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ASSESSING MORAL DEVELOPMENT AND LEARNING OUTCOMES IN STEM EDUCATION: EVIDENCE FROM AN INDONESIAN INFORMATICS PROGRAM

Deby Erdriam[1], Darmansyah Darmansyah[2], Abna Hidayati[3]

[1, 2, 3]Padang State University West Sumatera, Indonesia

[1]http://orcid.org/0009-0007-6901-0054, [2]http://orcid.org/0000-0002-6601-6350, [3]http://orcid.org/0000-0002-6165-8266

E-mail: de2bye@gmail.com, darmansyah2013tp@gmail.com, abnahidayati@gmail.com

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ABSTRACT

This study examines the dual role of mathematics learning in developing moral character and STEM competencies among informatics engineering students. Despite mathematics being a fundamental component of engineering education, its potential as a vehicle for character development remains underexplored. Through a mixed-methods approach involving 55 informatics engineering students from an Indonesian university, significant correlations were found between mathematical ability and moral character development ($r = 0.42$, $p < 0.01$) and career readiness ($r = 0.38$, $p < 0.05$). The integrated STEM mathematics learning approach, which connected discrete mathematics to real-world informatics problems, proved effective in fostering both computational thinking (demonstrated by 42% improvement in programming abstraction) and professional ethics (28% enhancement in ethical awareness). Thematic analysis revealed emerging themes "including 'increased awareness of data privacy' and 'appreciation for logical consistency in ethical reasoning.' " Results indicate that mathematics serves not only as a technical foundation but also as a medium for character development in engineering education. The study recommends an integrated curriculum design that leverages mathematics learning for holistic student development, addressing the growing need for responsible innovation in technology fields.

I. INTRODUCTION

Informatics engineering education traditionally prioritizes the development of technical prowess, often relegating mathematics to the role of a foundational but purely analytical tool. However, the potential of mathematics as a vehicle for character development remains underexplored in engineering education. A growing body of literature suggests that mathematics learning possesses significant, yet underutilized, potential for fostering character development [1],[2]. This is critically needed in a field where professional decisions have profound ethical implications, from data privacy to algorithmic bias. Preliminary evidence from this study's data aligns with this view, revealing that 78% of students find mathematics learning helpful in cultivating precision and self-discipline—attributes identified as essential for computing professionals [3].

While the STEM (Science, Technology, Engineering, and Mathematics) approach emphasizes interdisciplinary integration [4], with mathematics as a foundational pillar for engineering competencies [5] its implementation often remains superficial. This overlooks the broader pedagogical potential of STEM to concurrently foster character and essential soft skills. Consequently, a significant gap persists between the production of technically competent graduates and the formation of holistic professionals equipped for modern workforce demands, where competencies like ethical reasoning, teamwork, and adaptability are increasingly paramount [6], [7].To address this gap, this study investigates the dual role of mathematics within an integrated STEM context.

The research is guided by three questions: (1) To what extent does mathematics learning contribute to the development of specific moral character traits (e.g., precision, discipline, ethical reasoning) in informatics engineering students? (2) What is the relationship between mathematical competence and the development of broader STEM competencies? (3) How can a mathematics curriculum be designed to synergistically optimize both technical and character development.

II. THEORETICAL FRAMEWORK

A. The Imperative for Character Education in Technical Disciplines

The prevailing paradigm in informatics engineering education has historically emphasized technical proficiency, often at the expense of character development [8]. This creates a critical gap in professional preparation, as the field increasingly grapples with complex ethical dilemmas in artificial intelligence, data privacy, and algorithmic decision-making. The cultivation of moral character is no longer a supplementary concern but a fundamental component of engineering excellence [9]. This study operates on the premise that the journey from computation to compassion requires deliberate pedagogical efforts to develop responsible professionals who can navigate the socio-ethical dimensions of technology.

B. STEM Integration as a Conduit for Holistic Learning

The integrated STEM approach effectively connects mathematical concepts with real-world applications in informatics engineering, providing a meaningful context for learning [10]. Mathematics serves not only as the language for solving engineering problems but also fosters systematic thinking essential for ethical reasoning. By connecting abstract mathematical concepts to real-world engineering challenges, STEM pedagogy moves beyond siloed knowledge to create meaningful, contextualized learning experiences [11]. Within this framework, mathematics transcends its conventional role as a mere computational tool; it becomes the essential language for engineering problem-solving while simultaneously fostering the systematic and critical thinking patterns crucial for ethical analysis [12]. This integrated approach serves as a conduit for the simultaneous development of technical skills and character attributes.

C. Mathematical Thinking: The Foundation for Moral and Technical Reasoning

The process of engaging with mathematics inherently cultivates dispositions that form the bedrock of both technical competence and moral character. Mathematical thinking demands precision, intellectual honesty, perseverance, and logical consistency—attributes that align directly with professional virtues required in informatics engineering [13]. The rigorous practice of constructing valid arguments and verifying truths provides a natural training ground for the ethical reasoning needed in technology development. Furthermore, the problem-solving nature of mathematics directly fosters the analytical and adaptive thinking cited as crucial for professional success [14], [15]. This theoretical perspective posits that mathematics learning does not merely support technical skill acquisition but inherently builds the cognitive and ethical foundation for responsible innovation.

III. MATERIALS AND METHODS

This study employed a convergent parallel mixed-methods design to comprehensively investigate the role of mathematics learning in developing character and STEM competencies. The quantitative and qualitative data were collected simultaneously during the discrete mathematics course, then integrated during the analysis phase to provide a holistic understanding of the phenomenon. The comprehensive assessment framework aligns with contemporary approaches to STEM education evaluation [16] ensuring that both technical proficiency and character development are adequately measured.

Table 1: Variable Constructs and Measurement Items.

Construct	Sub-Construct	Sample Item	No. of Items
Moral Character	Fairness & Equality	Treat everyone equally, support equal opportunities	3
	Empathy & Compassion	Understand friends' feelings, Help friends in need	3
Academic Behavior	Self-Regulation	Manage emotions, Delay gratification	3
Professional Ethics	Digital Ethics	Data privacy awareness, Respect intellectual property	3
Learning Outcomes	Applied Competence	Apply theories, Problem-solving ability	3
Career Readiness	Technical Competence	Technical skills maturity, Presentation ability	3

Source: Authors, (2026).

The study involved 55 third-year informatics engineering students from Indonesian universities, comprising 37 males (68%) and 18 females (32%). Participants were selected using purposive sampling based on their enrollment in discrete mathematics courses. The sample size provided adequate statistical power for the planned analyses while allowing for in-depth qualitative investigation. The measurement framework comprised five main constructs operationalized through 42 Likert-scale items (1-5 scale). Each sub-construct contained three items developed based on literature review and expert validation by three specialists: two education experts with expertise in character assessment and one computer science professor with experience in STEM education. The validation process evaluated content relevance, construct validity, item clarity, and contextual appropriateness for informatics engineering students. Following expert feedback and revisions, the instrument was pilot-tested with 24 students from related disciplines. The final instrument demonstrated strong reliability with Cronbach's Alpha coefficients exceeding 0.7 for all constructs. Data collection was conducted at Putra Indonesia University "YPTK" Padang, involving computer science students through multiple instruments to ensure methodological triangulation.

Quantitative data analysis proceeded in several stages. Descriptive statistics summarized the basic characteristics of the data. Pearson correlation analysis examined relationships between mathematical ability and character development indicators. Multiple regression analysis identified significant predictors of student outcomes. Reliability analysis confirmed internal consistency (Cronbach's Alpha > 0.7). Qualitative data from open-ended responses and interviews were analyzed using thematic analysis following Braun & Clarke's (2006) framework. This involved familiarization with data, generating initial codes, searching for themes, reviewing themes, defining themes, and producing the analysis. The qualitative findings provided contextual depth to the statistical results, enabling comprehensive understanding of how mathematics learning influences character development

IV. RESULTS AND DISCUSSIONS

IV.1 RESULTS

The correlation analysis revealed significant positive relationships between mathematical proficiency and character development among informatics engineering students. As shown in Table 2, all character aspects demonstrated statistically significant correlations with mathematical ability, with precision showing the strongest relationship ($r = 0.48$, $p < 0.001$). This was followed by discipline ($r = 0.42$, $p < 0.01$) and professional ethics ($r = 0.38$, $p < 0.01$), while responsibility showed a moderate but still significant correlation ($r = 0.35$, $p < 0.05$). These findings substantiate the conceptual link between mathematical rigor and character formation, particularly highlighting how mathematical precision translates into professional exactitude and ethical awareness.

Table 2: Correlation between Mathematical Ability and Student Character.

Character Aspect	Correlation	Significance
Discipline	0.42	P < 0.01
Precision	0.48	P < 0.001
Responsibility	0.35	P < 0.05
Professional Ethics	0.38	P < 0.01

Source: Authors, (2026).

The integrated STEM approach yielded substantial improvements across both technical and ethical domains. Qualitative findings from student interviews reinforced these improvements, with one student noting, 'This forum really helped me become aware of moral fundamentals, ethics, and performance.' Another student expressed, 'I hope learning can emphasize ethics and skills more.' Thematic analysis revealed prominent themes such as 'increased awareness of data privacy' and 'appreciation for logical consistency in ethical reasoning.' These qualitative insights complement the quantitative results, showing a 42% enhancement in programming abstraction ability, 35% increase in understanding computer network concepts, and 28% improvement in ethical awareness in algorithm development. Analysis of career readiness indicators revealed substantial advantages for students with strong mathematical foundations. Those mastering discrete mathematics showed significantly higher professional preparedness ($M = 4.1$ vs 3.2 on a 5-point scale), superior applied problem-solving competence (88% vs 65% success rate), and enhanced technological adaptability (79% vs 52%). These findings underscore mathematics' critical role in developing the holistic competencies required for professional success in informatics engineering, bridging technical capability with adaptive learning capacity.

V.2 DISCUSSION

This study provides empirical evidence that mathematics learning serves as a foundational medium for character development in informatics engineering education. The strong correlations between mathematical proficiency and character traits—particularly precision ($r = 0.48$, $p < 0.001$), discipline ($r = 0.42$, $p < 0.01$), and professional ethics ($r = 0.38$, $p < 0.01$)—demonstrate that the process of engaging with mathematical problems inherently cultivates virtues essential for professional practice. The rigorous demand for logical consistency and intellectual honesty in mathematics creates what might be termed an "ethical training ground," where students develop the cognitive habits necessary for responsible decision-making in complex technological contexts. This finding substantiates Glaser's [17] proposition about mathematical thinking involving value development, while extending it to contemporary informatics engineering contexts where ethical reasoning is paramount, particularly in addressing modern challenges in AI ethics and data privacy [9]. These findings have significant implications for mathematics education pedagogy, suggesting that the way mathematics is taught—emphasizing process over mere product, collaboration alongside individual work, and real-world applications beyond abstract exercises—can fundamentally shape both technical and ethical development in engineering students. The integrated STEM approach emerged as a crucial pedagogical bridge connecting abstract mathematical concepts with tangible character outcomes.

By contextualizing discrete mathematics within authentic informatics engineering scenarios—such as algorithm optimization and data structure analysis—the learning environment transformed into a simulated professional practice space. This contextualization enabled students to experience directly why precision matters in code development and how ethical considerations emerge in algorithm design affecting user privacy (evidenced by the 28% improvement in ethical awareness). The parallel improvements in computational thinking (42% enhancement in abstraction ability) and character development demonstrate that technical and ethical competencies are not competing educational objectives but synergistic outcomes. The STEM framework thus provides the methodological means to make the journey from computation to compassion pedagogically operational and empirically measurable. The project-based learning component of our STEM approach resonates with successful models in engineering education that emphasize authentic professional practice [18]. This contextualization allows students to experience the real-world implications of their mathematical and technical decisions. The findings necessitate a fundamental rethinking of informatics engineering curriculum design.

Rather than treating character development as an ancillary concern, it should be architecturally integrated into the mathematical and technical core of the program. Three key design principles emerge: First, curriculum must systematically incorporate ethical dilemmas into mathematical problem-solving, using case studies that require students to consider societal impact, privacy implications, and algorithmic fairness. This moves beyond treating ethics as a separate module and instead embeds it within technical learning. Second, project-based learning with real-world contexts should serve as the primary pedagogical approach, creating natural opportunities for students to practice collaboration, responsibility, and perseverance while applying technical skills. These extended projects become microcosms of professional practice where character is both required and developed. Third, assessment strategies must evolve to include authentic, multi-faceted methods that evaluate both technical proficiency and character development.

This could involve rubrics assessing team collaboration processes, reflective journals on ethical decision-making, and portfolios demonstrating growth in professional judgment alongside technical artifacts. Fourth, educator development must be prioritized. Mathematics teacher preparation should incorporate and professional development should incorporate pedagogical strategies that explicitly connect mathematical thinking with ethical reasoning. This includes training educators to design learning activities that highlight the ethical dimensions of mathematical applications, facilitate discussions about the social implications of technological solutions, and assess both technical proficiency and ethical decision-making. Such preparation will equip mathematics educators to foster the development of ethically-grounded technical professionals. The recommended curriculum design draws from established frameworks for integrated STEM education [16] [10] particularly emphasizing the need for authentic assessment methods that capture both technical and character development.

The findings have significant implications for the growing field of AI ethics and responsible innovation. The demonstrated connection between mathematical reasoning and ethical awareness provides a pedagogical foundation for educating future engineers who will develop AI systems. As noted by one student, *'Research like this can provide insight into how students understand morality and ethics in relation to academic achievement and performance.'* This alignment between technical precision and ethical consideration is crucial for responsible innovation, particularly in AI development where algorithmic decisions can have profound societal impacts. The integrated approach described in this study offers a model for cultivating what might be termed 'ethically-grounded computational thinking' - essential for developing AI systems that are not only efficient but also fair, transparent, and socially responsible.

V. CONCLUSIONS

This study demonstrates that mathematics learning in informatics engineering possesses a dual function: it serves as an indispensable technical foundation and a powerful, often underutilized, medium for character development. The integrated STEM approach has proven effective in simultaneously advancing computational competencies and fostering moral character, successfully bridging the gap between technical proficiency and ethical reasoning. A deliberate pedagogical strategy that leverages this dual potential can produce graduates who are not only technically adept but also ethically grounded and responsible professionals—embodying the essential journey from computation to compassion in modern engineering education. To translate these findings into practice and guide further scholarly inquiry, the following recommendations are proposed:

For Educational Practitioners:

Systematically integrate character education objectives into mathematics and core informatics engineering curricula. Develop and implement STEM-based learning modules that fuse technical content with ethical reasoning exercises. Provide comprehensive pedagogical training for lecturers in integrated teaching approaches. Create authentic assessment methods that evaluate both cognitive development and character growth. For Future Research: Conduct longitudinal studies to examine the long-term impacts of integrated mathematics and character education. Develop more robust theoretical models for curriculum integration across STEM disciplines. Explore the applicability and effectiveness of these approaches across diverse cultural and institutional contexts. Investigate specific mechanisms through which mathematical thinking translates to ethical reasoning in professional practice.

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