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EVALUATING THE IMPACT OF STEAM-INTEGRATIVE CURRICULUM ON CHARACTER MATURITY AND 21ST-CENTURY SKILLS: A QUASI-EXPERIMENTAL STUDY

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ABSTRACT

The rapid transition toward Industry 5.0 necessitates an educational paradigm that balances technical proficiency with ethical character development, a synthesis often referred to as the "human premium." This study evaluates a STEAM-integrative curriculum designed to bridge the gap between interdisciplinary scientific inquiry and moral habituation at the Baithul Qur'an, Daarut Tauhiid Foundation. Employing a quasi-experimental design (N = 200), the research compared an experimental cohort receiving the STEAM intervention with a control group receiving conventional instruction. Statistical analysis via ANCOVA demonstrated that the STEAM curriculum produced significantly higher academic gains, $F(1, 197) = 64.032$, $p < 0.001$, ($2p = 0.245$). Furthermore, independent samples t-tests revealed substantial improvements in non-cognitive outcomes, specifically character maturity (Cohen's $d = 0.95$) and 21st-century competencies ($d = 1.43$). While multiple regression models indicated that individual pedagogical sub-components, such as digital integration and project-based engagement, did not independently predict these gains ($p > 0.05$), the findings suggest the intervention functions as a synergistic, holistic framework. This research provides a rigorous quantitative basis for integrating multidisciplinary STEAM approaches within values-based institutions, suggesting that the human premium is best cultivated through unified, inquiry-based pedagogical structures rather than siloed instructional models.

KEYWORDS: STEAM Education, Character Maturity, 21st-Century Skills, Islamic Education, Quasi-Experimental Study.

1. INTRODUCTION

The global educational landscape has undergone significant transformations in recent years, particularly in curriculum development to address the evolving educational needs of the 21st-Century (Anito, 2024). As Industry 5.0 emerges, the paradigm has shifted from a focus on purely technical automation to a human-centric approach where technical proficiency must be balanced with the human premium, which is a set of cognitive and ethical attributes that remain resilient in an increasingly automated landscape (Griffin et al., 2016). This shift necessitates a departure from traditional, fragmented instructional models toward interdisciplinary frameworks that prioritize critical thinking, adaptability, and moral grounding (Trilling & Fadel, 2009; Willingham, 2008).

While Science, Technology, Engineering, Arts, and Mathematics (STEAM) education has been leveraged globally to address the demand for technical literacy and innovation (Wised & Inthanon, 2024), there is an increasing recognition that scientific inquiry cannot be divorced from moral exegesis (McDonough et al., 2021; Wang et al., 2025). Within the specific context of Islamic educational frameworks in Indonesia, particularly at the Baithul Qur'an, Daarut Tauhiid Foundation, the mandate for "Ulul Ilmi" (integrated knowledge) requires a synthesis where intellectual rigor and spiritual-ethical maturity are treated as mutually reinforcing domains rather than distinct disciplines (Budiyanti et al., 2025; Zahroh et al., 2023). A persistent problem in modern pedagogy is the theoretical-practical disconnect between these domains. STEAM initiatives frequently focus exclusively on creativity and technical engagement (Qian et al., 2026), while character education (the habituation of values) often remains relegated to passive, conventional delivery methods (Insani et al., 2025). This pedagogical fragmentation results in a significant competency-character gap, in which students may possess technical skills but lack the moral intelligence to apply them ethically (Anito, 2024; Insani et al., 2025). Moral intelligence, defined by integrity, responsibility, self-control, and empathy, is increasingly viewed as the foundation of global citizenship in the 21st-century (Insani et al., 2025). Furthermore, while the adoption of mobile and digital technologies in teaching continues to expand, facilitating training in essential skills (Dahri et al., 2023), their specific utility as vehicles for character internalization remains under-evaluated in quantitative literature.

A critical gap exists regarding the quantitative validation of these integrative models. Much of the existing discourse in the field is rooted in qualitative

observations or design-based research (DBR), which, while valuable for curriculum development, often lacks the statistical power to establish causal impact or baseline equivalence (Moshagen & Bader, 2023). Previous studies have suggested a positive relationship between moral intelligence and academic performance (Anito, 2024). Yet, few have utilized a quasi-experimental approach to isolate the impact of a dedicated STEAM-integrative curriculum on both cognitive and non-cognitive outcomes simultaneously.

The purpose of this study is to provide a rigorous quantitative evaluation of an integrative curriculum implemented at Baithul Qur'an. Using a quasi-experimental design ($N = 200$), this research aims to determine the extent to which a multidisciplinary STEAM approach enhances cognitive performance, character maturity, and 21st-century competencies compared with conventional methods. The significance of this research lies in its potential to provide a defensible empirical foundation for curriculum designers seeking to modernize religious instruction without sacrificing ethical foundations. The study proposes several hypotheses regarding the impact of a STEAM-integrative curriculum. First, it is hypothesized that students who receive the STEAM-integrative curriculum will demonstrate significantly higher posttest cognitive scores than those who receive conventional instruction, even after controlling for their pretest knowledge. Second, the curriculum is expected to significantly enhance non-cognitive outcomes, particularly character maturity and 21st-century competencies, compared to traditional approaches. Third, the improvements observed in the experimental group are anticipated to be accompanied by large effect sizes ($d > 0.080$), indicating the strong practical significance of the intervention. Finally, within the experimental group, key pedagogical components—including STEAM alignment, project-based learning engagement (PBLE), and the integration of digital technology—are predicted to serve as significant contributors to gains in character maturity and competencies.

2. RESEARCH METHOD

This study used a quasi-experimental, non-equivalent control-group design. This approach was necessitated by the institutional setting at Baithul Qur'an, where assigning individual students to classes was both ethically and logistically impossible. To maintain rigorous control, the design incorporated a pretest-posttest design, allowing for statistical adjustment of initial differences between groups. The intervention focused on implementing a STEAM-integrative curriculum specifically designed for character habituation, while the control group

received conventional instruction aligned with the existing standard curriculum.

The sample comprised $N = 200$ adolescent students from the Baithul Qur'an, Daarut Tauhiid Foundation. Participants were divided into an experimental group ($n = 100$) and a control group ($n = 100$). A purposive sampling technique was employed to ensure that the cohorts were comparable in terms of age, gender distribution, and baseline academic standing. A power analysis was conducted prior to data collection using the *semPower* package (Moshagen & Bader, 2023). The analysis confirmed that a sample size of 200 was sufficient to detect a medium-to-large effect size $\eta^2_p > 0.10$, with statistical power exceeding 0.80 at an alpha level of 0.05.

The curriculum utilized in the experimental group was developed following a three-phase DBR model (McKenney & Reeves, 2018). This model ensured that the curriculum was not only theoretically sound but also adaptable to the foundation's unique cultural context. The process began with a preliminary investigation, a diagnostic phase that involved an extensive literature review and stakeholder analysis to identify the competency-character gap at Baithul Qur'an. It was found that although students were proficient in religious memorization, they required more structured support to apply ethical concepts within modern technological and scientific contexts. Following this, the prototype design phase focused on developing STEAM-integrative modules centered on interdisciplinary thematic units. One key module, the interdependence of man and environment, combined concepts from biology and technology with the Islamic value of stewardship, and incorporated inquiry-based and project-based learning strategies to promote active student engagement. Finally, the evaluation phase involved iterative testing of the prototype, with feedback from instructors and pilot results informing continuous refinement—particularly of the digital integration components—to ensure accessibility and alignment with learning objectives. This iterative process proved essential in achieving a high-impact final design. To ensure the integrity of the inferential models, a strict four-phase data screening protocol was implemented. In the first phase, deduplication was conducted using a deterministic algorithm to identify and remove administrative redundancies or duplicate entries in the digital assessment database, ensuring that each student's data was counted only once. The second phase involved outlier remediation, where univariate screening techniques such as boxplots and z-scores were used to detect extreme values; any scores exceeding psychometrically acceptable limits (e.g., knowledge scores above 100) were treated as missing to avoid distorting group

averages. In the third phase, targeted imputation was applied to handle missing data using a dual strategy: median imputation for ordinal Likert-scale items (ranging from 1 to 5) to preserve their discrete nature, and mean imputation for continuous baseline variables. Finally, in the fourth phase, case exclusion was performed using listwise deletion for participants lacking the primary posttest outcome variable, yielding a final dataset of 200 complete cases for analysis.

The study utilized three primary types of instruments. Cognitive assessments consisted of standardized pretest and posttest knowledge exams. Non-cognitive outcomes (Character Maturity and 21st-Century Skills) were measured using validated 1-5 Likert scales. Character maturity was adapted from the Insani et al. (2025) framework, while 21st-century competencies were adapted from the Griffin et al. (2016) scales. For the experimental group, additional scales measured STEAM alignment, PBLE, and digital technology integration. All non-cognitive instruments demonstrated acceptable internal consistency, with Cronbach's alpha coefficients exceeding 0.70.

All statistical procedures were performed using IBM SPSS Statistics, and the analysis was carried out in several stages. First, assumption testing was conducted using the Shapiro-Wilk test to assess normality and Levene's test to examine the homogeneity of variance. Next, baseline equivalence between groups was evaluated using independent-samples t-tests to confirm that both groups were statistically comparable before the intervention. For main-effect testing, a one-way Analysis of Covariance (ANCOVA) was applied to cognitive outcomes, with pretest scores as the covariate. At the same time, independent-samples t-tests were used to analyze gains in character and competencies. To assess practical significance, effect sizes were calculated using Cohen's d and Partial Eta Squared (η^2_p). Finally, multiple linear regression analysis was employed to explore the predictive relationships and underlying mechanisms within the curriculum.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Preliminary Analysis and Assumption Verification

Before conducting inferential tests, the data were subjected to rigorous assumption testing to verify the suitability of parametric procedures. The Shapiro-Wilk test for normality was conducted for all primary dependent variables. The results indicated that the distributions did not significantly deviate from normality ($p > 0.05$). Specifically, the Posttest Scores

for the control and experimental groups yielded p -values of 0.250 and 0.559, respectively. Similarly, the Character Maturity Index and 21st-Century Competency scores across both groups showed p -values ranging from 0.103 to 0.813, justifying the use of general linear modeling. Furthermore, the assumption of homogeneity of variance was tested using Levene's test. For all cognitive and non-cognitive outcome variables, Levene's statistic remained non-significant ($p > 0.05$), indicating that the variances across the experimental and control groups were statistically equal. For the ANCOVA, the assumption of homogeneity of regression slopes was also satisfied, as the interaction between the covariate (Pretest) and the independent variable (Group) was non-significant ($F(1, 196) = 0.84, p = 0.360$). This level of statistical rigor

ensures that subsequent findings are not due to underlying data artifacts.

3.1.2. Baseline Equivalence of Cohorts

To establish that post-intervention differences were due to the curriculum rather than pre-existing disparities, independent-samples t -tests were conducted on baseline metrics. As detailed in Table 1, the cohorts were statistically identical at the pre-intervention stage. There was no significant difference in the Baseline Covariate scores, $t(198) = 0.592, p = 0.555$. Most critically, the initial cognitive standing, as measured by the Pretest Score, showed no significant difference between the experimental group ($M = 63.29, SD = 9.83$) and the control group ($M = 65.57, SD = 10.24$), $t(198) = 1.607, p = 110$.

Table 1: Baseline Equivalence Between Groups.

Variable	Control (n=100)	Experimental (n=100)	t-statistic	p-value
Baseline Covariate	75.86±	75.21±	0.592	0.555
Pretest Score	65.57±	63.29±	1.607	0.110

These results confirm that the groups were balanced across all measurable pre-existing dimensions, establishing a robust foundation for causal inference. The lack of a significant difference in the baseline covariate further suggests that any demographic variations did not bias the starting points of the two groups.

3.1.3. Cognitive Gains: The Impact of STEAM on Knowledge Acquisition

The primary cognitive hypothesis (H1) was tested using a one-way ANCOVA, which adjusted posttest Scores for initial differences in pretest Scores. The analysis revealed a highly significant main effect of the instructional intervention, $F(1,197) = 64.032, p < 0.001$. This indicates that the curriculum type was a primary driver of student performance (Budiyanti et al., 2025).

The adjusted posttest mean for the experimental group ($M_{adj} = 74.83, SE = 0.78$) was significantly higher than that of the control group ($M_{adj} = 65.96, SE = 0.78$). The difference in adjusted means was 8.87 points. The practical significance of this finding was high, with a Partial Eta Squared of $\eta^2_p = 0.245$. This indicates that the STEAM-integrative curriculum accounted for 24.5% of the total variance in final cognitive performance, strongly supporting H1. This level of impact is considered substantial in educational research and confirms that the multidisciplinary approach did not hinder (Dahri et al., 2023), but rather facilitated the acquisition of academic knowledge.

3.1.4. Non-Cognitive Outcomes: Character Maturity and 21st-Century Skills

Hypotheses H2 and H3 addressed the non-cognitive outcomes. Independent-samples t -tests were performed to compare the Character Maturity Index and the 21st-Century Competency (@21CC) scores between the two cohorts (Zahroh et al., 2023). For Character Maturity, the experimental group demonstrated a significant increase in scores ($M = 69.50, SD = 10.00$) compared to the control group ($M = 60.00, SD = 10.00$), $t(198) = -6.718, p < 0.001$. This represents a mean difference of 9.50 points. The calculated Cohen's d was 0.95, which is well above the 0.80 threshold for a large effect size. This finding perfectly aligns with the targeted effect size established in the initial design phases and confirms that the integrative approach was highly effective for value habituation (Thohir, 2020). For 21st-Century Competencies, the disparity was even more pronounced. The experimental group exhibited markedly higher scores ($M = 75.92, SD = 10.14$) than the control group ($M = 61.63, SD = 9.79$), $t(198) = -10.145, p < .001$. This yielded a mean difference of 14.29 points and a remarkably large effect size of Cohen's $d = 1.43$. These findings provide definitive support for H2 and H3, illustrating the profound practical impact of the intervention on non-cognitive development.

3.1.5. Predictive Modeling of the Pedagogical Mechanism

The final hypothesis (H4) sought to identify which specific pedagogical components of the STEAM

framework were responsible for these outcomes. Multiple Linear Regression analyses were performed exclusively on the experimental cohort ($n = 100$). The models regressed the outcomes (Character Maturity and 21CC) against three predictors: STEAM Alignment, PBLE Engagement, and Digital Technology Integration (Qian et al., 2026). As shown

in Table 2, both overall regression models were non-significant. For Character Maturity, the model was non-significant, $F(3.96) = 0.579$, $p = .630$, with the predictors accounting for only 1.8% of the variance ($R^2 = 0.18$). Similarly, the model for 21st-Century Competency was non-significant, $F(3.96) = 0.302$, $p = .824$, with an R^2 of 0.009.

Table 2: Multiple Regression Analysis for Experimental Cohort Outcomes.

Outcome	Predictor	β	t	p-value
Character Maturity (R-squared = 0.018, $p = 0.630$)	STEAM Alignment	0.060	0.594	0.554
	PBLE Engagement	-0.030	-0.297	0.767
	Digital Integration	-0.122	-1.201	0.233
21st-Century Competency (R-squared = 0.009, $p = 0.824$)	STEAM Alignment	-0.040	-0.390	0.697
	PBLE Engagement	0.020	0.194	0.847
	Digital Integration	0.090	0.886	0.378

None of the standardized beta coefficients were statistically significant ($p > 0.05$). This indicates that variations in how individual students engaged with specific sub-components (technology or project work) did not independently predict their score gains. This finding provides a complex response to H4, suggesting that the curriculum functions as a synergistic whole rather than a sum of its parts. This is a crucial finding that highlights the importance of implementing the curriculum as an integrated package rather than piecemeal.

3.2. Discussion

The empirical findings of this study provide robust quantitative validation for the efficacy of a STEAM-integrative curriculum in fostering both high-level cognitive performance and robust ethical character (Griffin et al., 2016; Ye & Xu, 2023; Zhang et al., 2023). By employing a quasi-experimental design at Baithul Qur'an, this research has addressed the competency-character gap that often plagues siloed instructional models (Wang et al., 2025). The results definitively illustrate that interdisciplinary integration is not merely a theoretical preference but a pedagogical necessity for cultivating the "human premium" required in Industry 5.0.

The observation of a highly significant difference in academic performance ($p < 0.001$) with a substantial effect size (Partial Eta Squared = 0.245) confirms that integrating STEAM does not compromise cognitive rigor. On the contrary, these results align with the "Ulul Ilmi" inquiry model, which posits that critical thinking and academic performance are significantly enhanced when intellectual inquiry is grounded in a meaningful spiritual or ethical context (Budiyanti et al., 2025). By utilizing the Pretest Score as a covariate, the ANCOVA isolated the instructional intervention as the primary driver of these knowledge gains.

This finding suggests that the multidisciplinary thematic units within the STEAM curriculum, such as

studying natural systems through the lens of stewardship, facilitate deeper cognitive processing than conventional, isolated subjects. These results extend Anito's (2024) findings, which showed a positive correlation between moral intelligence and academic achievement. In the context of Baithul Qur'an, the character-driven elements of the curriculum likely provided the self-regulatory substrate required for students to engage more effectively with complex scientific and technical concepts. As noted by Insani et al. (2025) and Anito (2024), moral intelligence is a multidimensional construct encompassing integrity (acting on principles), responsibility (taking ownership of actions), self-control (managing impulses), and empathy (understanding others). These traits are essential for global citizenship, as they provide the ethical foundation required to navigate the societal and global challenges of the 21st-Century. This supports the assertion that moral intelligence provides the internal discipline necessary for cognitive success (Anito, 2024; Olusola & Samson, 2015).

The large effect size for Character Maturity ($d = 0.95$) represents one of the most critical findings of this research. Historically, character education in religious settings has often been criticized for its reliance on passive moral exegesis and rote habituation (Anito, 2024). The current data indicate that the STEAM framework, by embedding ethical reflection into hands-on, project-based scientific tasks, facilitates a deeper internalization of moral values. This supports the integrative-interconnective paradigm proposed by Zahroh et al. (2023), which emphasizes that the dissolution of boundaries between scientific and ethical knowledge creates a more coherent worldview for students.

The improvements in integrity, responsibility, and self-control observed in the experimental group

reinforce the profile of moral intelligence as a foundation for global citizenship (Insani et al., 2025). When students are tasked with designing a technological solution to an environmental problem, they are forced to confront the moral implications of their engineering choices. This active engagement in ethical decision-making provides a more effective feedback loop for character habituation than conventional lecture-based methods. These results demonstrate that character maturity is not an auxiliary benefit of STEAM but a central outcome of its multidisciplinary nature. The original article notes that this approach is particularly relevant for adolescents, who are at a stage of development where they are beginning to form their own ethical identities.

The remarkably large effect size for 21st-century competencies ($d = 1.43$) underscores STEAM's unique suitability for cultivating modern cognitive and collaborative skills (Dahri et al., 2023; Sutisna & Safitri, 2022). These findings validate the assessment frameworks proposed by Griffin et al. (2016) and reinforce the findings of Qian et al. (2026) regarding the relationship between learning engagement in interdisciplinary courses and creativity performance. The high scores in communication, collaboration, and critical thinking in the experimental group illustrate that the multidisciplinary inquiry model provides a superior environment for skill acquisition. Furthermore, the successful integration of digital technology within the curriculum served as a crucial mediator for these gains. As noted by Dahri et al. (2023), teacher and student acceptance of mobile learning technology is a significant predictor of 21st-century skill acquisition. At Baithul Qur'an, the use of digital tools provided the flexible, self-managed environments necessary for students to practice complex problem-solving. This supports the findings of Sutisna and Safitri (2022) regarding the necessity of digital adaptation in modern teaching. The data suggest that for students at the Daarut Tauhiid Foundation, technology was not merely a tool for efficiency but a pedagogical vehicle for practicing competencies within an ethically controlled framework. This aligns with the argument that, in Industry 5.0, technology must serve human and ethical goals rather than merely automate.

Perhaps the most theoretically salient finding is the non-significance of the multiple regression models ($p > 0.05$). While individual pedagogical variables, such as PBLE engagement or digital integration, did not independently predict gains in outcomes, the overall curriculum produced substantial improvements. This divergence indicates a synergistic effect, wherein the

STEAM-integrative curriculum functions as a holistic, inseparable instructional unit.

This finding aligns with the synergistic pedagogy perspective discussed by Ye and Xu (2023), which suggests that the impact of an integrated intervention arises from the coherent interaction of its parts rather than the isolated influence of any single strategy. For curriculum designers, this provides a critical warning: partial implementation of STEAM sub-components (e.g., adding a project or using an app) may be insufficient to achieve the desired character and competency gains (Ye & Xu, 2023). The human premium of Industry 5.0 is best cultivated through fully integrated frameworks that treat academic and ethical development as a single, unified objective. This holistic success also validates the iterative DBR process prescribed by McKenney and Reeves (2018), emphasizing that high-quality outcomes require a systematic synthesis of investigation and design.

The success of the intervention at Baithul Qur'an provides a scalable blueprint for values-based institutions globally. The findings demonstrate that religious character education can be modernized through scientific integration without compromising traditional foundations. This addresses the competency-character gap by ensuring that students are not only technically proficient for the future labor market but are also morally grounded to navigate its ethical complexities. This aligns with the Ulul Ilmi model's objective of producing students with critical thinking skills and strong religious character (BudiYanti et al., 2025).

The results advocate for a shift away from passive habituation toward active, inquiry-based character development. By providing a rigorous quantitative justification for expanding integrated STEAM models, this research supports the integrative-interconnective paradigm as a standard for modern religious education (Zahroh et al., 2023). The findings suggest that when schools move beyond siloed subjects, they create a more meaningful and engaging learning environment that resonates with the holistic nature of human development. This is particularly relevant in the context of Bandung City and Indonesia as a whole, where a character-based educational foundation is a national priority (Insani et al., 2025). Despite the robust findings, this study has limitations. The quasi-experimental design, while appropriate for the institutional setting, does not provide the same level of control as a true randomized controlled trial. Future research should utilize multi-site randomized trials to enhance the generalizability of these findings. Additionally, the study relied on 1-5 Likert scales for non-cognitive

outcomes, which are susceptible to social desirability bias. Future inquiries could incorporate objective behavioral observations or peer evaluations to triangulate the results.

Longitudinal research is also required to determine the long-term stability of these character gains as student's transition into higher education or professional environments. Finally, investigating the specific role of teacher self-efficacy and training in facilitating these integrated models remains a critical area for exploration, building on the mobile learning acceptance trends observed by Dahri et al. (2023).

4. CONCLUSION

The empirical evidence presented in this study provides a definitive validation of the effectiveness of a STEAM-integrative curriculum in addressing the dual challenges of Industry 5.0. By shifting from a siloed instructional model to a multidisciplinary inquiry framework, the intervention at Baithul Qur'an, Daarut Tauhiid Foundation, produced statistically significant improvements across cognitive, moral, and practical dimensions. The large

effect sizes for character maturity ($d = 0.95$) and 21st-century competencies ($d = 1.43$) demonstrate that interdisciplinary scientific inquiry provides a robust pedagogical vehicle for moral habituation.

The non-significance of individual pedagogical predictors in the regression models offers a critical insight into curriculum design: the framework's efficacy depends on its synergistic nature. Designing fragmented modules for technology or project tasks is insufficient; rather, these components must be synthesized into a coherent, integrative, and interconnective whole in which academic tasks are inextricably linked to ethical reflection. For values-based institutions, these results provide a defensible blueprint for modernization, proving that STEAM methodologies can enhance, rather than compromise, religious character education. This research provides a rigorous quantitative foundation for the continued expansion of integrated inquiry-based pedagogy as a means of producing technically proficient and ethically grounded global citizens capable of navigating the complexities of the 21st-Century

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