

Integrating AI Ethics and Bias Awareness into Undergraduate Engineering Education: A Curriculum-Embedded Framework

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Abstract-The current engineering education system faces rising difficulties in developing students who can practice responsibility when working with AI systems in technological environments. The growing use of AI systems across industries has not led to ethical reasoning and bias awareness becoming core components of undergraduate engineering education because these subjects continue to exist as optional courses. Students face learning obstacles because they cannot predict how engineering work will affect society through their lack of necessary information. The research study introduces a new educational framework which embeds AI ethics and bias awareness education into undergraduate engineering programs to make ethical competence a fundamental learning objective instead of an additional requirement. The educational framework consists of four main teaching components: learning about the ethical risks of AI systems, analysing how society will be affected, performing hands-on activities for practical learning, and practising ethical choices in real engineering environments. The framework underwent its initial test through a pilot program that took place during the 2024–25 academic year at a shared undergraduate course that enrolled B.Tech and MCA students (total enrolment of 120 students; 106 students completed matched longitudinal surveys). The research study conducted a longitudinal assessment which tracked how students developed their ability to recognize ethical issues and their skills to detect bias and their confidence in making ethical choices and their knowledge about artificial intelligence effects on society. The results demonstrate that all learning outcomes showed major progress because large effect sizes appeared between baseline and post-intervention assessments. Faculty members showed through their feedback that the new content could fit into existing courses

without requiring major changes to the curriculum structure. The findings demonstrate that ethics-integrated pedagogy can meaningfully enhance engineering students' readiness for responsible innovation. The study provides engineering educators with practical knowledge which helps them integrate ethical skills into their outcome-based and practice-focused educational programs.

Keywords - Algorithmic Bias; Curriculum Design; Engineering Education; Ethical Awareness; Responsible Innovation; Sustainable Development Goals

I. INTRODUCTION

Artificial intelligence in modern technological systems has provoked an indispensable change in the training of engineers. The process of decision making of critical sectors is now relying on AI based applications in healthcare diagnostics, autonomic mobility, financial services, employment and governance of the people [1]. Engineering students must be taught not just their technical skills but also how to foresee and handle social and moral impacts of the systems that they develop, due to the current technological development. The normal undergraduate courses in engineering do not equip them with sufficient ethical training that would allow them to manage the intricate social aspects of engineering practice incorporating AI systems [2].

The main focus of traditional engineering education programs has always been on teaching students technical skills together with mathematical concepts and

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efficient methods to solve problems. The core competencies remain vital, but they do not prepare

students for AI system interactions, which require understanding of social values and human rights and institutional frameworks. The current approach to ethics education limits its presence to separate humanities classes and short professional ethics segments and accreditation-based compliance standards which do not connect with essential technical education. Students who graduate will have strong algorithm knowledge, but they will lack the ability to identify system biases and evaluate social risks and make ethical decisions when working with AI-based engineering systems.

The educational gap becomes more apparent because recent AI system breakdowns have occurred in multiple high-profile cases. The documented cases of bias in facial recognition technology against racial groups, automated hiring systems that perpetuate gender discrimination, and predictive policing systems that exacerbate social inequalities demonstrate how technical systems reproduce existing social discrimination through their design decisions. The final results arise from educational limitations that hinder students from learning how to analyse their data, models, and deployment environments [6], rather than from any intentional wrongdoing. The existing cases reveal that educational programs need to shift their focus from teaching ethics as theoretical knowledge to teaching it as an essential engineering skill.

In the present study, AI ethics is an indispensable factor, which is destined to transform the engineering education rather than consider it a governance or policy issue. The paper presents a new framework that merges AI ethics with bias recognition in current undergraduate engineering courses, and researchers tested its effectiveness through their study. The framework connects ethical thinking with technical coursework instead of adding separate ethics classes, which helps students learn through practical experiences and achieve their educational outcomes according to modern engineering teaching methods.

The study investigates how teaching methods, learning results, and staff execution practices address the current lack of expandable systems, which combine different academic fields to teach ethical skills in AI-based engineering environments. The research advances engineering education knowledge because it shows how students can learn about ethical thinking, bias detection, and responsible choices through core courses, which keep all necessary technical material intact.

RESEARCH OBJECTIVES

The research study has set specific objectives, which include the following:

1. The study aims to build a complete educational framework which will connect AI ethics and bias awareness to undergraduate engineering programs through their existing curriculum.
2. The project requires development of teaching methods which must serve computer science, mechatronics and business systems educational programs.
3. The research study will assess how students develop ethical awareness and their ability to identify bias and their confidence in making ethical decisions after using the framework.
4. The study will investigate how educators view the possibility of teaching ethics through engineering courses and their opinions about course expansion and teaching value.

II. LITERATURE REVIEW

The academic community continues to study how engineering education should include ethical competence because technological systems now determine social, economic and institutional outcomes. The growth of engineering practice beyond its original technical problem-solving role requires educators to develop students who possess both engineering knowledge and ethical decision-making abilities for their future work. The vast scale of artificial intelligence systems together with their hidden operations and extensive social impact, creates an even greater challenge when dealing with artificial intelligence.

The literature review brings together three connected research areas which support this study: *first*, 'research on engineering ethics education'; *second*, 'established AI ethics frameworks'; and *third*, 'studies on algorithmic bias as a technical and educational concern'. The different research areas show that ethical principles stand apart from educational methods, which makes it essential to develop teaching methods that merge ethical thinking with fundamental engineering lessons.

ENGINEERING ETHICS EDUCATION

The educational field of engineering ethics has undergone major transformations during the last century due to the combination of professional codes, accreditation standards, and changing public requirements for engineers [7]. The accreditation system which ABET operates demands students who graduate from engineering programs must develop the ability to identify ethical and professional responsibilities which they will

face in their engineering careers [8]. The educational system does not effectively teach ethics because of these requirements, which exist without proper implementation.

Research in engineering ethics education shows that educational programs provide scattered and minimal ethics instruction to their students. The majority of educational programs teach micro-ethics, which covers personal and professional behavior and rule following, but they do not provide enough instruction about macro-ethical topics, which include social justice, long-term community effects and systemic risk [9]. The current system generates severe difficulties for AI-based engineering systems because these systems produce ethical issues through their automated control of technical decisions and their automated management of data networks, which affect social systems.

AI ETHICS FRAMEWORKS

Organizations have developed ethical frameworks which direct their artificial intelligence systems to operate following responsible usage requirements because society faces rising concerns about this technology. The three main examples of ethical AI guidelines consist of IEEE's Ethically Aligned Design [10], the European Union's Ethics Guidelines for Trustworthy AI [11] and the Montreal Declaration for Responsible AI [12]. The different frameworks share fundamental principles, which include fairness, transparency, accountability, privacy protection, and human control over technology [13].

The high-level principles which these initiatives establish serve as useful normative guidance, yet scholars continue to find them difficult to apply during engineering work and in educational settings [14]. Engineering students are exposed to ethical frameworks only in a theoretical aspect since they are not provided with sufficient opportunities to enforce these principles when they are left to make design decisions and technical decisions as well as real-life engineering problems. The current disconnect between the ethical theory and engineering practice prompts an adaptation of new teaching methods that would be a norm in engineering education programs.

ALGORITHMIC BIAS

The central meaning of algorithmic bias refers to the fact that automated decision systems create unfair treatment by the programmed working mechanisms, which has now become a significant ethical and technical problem of AI scientists and practitioners [15]. Bias may be integrated at

different stages of the AI development, such as specifying problems, collecting data, selecting features, model construction, testing and implementation of models, and deployment [16]. The deployment of AI systems on a large scale produces different results for various demographic groups because these systems contain built-in biases, which become more apparent during critical decision-making applications.

The educational approach to algorithmic bias requires students to learn about social impacts, while they also need to understand the technical processes that create and combat bias in computer systems. Research shows engineering students need to learn data examination skills and model assumption evaluation and deployment environment assessment to properly handle bias-related risks [17]. The current educational programs treat bias as an abstract ethical matter instead of teaching it as a fundamental aspect which needs to be considered during technical system development.

INTEGRATING ETHICS INTO ENGINEERING CURRICULUM DESIGN

The existing body of research about engineering ethics and AI governance and algorithmic bias contains numerous studies, but only a few examine methods to integrate ethical skills into fundamental engineering education programs. The Outcome-Based Education (OBE) approach in educational research demands that learning outcomes should connect directly to both teaching methods and assessment approaches for students to achieve their required competencies. The accreditation systems of ABET and the National Board of Accreditation (NBA) require students to develop graduate attributes, which include ethical conduct and social responsibility and professional duty awareness.

The educational methods of constructive alignment, experiential learning and curriculum scaffolding present effective approaches to teaching ethical principles within technical education programs. The engineering curriculum needs to include ethical inquiry throughout each subject, and students should develop their skills throughout their entire program to achieve a complete socio-technical education. The available research lacks sufficient evidence about the success and operational challenges which integrated educational methods present for AI-enhanced engineering education programs.

The present study solves this research gap through its development of a curriculum-based model which links ethical learning objectives to technical teaching approaches and hands-on learning experiences and evaluation methods. The research offers new insights for engineering education because it demonstrates methods to

teach AI ethics and bias recognition through outcome-based undergraduate engineering programs.

FROM LITERATURE GAPS TO FRAMEWORK DESIGN

The reviewed literature shows that AI governance frameworks which contain ethical principles fail to achieve their intended results because undergraduate engineering programs continue to struggle with this issue. The engineering ethics field shows that graduates need to develop ethical responsibility as their primary attribute, yet current academic programs fail to establish enduring learning experiences which combine ethical responsibility with AI ethics frameworks that focus on fairness and accountability and social effects. The current academic programs enable students to learn about ethical responsibility and AI ethics frameworks, but these learning experiences fail to establish lasting educational experiences which connect with the principles of fairness and accountability and social impact assessment. The research field that studies algorithmic bias focuses on system bias development and its effects, but it fails to provide methods that would let students apply these concepts to their core engineering studies.

The various educational approaches share a fundamental problem because their engineering ethics programs exist as separate entities which create theoretical content that makes students feel confused about how to connect their academic studies to their technical work. The current research fails to provide evidence about methods which enable students to develop ethical awareness and bias detection skills and responsible decision-making abilities through outcome-based engineering programs that focus on specific disciplines while maintaining assessment standards and teaching coherence. The research community lacks sufficient evidence about educational methods that merge ethical thinking with hands-on learning and practical skills development through AI technology in educational settings.

The current research presents a curriculum-based framework which integrates ethical competence into engineering education as an essential element instead of treating it as an extra addition. The framework, which follows constructive alignment principles and experiential learning and outcome-based education systems links ethical learning goals to technical education and hands-on activities and evaluation methods for all programme stages. The framework solves multiple teaching problems that research has identified by merging ethical assessments with standard engineering assignments to help students develop AI ethical and bias detection abilities through their engineering work.

The upcoming section explains the framework design and organizational layout while showing its essential components and teaching approach and operational environment for undergraduate engineering courses.

III. FRAMEWORK DESIGN

The proposed framework needs to function because it links ethical competence with the first-year engineering courses which universities now offer. The framework approaches AI ethics through its connection with core technical learning experiences, which include ethical reasoning and bias awareness and social responsibility education. The framework utilises outcome-based education, constructive alignment, and experiential learning principles to create a system that connects all course elements for teaching and assessing ethical learning goals across the entire curriculum.

FOUR-DIMENSIONAL PEDAGOGICAL STRUCTURE

The framework consists of four interconnected educational dimensions which work together to achieve specific learning objectives (Fig. 1). The three dimensions work to develop ethical competence across different levels while they continue to support technical instruction methods.

1. **Technical Understanding** – *This* dimension works to establish basic knowledge about the ethical threats which AI systems with automated functionality produce. Students study the main technical elements, which include data quality and model assumptions and engineering solution bias origins. Students must learn to identify the ethical consequences which result from their technical design decisions.

Aligned Course Outcomes: Ability to identify ethical risks within engineering systems.

Aligned Graduate Attributes: Ethics, professional responsibility, and societal awareness.

2. **Critical Evaluation** - The second dimension allows the students to develop their capacity to evaluate the engineering solutions in the context of their social environment and their impact to the environment. Through organized evaluation and self-reflection processes, students conduct analysis of AI system interaction with social networks and institutions and other groups of stakeholders. This dimension enables the user to perform analytical thinking that extends to the general assessment of technical performance measures.

Aligned Course Outcomes: Ability to evaluate societal implications of engineering decisions.
Aligned Graduate Attributes: Societal impact, sustainability, and lifelong learning.

3. **Hands-on Practice** - Students obtain their ethical knowledge by direct experience but this is mixed by their educational programs with their technical knowledge. When students work on real tasks, analyse case studies and are engaged in applied exercises simulating real-life engineering scenarios, they are practicing ethical thinking skills. Through the dimension, ethical knowledge is transformed into working procedures that engineers may apply to their practice.

Aligned Course Outcomes: Application of ethical reasoning during problem-solving and system design.

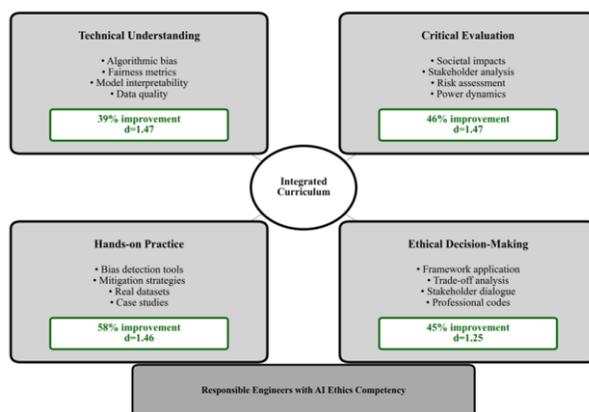
Aligned Graduate Attributes: problem-solving, experimentation, and interdisciplinary competence.

4. **Ethical Decision-Making** - The engineers are required to develop their instincts and conscience since they have to resolve complicated problems in engineering. Students should be taught to make decisions in relation to an ethical issue as they should choose whether to focus on the technical success or offer equal treatment, which leads to the positive social outcomes. The exercises are used to make decisions and the students learn their professional integrity and accountability that is crucial in achieving success in the real engineering jobs.

Aligned Course Outcomes: Ability to make informed and responsible engineering decisions.

Aligned Graduate Attributes: Ethical leadership, accountability, and professional conduct.

The four dimensions are in place as a cohesive mechanism that imparts ethical competence by taking students through the varying levels of learning through the simple concepts to the sophisticated decision making skills. Its design enables the engineering departments to alter their content since it has a system of well-structured academic program.



Source: Authors

Fig. 1. Four-Dimensional AI Ethics Integration Framework illustrates the alignment of pedagogical dimensions with learning outcomes.

IMPLEMENTATION CONTEXT

The framework underwent its first operational assessment during the academic year of 2024–25 when students from different engineering programs took the same undergraduate course together. The evaluation team selected this learning environment to test the framework's operational capabilities because they wanted to keep the current course structure intact. The course maintained an enrolment of 120 students who split their registration between B.Tech and MCA programmes, with 60 students in each programme. The research team gathered longitudinal assessment data from 106 students who completed all their required evaluation stages. The framework operated through normal teaching practices and student work and tests, which allowed teachers to assess student learning without altering their usual classroom activities.

IV. METHODOLOGY

The research method assesses the educational value which the ethics-integrated framework produces through its implementation in undergraduate engineering courses which exist in real-world academic environments. The methodology follows outcome-based education principles through the connection of planned learning outcomes to assessment instruments and data collection methods, which monitor student development in ethical understanding, analytical skills, and decision-making abilities across different time points.

STUDY DESIGN

The research followed a longitudinal quasi-experimental design which involved multiple assessment points throughout one academic semester. The research team collected data at three established assessment points, which consisted of a Week 1 baseline measurement, a Week 7 mid-semester evaluation, and a Week 14 post-intervention assessment. The design enabled researchers to track student learning growth because students worked with all four teaching components of the framework during their complete time at school.

Formal engineering education programs require a quasi-experimental research design because their academic environment prevents them from conducting controlled experiments through random participant assignments. The research method involved using one participant group for repeated testing because this method allowed each subject to serve as their own control, which made the study more dependable while maintaining a natural research setting. Research scientists in engineering education employ these design types to study how teaching approaches work in their regular classroom activities.

ASSESSMENT INSTRUMENTS AND OUTCOME ALIGNMENT

The framework needed four authorised assessment tools to link its educational components to the learning goals it sought to achieve. The tools functioned as particular instruments that aligned course outcomes with graduate attributes, which specifically addressed ethical competence.

1. The *AI Ethics Knowledge Test (AEKT)* contains twenty items that check students' knowledge about AI systems' ethical concerns in their natural environment. This measurement tool matches the technical understanding element of the framework and demonstrates high internal consistency at $\alpha = 0.87$.
2. The *Bias Identification Skills Assessment (BISA)* consists of fifteen items that evaluate student capabilities to identify and interpret bias-related risks using a performance-based evaluation. The assessment tool uses two main factors to measure student capabilities between critical evaluation and hands-on practice ($\alpha = 0.82$).
3. The *Ethical Self-Efficacy Scale (ESES)* evaluates student self-confidence in engineering ethical decision-making through a 7-point Likert scale based on Bandura's self-efficacy model. With its item set, the scale has high reliability in determining ethical decision-making with 0.91 of 0.91.
4. The *Social Impact Awareness Survey (SIAS)* is based on a 7-point scale to measure the level of understanding of the students concerning the impact of AI-powered engineering systems on the society as a whole. The assessment tool assists organizations to identify their performance with reference to their social responsibilities and sustainability objectives in terms of outcomes (0.85).

All the instruments were used at each data collection point by the research team to address the question of how the students would attain learning outcomes based on the framework as the entire study period approached.

PARTICIPANTS AND DATA COLLECTION

The team of researchers made their study in the period of 2024 and 2025 academic year in a traditional undergraduate classroom, which received students of different spheres of study. The course had 120 students who were equally enrolled in B.Tech. and MCA programs; 60 students in each. The study obtained matching longitudinal information from 106 students who finished all necessary assessments during the specified assessment dates. The assessments became part of standard coursework, which helped students stay focused while continuing their normal class activities. The research team secured confidentiality by removing identification data from all research data before beginning their analysis work, which also supported the double-blind review process.

VALIDITY CONSIDERATIONS AND METHODOLOGICAL LIMITATIONS

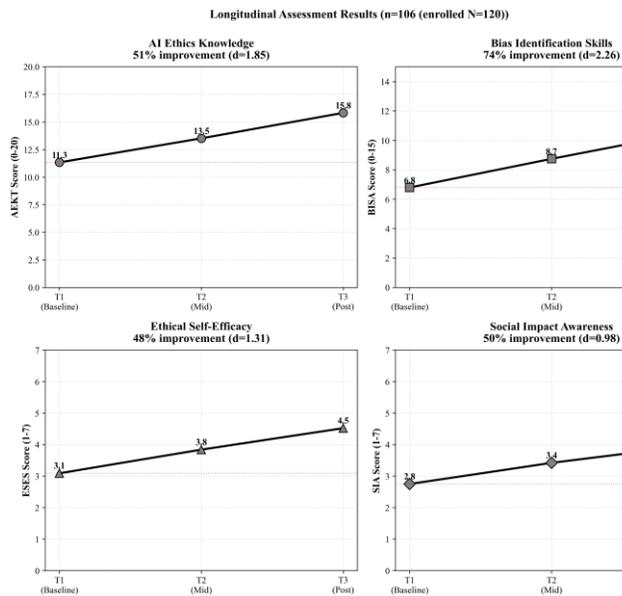
The study faces various research environment limitations which need to be identified by the educational research team. First, participant attrition across timepoints may introduce response bias, although matched longitudinal analysis was used to mitigate this effect. Second, instructor influence cannot be eliminated, as the framework was implemented within a single instructional context. People tend to answer questions about their ethical abilities and social awareness in ways that show their good side when they use self-report tools. The research team used a longitudinal design along with validated instruments which matched their defined learning outcomes to produce trustworthy results. The research method emphasises two essential elements that meet the requirements of engineering education research.

VI. RESULTS

The research findings, which support the educational goals of the proposed framework, show how students develop their knowledge of basic concepts toward making ethical choices in their practical work. The research team conducted three assessment points, which allowed them to track the learning outcome achievement for every educational element within the framework.

LONGITUDINAL OUTCOME ATTAINMENT

The assessment results show a steady pattern of major progress, which started at the baseline level in T1 and reached its highest point in T3 after the intervention. Students showed continuous improvement throughout the course, as illustrated in Fig. 4, which demonstrates their growth in conceptual understanding, analytical abilities, ethical self-assurance, and social recognition.



Source: Authors

Fig. 4. Longitudinal assessment results across four outcome measures (n = 106; enrolled N = 120; academic year 2024–25).

The patterns show that the system provides ongoing learning opportunities which match the teaching goals of outcome-based and experiential education.

ATTAINMENT OF ETHICAL KNOWLEDGE OUTCOMES (AEKT)

The AI Ethics Knowledge Test results demonstrate that students achieved strong performance on all course learning objectives, which focus on basic ethical knowledge for AI-based engineering systems. The students showed continuous improvement in their test results from their initial baseline measurements until their final assessment after the teaching intervention, which produced rising learning achievement throughout the semester. Students achieved better conceptual understanding according to Table I, which demonstrates their success in meeting all learning objectives for the

Technical Understanding dimension of the framework. The data reveals two important findings: first, the students made significant progress, and second, the effect size reached a high value, indicating that ethics-related knowledge has become an essential part of technical education rather than being taught as a separate subject.

TABLE I
AI ETHICS KNOWLEDGE TEST (AEKT) LONGITUDINAL RESULTS

| Timepoint | Mean | Range | % Correct | Improvement | Effect Size |
|---------------------|-------------|----------|---------------|-------------|-----------------------|
| t | n | e | t | t | |
| | (SD) | | | | |
| T1 (Baseline) | 11.3 (2.7) | 4.0-17.0 | 57% | — | — |
| T2 (Mid) | 13.5 (2.8) | 7.0-20.0 | 68% | +19% | d=0.78 (T1-T2) |
| T3 (Post) | 15.8 (3.4) | 8.0-20.0 | 79% | +39% | d=1.47 (T1-T3) |
| T1→T3 Change | +4.5 | — | +22 pp | +39% | d=1.47 (T1-T3) |

Source: Authors

DEVELOPMENT OF BIAS IDENTIFICATION AND ANALYTICAL SKILLS (BISA)

The Bias Identification Skills Assessment measures students' ability to identify and analyse bias-related dangers they encounter in their actual work, in relation to their achievement of analytical and evaluative learning outcomes. Table II presents the results, which show that students achieved better results as their time in the programme progressed. The observed gains demonstrate that students developed the capacity to critically examine engineering systems beyond surface-level functionality, aligning with the Critical Evaluation and Hands-on Practice dimensions of the framework. The results demonstrate that the learners were able to develop their ethical consciousness into the essential aspects of analytical skills, which is the main purpose of ethics-focused engineering education.

TABLE II
BIAS IDENTIFICATION SKILLS ASSESSMENT (BISA) LONGITUDINAL RESULTS

| Timepoint | Mean | Range | % Correct | Improvement | Effect Size |
|---------------|------|----------|-----------|-------------|----------------|
| t | n | e | t | t | |
| | (SD) | | | | |
| T1 (Baseline) | 6.8 | 4.0-10.0 | 57% | — | — |
| T2 (Mid) | 8.7 | 7.0-10.0 | 68% | +19% | d=0.78 (T1-T2) |

| | | | | | |
|-------------------------|---------------|--------------|---------------|-------------|---------------------------------|
| T1 (Baseline) | 6.8 (2.5) | 1.0- 15.0 | 45% | — | — |
| T2 (Mid) | 8.7 (2.7) | 3.0- 15.0 | 58% | +29% | d=0.7 4 (T1- T2) |
| T3 (Post) | 10.6 (2.7) | 4.0- 15.0 | 71% | +58% | d=1.4 6 (T1- T3) |
| T1→T3 Change | +3.8 | — | +26 pp | +58% | d=1.4 6 (T1- T3) |

GROWTH IN ETHICAL SELF-EFFICACY AND PROFESSIONAL JUDGEMENT (ESES)

The results of ethical self-efficacy as indicated in Table III reveal that students acquired a greater conviction towards the capacity to engage in ethical reasoning in making engineering decisions. The dimension presents high learning outcomes that cultivate the capacity of the students to make decisions and assume responsibility and uphold their standards of professionalism. The students were also able to become more self confident during the semester as they were involved in several activities on the basis of ethics and this allowed them to develop the capacity of managing ethical concerns. The findings of the study correspond to the ethical decision-making aspect of the framework, and they also correspond to the graduate attributes, which dwell upon professional responsibility and ethical leadership development.

TABLE III
ETHICAL SELF-EFFICACY SCALE (ESES) LONGITUDINAL RESULTS (7-POINT SCALE)

| Timepoint | Mean (SD) | Range | Improvement | Effect Size |
|-------------------------|--------------|----------|-------------|---------------------------|
| T1 (Baseline) | 3.1 (0.8) | 1.0-5.3 | — | — |
| T2 (Mid) | 3.8 (0.9) | 1.2-5.8 | +24% | d=0.89 (T1-T2) |
| T3 (Post) | 4.5 (1.1) | 2.3-7.0 | +46% | d=1.47 (T1-T3) |
| T1→T3 Change | +1.4 | — | +46% | d=1.47 (T1-T3) |

Source: Authors

ENHANCEMENT OF SOCIETAL IMPACT AWARENESS

The learners showed significant improvement in their cognitive and skill-based success scores as a result of learning about the role that AI engineering systems play

in the society. The baseline to post-intervention changes in the Social Impact Awareness scores were enormous, which demonstrated that the participants formed a more profound perception of both social fairness and social inclusion and the consequences of their actions in society. This was the result that achieved the learning objectives concerning the societal responsibility and sustainability. The students enhance their knowledge of engineering being a socio-technical system through their enhancement in performance that comes about when the technical courses incorporate ethical material in the curriculum.

RESULTS SUMMARY

The findings indicate that students achieved their academic goals on all 4 dimension of the model. Their performance was generally high. The acquisition of knowledge and analytical skills in a combination with the ethical confidence and social awareness demonstrates that teaching ethics in the integrated approach will allow the student to complete the engineering education without losing the necessary technical one.

VII. DISCUSSION

The empirical evidence presented in the research findings showed the support of the educational worth of AI ethics teaching methods performed in the undergraduate level engineering programs, based on curriculum learning of AI ethics. The findings indicate that the development of ethical competence in technical education and hand-on experiences teaching approaches has a more positive result but does not decrease the academic discipline standards. The research found out significant effect sizes, and they were statistically significant and demonstrated that learning styles resulted in meaningful learning effects on students.

The research results support previous studies, which show that engineering ethics education through separate courses fails to prepare students for AI system challenges that combine social and technical elements. The proposed framework solves the literature gap by including ethical assessment into standard engineering education activities which students already participate in. The students showed strong progress in their ability to identify biases, which proves they can use their ethical knowledge to develop practical analytical skills through combined ethical learning and technical practice.

The findings reveal that the students had attained the desired learning outcomes that relate to the graduate qualities of ethics, societal impact, and professional responsibility as per the principles of outcome-based

education. The findings of different tests indicate that the students reach an ethical competence level due to the constant learning process that contributes to the learning models that promote the knowledge creation by means of the hands-on experience and the student participation in their educational process.

IMPLICATIONS FOR ENGINEERING CURRICULUM DESIGN

The study offers several useful findings, which are useful in the establishment of the structure of curriculum of engineering programs in educational institutions. The research demonstrates that during their ordinary coursework, students can achieve ethical learning outcomes without having special ethics courses or significant alterations to the course of their present academic program. The main technical material remains unchanged since the programs can address the accreditation requirements by including ethics in them, which are present in their existing technical courses. The model that curriculum designers can emulate is the framework, which is based on the principles of outcome-based education, explicitly stated learning outcomes, and constructive alignment and continuous assessment. Academic institutions need to track student learning results because ABET and NBA now require them to do so for their accreditation process. The method enables educational programs to shift from teaching ethics through rule following toward building ethical abilities which produce measurable results.

IMPLICATIONS FOR FACULTY DEVELOPMENT AND PEDAGOGY

The operational framework allows faculty members to grow their professional skills through their educational practices. The feedback from faculty shows that ethics education becomes possible through teaching when students receive structured guidelines and evaluation systems. Instead of asking teachers to teach entirely different subjects, the method enables them to teach ethical thinking through their existing technical lessons. The research results show that engineering faculty members view ethics education as a subject that exists beyond their established scientific fields. The framework shows that engineers can learn ethics through their work in solving problems and making design choices, which helps teachers become more confident in their instruction. The effectiveness of these programs will probably improve when faculty members receive development

training which teaches them to present ethics correctly and to guide students through reflection and assessment work.

SCALABILITY ACROSS ENGINEERING DISCIPLINES

The framework worked at a limited operational level during its evaluation in one educational setting, but its architecture supports growth across various engineering disciplines. The four-dimensional structure functions as an independent system because users can apply its framework to academic areas which include computer science, mechanical engineering, electronics and interdisciplinary educational programs. The framework, which focuses on educational principles instead of specialised tools, enables institutions to develop ethical teaching methods that suit their academic disciplines while maintaining consistent student learning achievements. The research findings prove that ethics-based teaching methods succeed when students from various academic standings learn together, which makes them appropriate for engineering programs that combine different academic fields. Organizations need to expand their operations because students acquire ethical knowledge from graduate courses which link their academic studies with their current position requirements. Students can monitor their academic progress because the system offers a website which displays their grade information. The system enables users to create and modify data through its accessible user interface, which they can reach from anywhere.

LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

The research study offers valuable data, which contains multiple limitations that require a detailed examination. The research results stem from one educational institution with a medium number of participants, which restricts their application to other settings. The research revealed students learned new information during their semester, but it did not investigate what would happen to their ethical knowledge after the course was finished or how they would use it in their upcoming professional settings. Future researchers should build upon this study by conducting research across multiple universities that employ various teaching approaches, and they should track students after they complete their college education. The research methods, which study student ethical reasoning in engineering education through qualitative approaches, will combine with quantitative results to

achieve a deeper understanding of ethical competence development in students.

CONCLUSION AND IMPLICATIONS

The field of engineering education research continues to develop because this study shows that artificial intelligence ethical skills should exist as a permanent requirement in undergraduate engineering programs. The research team developed a new educational system which they tested to teach AI ethics alongside bias identification skills to engineering students who will require this knowledge for their future careers. The research demonstrates that students will achieve vital learning outcomes through ethics-based teaching approaches, as these approaches incorporate the existing technical course material in schools. The student group of 106 participants from 2024–25 achieved major progress in all their learning goals through the longitudinal assessment, which investigated their ethical knowledge and bias recognition abilities and their ethical self-efficacy and social consequences understanding. The research findings demonstrate that the educational method follows the framework's teaching principles while students achieve their learning goals through practical engineering education experiences. The development of ethical abilities requires students to practice their technical skills repeatedly because they need to build them through continuous educational experiences.

The framework functions according to outcome-based education principles because it establishes direct connections between educational targets and the methods used for teaching and assessment. The system enables the educational institutions to relate their ethical competencies with course outcomes and graduate attributes to facilitate manner of tracking the progress of the students through course assessment that satisfy the accreditation requirements and quality management. The research paper offers a functional system that enables engineering education to evaluate ethics as a measurable part of its academic program. The subject matter carries importance, which exceeds its present university setting. The Indian engineering education system requires accreditation bodies to evaluate professional responsibility and societal impact and sustainable development, which the proposed framework achieves through its expandable system that integrates these requirements into essential academic programs. Research evidence supports international efforts to train engineers in creating responsible innovations, as AI work environments demand competencies that engineering

education provides to address complex social problems.

Scientists discovered promising results, but they need to continue their research to further develop the foundational discoveries they have already made. The study needs to track ethical competence development through time because it needs to determine how ethical competencies impact work performances after students complete their education. Multiple institutions that cross different academic disciplines should conduct replication studies to improve the generalisability of results while showing how various teaching methods perform against each other. The research team will use qualitative methods to study student ethical decision-making because they want to understand how students develop their ethical abilities during their engineering studies.

The research discovered that engineering programs at the undergraduate level effectively teach students about AI ethics and bias detection through their standard academic curriculum. The proposed framework connects ethical education to outcome-based programs which teach students through hands-on methods to develop their technical abilities and moral values needed for AI technology work.

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