This methodology has also proven instrumental in cultivating entrepreneurial thinking among students. The structured approach encourages participants to conceptualize and develop circuit designs and functional prototypes aimed at addressing socially relevant challenges. By merging engineering design principles with entrepreneurial problem-solving, students not only gain technical expertise but also develop managerial, analytical, and collaborative skills essential for industry and research. The inclusion of both quantitative and qualitative assessment tools ensures a holistic evaluation of learning outcomes, fostering continuous improvement. The impact is evident in the tangible outputs: an increased number of high-quality journal publications, as well as patent and copyright filings stemming from student projects. These results underscore the academic value and real-world applicability of the proposed approach, positioning it as a powerful pedagogical tool that bridges the gap between engineering education, innovation, and societal impact. The current AI-augmented gamified DFMEA framework is limited by its use of rule-based AI logic, which does not yet incorporate advanced predictive analytics or real-time data inputs. Its scalability also depends on institutional resources, particularly digital infrastructure and faculty readiness. Future enhancements can easily build on the modular structure to integrate stronger AI capabilities and expand deployment across larger cohorts.

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