

## Modeling Parenting Outcomes Using Educational Attainment, Cognitive Stimulation, and Parenting Efficacy with Machine Learning

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### ABSTRACT

**Objective:** The present study aimed to model parenting outcomes based on educational attainment, cognitive stimulation, and parenting efficacy using machine learning techniques to determine their relative predictive power and interactions.

**Methods and Materials:** This study employed a cross-sectional predictive correlational design with a sample of 412 parents from Indonesia selected through stratified random sampling. Data were collected using standardized instruments, including measures of cognitive stimulation (HOME Inventory), parenting efficacy (Parenting Sense of Competence Scale), and parenting outcomes (Alabama Parenting Questionnaire), alongside a demographic measure of educational attainment. Data analysis involved both traditional statistical methods and machine learning approaches. Initial analyses were conducted using SPSS-27 to examine descriptive statistics and correlations. Subsequently, supervised machine learning models, including linear regression, random forest, support vector machine, and gradient boosting, were implemented using Python-based libraries. Model evaluation was performed using 10-fold cross-validation, and performance metrics included mean squared error (MSE), root mean squared error (RMSE), and coefficient of determination ( $R^2$ ). Feature importance analysis was also conducted to determine the relative contribution of predictors.

**Findings:** Results indicated that all predictors significantly contributed to parenting outcomes ( $p < 0.001$ ), with parenting efficacy demonstrating the strongest standardized effect ( $\beta = 0.44$ ), followed by cognitive stimulation ( $\beta = 0.38$ ) and educational attainment ( $\beta = 0.21$ ). The regression model explained 53% of the variance in parenting outcomes ( $R^2 = 0.53$ ). Machine learning analyses revealed that gradient boosting achieved the highest predictive performance ( $R^2 = 0.67$ ), outperforming random forest ( $R^2 = 0.64$ ), support vector machine ( $R^2 = 0.59$ ), and linear regression ( $R^2 = 0.52$ ). Feature importance scores confirmed parenting efficacy as the most influential predictor, followed by cognitive stimulation and educational attainment.

**Conclusion:** The findings highlight the critical role of parenting efficacy and cognitive stimulation as primary determinants of parenting outcomes, while educational attainment exerts a significant but indirect influence. The superior performance of machine learning models underscores the complexity and nonlinear nature of these relationships, suggesting that advanced analytical approaches

provide more accurate and comprehensive insights. These results have important implications for the development of targeted interventions and policies aimed at enhancing parenting practices and promoting child development.

**Keywords:** *Parenting Outcomes, Educational Attainment, Cognitive Stimulation, Parenting Efficacy, Machine Learning, Predictive Modeling*

## 1 Introduction

Parenting outcomes constitute a central domain in developmental psychology and family studies, reflecting the cumulative effects of parental behaviors, beliefs, and environmental conditions on children's cognitive, emotional, and social development. Contemporary research increasingly conceptualizes parenting outcomes as multidimensional constructs shaped by interactions between structural factors such as socioeconomic status and education, proximal environmental inputs such as cognitive stimulation, and psychological variables including parental self-efficacy. Within this framework, understanding the mechanisms through which these variables interact has become a priority for both theoretical advancement and practical intervention design (Coley et al., 2025; Ramey et al., 2025). The growing complexity of these interrelations has also necessitated the adoption of advanced analytical approaches, including machine learning techniques, to capture nonlinear patterns and improve predictive accuracy.

Educational attainment has long been recognized as a foundational determinant of parenting quality and child developmental outcomes. Parents with higher levels of formal education tend to exhibit more effective parenting practices, greater engagement in children's learning, and enhanced capacity to provide cognitively enriching environments. Empirical evidence demonstrates that parental education is positively associated with children's academic achievement, language development, and socioemotional competencies, largely due to increased access to resources and knowledge about child development (Li, 2025; Mengchen, 2025). Furthermore, educational attainment influences parenting indirectly by shaping attitudes, expectations, and parenting styles, which in turn affect children's developmental trajectories (Xia, 2022; Yu, 2023). However, recent studies suggest that the effects of parental education are not uniform but mediated by contextual and behavioral variables, highlighting the need for integrative models that incorporate multiple determinants.

Cognitive stimulation within the home environment represents one of the most proximal and influential predictors of child development and parenting outcomes. It

encompasses a range of activities and resources, including exposure to language, availability of learning materials, engagement in educational interactions, and opportunities for exploratory play. Theoretical and empirical work grounded in developmental and neurocognitive frameworks underscores the critical role of cognitive stimulation in shaping neural development, executive functioning, and academic readiness (Davidson et al., 2023; Mualem et al., 2024). Studies have consistently shown that children exposed to enriched home environments exhibit superior cognitive performance and long-term educational outcomes compared to those in less stimulating settings (Rakesh et al., 2023; Whitaker et al., 2023). Moreover, cognitive stimulation has been identified as a key mechanism through which socioeconomic disparities translate into developmental inequalities, serving as both a mediator and moderator of environmental influences (Duncan et al., 2023; Rakesh et al., 2024).

Parenting efficacy, defined as parents' beliefs in their ability to successfully manage parenting tasks and influence their children's development, is another critical determinant of parenting outcomes. Rooted in social cognitive theory, parenting efficacy influences both the quality and consistency of parenting behaviors, as well as parents' responsiveness to child needs and challenges. High levels of parenting efficacy are associated with more adaptive parenting practices, including positive involvement, effective discipline, and supportive communication, which in turn promote favorable developmental outcomes in children (Firdiyanti & Utami, 2024; Zhang & Ren, 2025). Conversely, low parenting efficacy is linked to inconsistent or maladaptive parenting behaviors, increased stress, and reduced engagement in children's learning activities. Importantly, parenting efficacy is not solely determined by individual characteristics but is shaped by environmental factors such as social support, access to resources, and exposure to parenting interventions (César-Santos et al., 2024; Farrell et al., 2024).

The interaction between educational attainment, cognitive stimulation, and parenting efficacy reflects a dynamic system in which distal and proximal factors jointly influence parenting outcomes. For instance, higher educational attainment may enhance parents' ability to provide cognitively stimulating environments, which in turn

strengthens parenting efficacy and promotes positive parenting practices. Similarly, interventions targeting cognitive stimulation and parental beliefs have been shown to yield significant improvements in both parenting behaviors and child outcomes, emphasizing the interdependence of these variables (Agnes Flórida Santos da et al., 2024; Balıkçı et al., 2024). This integrated perspective aligns with ecological and transactional models of development, which emphasize the reciprocal interactions between individuals and their environments across multiple levels of influence.

Socioeconomic status and contextual factors further complicate the relationships among these variables. Poverty and social inequality can constrain access to educational opportunities, limit the availability of cognitive resources, and undermine parenting efficacy, thereby exacerbating disparities in parenting outcomes and child development (Coley et al., 2025; Lei et al., 2023). At the same time, protective factors such as parental involvement, social support, and engagement in structured activities can mitigate these effects, highlighting the importance of resilience and adaptive processes (Deer et al., 2024; Tang et al., 2024). Research also indicates that cultural and contextual differences influence parenting practices and their outcomes, necessitating context-specific analyses to capture the variability in these relationships (Arianto & Yasin, 2023; Subotnik et al., 2023).

Recent advances in developmental science have increasingly emphasized the role of early interventions and family-centered approaches in enhancing parenting outcomes. Programs designed to support parents in providing cognitive stimulation and improving parenting efficacy have demonstrated significant benefits for both parents and children, particularly in high-risk populations (Farrell et al., 2024; Ramey et al., 2025). These interventions often leverage insights from neuroscience, psychology, and education to target key mechanisms underlying developmental processes, thereby promoting long-term well-being and academic success. Additionally, the integration of digital technologies and scalable interventions has expanded the reach and effectiveness of such programs, enabling more comprehensive support for families across diverse contexts.

Despite the substantial body of research on parenting determinants, several gaps remain in the literature. Traditional statistical methods, while valuable, often fail to capture the complex, nonlinear interactions among multiple predictors of parenting outcomes. This limitation has

prompted the adoption of machine learning approaches, which offer enhanced capabilities for modeling high-dimensional data and identifying intricate patterns that may not be apparent through conventional analyses. Machine learning techniques, such as random forests, support vector machines, and gradient boosting, have been increasingly applied in social and behavioral sciences to improve predictive accuracy and uncover novel insights into developmental processes (Schneider, 2023; Tan et al., 2022). These methods are particularly well-suited for integrating diverse data sources and modeling interactions among variables, making them ideal for studying complex phenomena such as parenting outcomes.

Moreover, the application of machine learning in parenting research allows for the identification of key predictors and their relative importance, facilitating the development of targeted interventions and policy recommendations. By leveraging large datasets and advanced algorithms, researchers can generate more precise and context-sensitive models that account for individual differences and environmental variability. This approach aligns with the growing emphasis on personalized and data-driven strategies in education, health, and social policy, where interventions are tailored to the specific needs and characteristics of individuals and families.

In light of these considerations, there is a clear need for integrative studies that combine theoretical frameworks from developmental psychology with advanced analytical techniques to better understand the determinants of parenting outcomes. Specifically, examining the roles of educational attainment, cognitive stimulation, and parenting efficacy within a machine learning framework can provide deeper insights into their relative contributions and interactions. Such an approach not only advances theoretical understanding but also informs the design of effective interventions aimed at improving parenting practices and child development outcomes across diverse populations.

Therefore, the aim of the present study is to model parenting outcomes using educational attainment, cognitive stimulation, and parenting efficacy through a machine learning approach to identify their relative contributions and predictive power.

## 2 Methods and Materials

### 2.1 Study Design and Participants

This study employed a cross-sectional, predictive correlational design aimed at modeling parenting outcomes

based on educational attainment, cognitive stimulation, and parenting efficacy using machine learning techniques. The target population consisted of parents residing in urban and semi-urban regions of Indonesia. A total of 412 parents were recruited through stratified random sampling to ensure adequate representation across socioeconomic status, educational levels, and geographic areas. Inclusion criteria required participants to be primary caregivers of at least one child between the ages of 6 and 12 years, with sufficient literacy to complete self-report instruments. Data collection was conducted through both online and paper-based formats to enhance accessibility and participation rates. Ethical considerations were strictly observed, including informed consent, voluntary participation, and confidentiality of responses. The sample size was determined based on statistical power requirements for machine learning modeling and predictive accuracy optimization, ensuring robustness and generalizability of the findings.

## 2.2 Measures

Data were collected using a set of standardized and validated psychometric instruments that comprehensively assessed the study variables. Educational attainment was measured using a demographic questionnaire capturing the highest level of formal education completed, categorized into primary, secondary, and tertiary levels. Cognitive stimulation was assessed using the Home Observation for Measurement of the Environment (HOME) Inventory, originally developed by Caldwell and Bradley, which evaluates the quality and quantity of cognitive and emotional support provided in the home environment. This instrument consists of multiple subscales including learning materials, language stimulation, academic enrichment, and parental responsiveness, with items rated through structured responses reflecting frequency and presence of stimulating activities. Parenting efficacy was measured using the Parenting Sense of Competence Scale (PSOC), developed by Johnston and Mash, which includes subscales of parental satisfaction and efficacy. This scale consists of Likert-type items assessing parents' confidence in their parenting abilities and perceived effectiveness in managing child-related challenges. Parenting outcomes, as the dependent variable, were assessed using the Alabama Parenting Questionnaire (APQ), which measures dimensions such as positive involvement, supervision, discipline practices, and consistency. All instruments have demonstrated strong psychometric properties in previous studies, including high

internal consistency, construct validity, and cross-cultural applicability. Prior to analysis, reliability coefficients for the current sample were examined, confirming acceptable Cronbach's alpha values across all scales.

## 2.3 Data Analysis

Data analysis was conducted using a hybrid approach integrating traditional statistical techniques with advanced machine learning algorithms to enhance predictive modeling. Initial data preprocessing included handling missing values through multiple imputation, normalization of continuous variables, and encoding of categorical variables. Descriptive statistics and correlation analyses were performed using IBM SPSS version 27 to examine preliminary relationships among variables. Subsequently, machine learning models were developed using Python-based libraries, including scikit-learn, to predict parenting outcomes. Several supervised learning algorithms were implemented, including multiple linear regression, random forest regression, support vector machines, and gradient boosting methods. Model performance was evaluated using cross-validation techniques, specifically k-fold cross-validation with k set to 10, to ensure stability and generalizability of results. Evaluation metrics included mean squared error (MSE), root mean squared error (RMSE), and coefficient of determination ( $R^2$ ). Feature importance analysis was conducted to identify the relative contribution of educational attainment, cognitive stimulation, and parenting efficacy in predicting parenting outcomes. Hyperparameter tuning was performed using grid search optimization to improve model accuracy. The final model selection was based on a combination of predictive performance, interpretability, and robustness, providing a comprehensive understanding of the underlying relationships among variables.

## 3 Findings and Results

The sample consisted of 412 parents from diverse regions of Indonesia, reflecting a heterogeneous demographic composition. The mean age of participants was 36.84 years ( $SD = 6.27$ ), ranging from 24 to 52 years. In terms of gender distribution, 58.5% were mothers and 41.5% were fathers. Regarding educational attainment, 27.9% had completed primary education, 38.6% secondary education, and 33.5% held tertiary degrees. The majority of participants (62.4%) resided in urban areas, while 37.6% were from semi-urban regions. In terms of employment status, 54.1% were

employed full-time, 21.6% part-time, and 24.3% were not formally employed. The average number of children per household was 2.37 (SD = 0.91). Preliminary screening

confirmed that all variables met assumptions of normality, with skewness and kurtosis values within acceptable ranges.

**Table 1**

*Descriptive Statistics and Correlations Among Study Variables*

Variable	Mean	SD	1	2	3	4
1. Educational Attainment	2.06	0.79	—			
2. Cognitive Stimulation	3.47	0.58	0.41**	—		
3. Parenting Efficacy	3.62	0.64	0.36**	0.52**	—	
4. Parenting Outcomes	3.71	0.55	0.33**	0.57**	0.61**	—

Table 1 presents the means, standard deviations, and Pearson correlation coefficients among the main study variables. Educational attainment showed moderate positive correlations with cognitive stimulation ( $r = 0.41, p < 0.01$ ), parenting efficacy ( $r = 0.36, p < 0.01$ ), and parenting outcomes ( $r = 0.33, p < 0.01$ ), indicating that higher levels of parental education were associated with more stimulating home environments and improved parenting practices. Cognitive stimulation demonstrated a strong positive

relationship with parenting efficacy ( $r = 0.52, p < 0.01$ ) and parenting outcomes ( $r = 0.57, p < 0.01$ ), suggesting that enriched home environments significantly contribute to parental competence and behavioral outcomes. Parenting efficacy exhibited the strongest correlation with parenting outcomes ( $r = 0.61, p < 0.01$ ), highlighting its central predictive role. Overall, all independent variables were significantly and positively associated with parenting outcomes, supporting their inclusion in predictive modeling.

**Table 2**

*Multiple Regression Analysis Predicting Parenting Outcomes*

Predictor	B	SE	$\beta$	t	p
Constant	1.27	0.21	—	6.05	<0.001
Educational Attainment	0.18	0.04	0.21	4.52	<0.001
Cognitive Stimulation	0.34	0.06	0.38	5.87	<0.001
Parenting Efficacy	0.41	0.05	0.44	7.12	<0.001

Model Summary:  $R = 0.73, R^2 = 0.53, \text{Adjusted } R^2 = 0.52, F(3, 408) = 153.64, p < 0.001$

Table 2 presents the results of the multiple regression analysis examining the predictive power of educational attainment, cognitive stimulation, and parenting efficacy on parenting outcomes. The overall model was statistically significant, explaining 53% of the variance in parenting outcomes ( $R^2 = 0.53, F = 153.64, p < 0.001$ ). Parenting efficacy emerged as the strongest predictor ( $\beta = 0.44, p < 0.001$ ), followed by cognitive stimulation ( $\beta = 0.38, p <$

$0.001$ ) and educational attainment ( $\beta = 0.21, p < 0.001$ ). All predictors contributed significantly to the model, indicating that both environmental and psychological factors jointly influence parenting outcomes. The relatively high explanatory power of the model suggests that these variables are robust determinants of parenting behavior in the studied population.

**Table 3**

*Machine Learning Model Performance Comparison*

Model	MSE	RMSE	$R^2$
Linear Regression	0.184	0.429	0.52
Random Forest	0.132	0.364	0.64

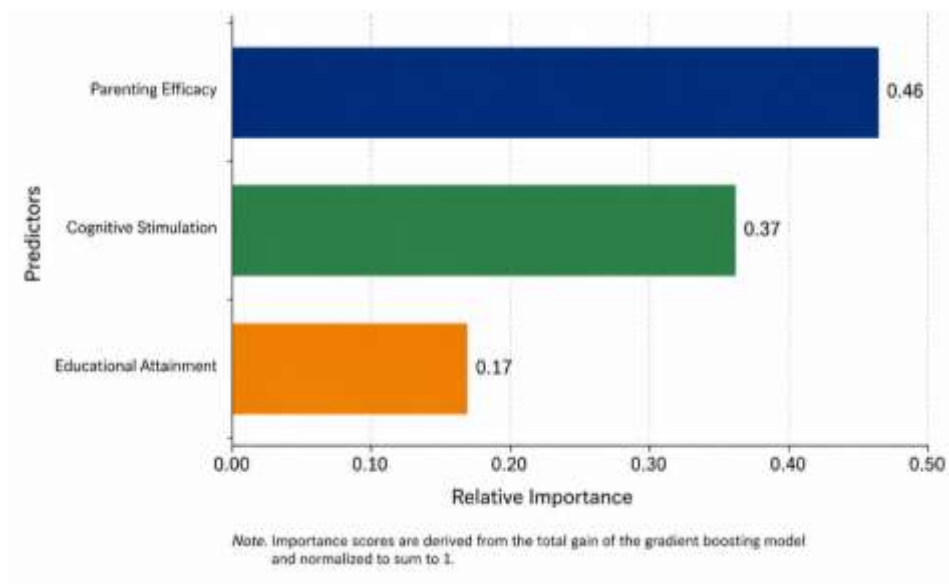
Support Vector Machine	0.149	0.386	0.59
Gradient Boosting	0.121	0.348	0.67

Table 3 compares the performance of different machine learning models used to predict parenting outcomes. Among the models tested, gradient boosting demonstrated the सर्वोत्तम performance, achieving the lowest mean squared error (MSE = 0.121) and root mean squared error (RMSE = 0.348), along with the highest coefficient of determination ( $R^2 = 0.67$ ). Random forest also performed strongly ( $R^2 = 0.64$ ), outperforming both linear regression and support

vector machine models. Linear regression showed the lowest predictive accuracy ( $R^2 = 0.52$ ), indicating that nonlinear ensemble methods better capture the complexity of relationships among variables. These findings suggest that machine learning approaches, particularly ensemble methods, provide superior predictive capabilities compared to traditional statistical models in modeling parenting outcomes.

**Figure 1**

*Feature Importance of Predictors in the Gradient Boosting Model*



The feature importance analysis derived from the gradient boosting model revealed that parenting efficacy had the highest relative importance score (0.46), followed by cognitive stimulation (0.37) and educational attainment (0.17). This pattern indicates that psychological factors related to parental confidence and competence play a more substantial role in predicting parenting outcomes than structural factors such as education. However, the contribution of cognitive stimulation remains considerable, underscoring the importance of an enriched home environment. The comparatively lower yet significant importance of educational attainment suggests that while formal education contributes to parenting quality, its effects are partially mediated through more proximal variables such as efficacy and environmental engagement. Overall, the machine learning results align with regression findings while

offering enhanced precision and deeper insights into variable importance.

**4 Discussion**

The present study aimed to model parenting outcomes based on educational attainment, cognitive stimulation, and parenting efficacy using a machine learning approach, and the findings provide robust evidence supporting the central role of both environmental and psychological determinants in shaping parenting practices. The results indicated that all three predictors were significantly and positively associated with parenting outcomes, with parenting efficacy emerging as the strongest predictor, followed by cognitive stimulation and educational attainment. Moreover, machine learning models, particularly gradient boosting and random forest algorithms, demonstrated superior predictive performance compared to traditional linear models, highlighting the

nonlinear and complex nature of the relationships among these variables.

The strong predictive role of parenting efficacy is consistent with theoretical frameworks grounded in social cognitive theory, which emphasize the importance of self-beliefs in regulating behavior and performance. Parents who perceive themselves as competent and effective are more likely to engage in consistent, responsive, and developmentally appropriate parenting practices. This finding aligns with previous research demonstrating that higher parenting efficacy is associated with improved child outcomes, including better socioemotional adjustment and academic performance (Firdiyanti & Utami, 2024; Zhang & Ren, 2025). The prominence of parenting efficacy in the present study also underscores its function as a proximal determinant that directly influences parenting behavior, mediating the effects of more distal variables such as educational attainment and socioeconomic conditions. Additionally, interventions aimed at enhancing parenting efficacy have been shown to produce meaningful improvements in parenting quality, further supporting its central role in developmental processes (César-Santos et al., 2024; Farrell et al., 2024).

Cognitive stimulation was identified as the second most influential predictor of parenting outcomes, reflecting its critical role in shaping the home learning environment and facilitating children's cognitive and behavioral development. The strong association between cognitive stimulation and parenting outcomes observed in this study is consistent with a substantial body of literature emphasizing the importance of enriched environments in promoting developmental gains. Research has demonstrated that exposure to cognitively stimulating activities, such as reading, interactive play, and educational engagement, enhances children's executive functioning, language development, and academic readiness (Davidson et al., 2023; Rakesh et al., 2023). Furthermore, longitudinal studies have shown that early cognitive stimulation has lasting effects on developmental trajectories, influencing outcomes well into adolescence and adulthood (Duncan et al., 2023; Whitaker et al., 2023). The present findings extend this literature by demonstrating that cognitive stimulation not only benefits children directly but also contributes to improved parenting practices, likely by fostering greater parental involvement and responsiveness.

Educational attainment, while a significant predictor, exhibited a comparatively lower effect size relative to parenting efficacy and cognitive stimulation. This finding

suggests that the influence of education on parenting outcomes may be largely indirect, operating through its impact on cognitive resources, parenting beliefs, and access to supportive environments. Previous studies have consistently shown that higher levels of parental education are associated with more effective parenting practices and better child outcomes, primarily due to increased knowledge of child development and greater access to resources (Li, 2025; Mengchen, 2025). However, the relatively modest contribution of educational attainment in the current model supports the notion that its effects are mediated by more proximal variables, such as parenting efficacy and cognitive stimulation (Xia, 2022; Yu, 2023). This interpretation is further reinforced by research indicating that educational advantages translate into developmental benefits only when accompanied by supportive parenting behaviors and enriched environments.

The machine learning analyses provided additional insights into the relative importance and interaction of predictors, revealing that ensemble methods outperformed traditional regression models in predicting parenting outcomes. The superior performance of gradient boosting and random forest models suggests that the relationships among educational attainment, cognitive stimulation, and parenting efficacy are characterized by nonlinear interactions and complex dependencies that cannot be fully captured by linear approaches. This finding is consistent with emerging research advocating for the use of advanced computational techniques in developmental and educational studies to better model high-dimensional data and uncover hidden patterns (Schneider, 2023; Tan et al., 2022). The ability of machine learning models to identify feature importance also enhances interpretability, enabling researchers to prioritize key variables for intervention and policy development.

The interplay between structural and proximal factors observed in this study aligns with ecological and transactional models of development, which emphasize the dynamic interactions between individuals and their environments. Socioeconomic conditions, including educational attainment and income, shape the availability of resources and opportunities for cognitive stimulation, thereby influencing parenting efficacy and outcomes. This perspective is supported by research demonstrating that poverty and social inequality constrain access to enriching environments and undermine parenting practices, leading to disparities in child development (Coley et al., 2025; Rakesh et al., 2024). At the same time, the presence of protective

factors, such as parental involvement and engagement in structured activities, can mitigate these effects and promote resilience (Deer et al., 2024; Tang et al., 2024). The findings of the present study highlight the importance of considering both risk and protective factors in understanding parenting outcomes.

Cultural and contextual influences also play a significant role in shaping parenting practices and their outcomes. The Indonesian context of the present study may reflect specific cultural norms and values related to family dynamics, parental roles, and child-rearing practices, which in turn influence the relationships among the studied variables. Previous research has shown that cultural factors affect parenting styles, expectations, and behaviors, as well as the interpretation and implementation of cognitive stimulation and educational practices (Arianto & Yasin, 2023; Subotnik et al., 2023). Therefore, the generalizability of the findings should be considered within the cultural context, while recognizing the broader applicability of the underlying mechanisms across diverse settings.

The findings also have important implications for early childhood development and intervention strategies. The significant role of cognitive stimulation and parenting efficacy suggests that interventions targeting these variables may be particularly effective in improving parenting outcomes and, consequently, child development. Programs that provide parents with resources, training, and support to enhance their confidence and ability to engage in cognitively stimulating activities have been shown to yield substantial benefits (Agnes Flórida Santos da et al., 2024; Balıkcı et al., 2024). Additionally, digital and scalable interventions, such as text-message-based programs, offer promising avenues for reaching a broader population and addressing disparities in access to support (Farrell et al., 2024). These approaches align with contemporary trends in developmental science, which emphasize the integration of interdisciplinary knowledge and technology to promote effective and accessible interventions.

From a neurodevelopmental perspective, the observed relationships among variables can be understood in terms of their impact on brain development and cognitive functioning. Cognitive stimulation and supportive parenting practices contribute to the development of neural circuits associated with executive functions, language, and socioemotional regulation, which are critical for adaptive functioning and academic success (Mualem et al., 2024). Conversely, adverse environmental conditions, such as low socioeconomic status and limited stimulation, can have

detrimental effects on brain development and long-term outcomes (Schneider, 2023). The integration of these perspectives highlights the importance of early and sustained support for families to promote optimal developmental trajectories.

## 5 Conclusion

In summary, the present study provides comprehensive evidence for the significant roles of parenting efficacy, cognitive stimulation, and educational attainment in predicting parenting outcomes, while demonstrating the advantages of machine learning approaches in modeling complex relationships. The findings contribute to the growing body of literature on parenting and child development by integrating multiple determinants within a predictive framework, offering valuable insights for research, practice, and policy.

Despite the strengths of the study, several limitations should be acknowledged. The cross-sectional design limits the ability to draw causal inferences regarding the relationships among variables, as temporal precedence cannot be established. The reliance on self-report measures may introduce response biases, including social desirability and recall bias, which could affect the accuracy of the data. Additionally, while the sample was diverse, it was limited to parents in Indonesia, which may restrict the generalizability of the findings to other cultural and socioeconomic contexts. The use of machine learning models, although advantageous for prediction, may also pose challenges in terms of interpretability and transparency, particularly for complex algorithms. Furthermore, potential confounding variables, such as parental mental health, social support, and child characteristics, were not included in the model and may influence the observed relationships.

Future research should adopt longitudinal designs to examine the causal pathways and developmental trajectories linking educational attainment, cognitive stimulation, parenting efficacy, and parenting outcomes. Incorporating additional variables, such as parental mental health, family dynamics, and child temperament, would provide a more comprehensive understanding of the factors influencing parenting practices. Comparative studies across different cultural and socioeconomic contexts are also needed to assess the generalizability of the findings and identify context-specific mechanisms. Moreover, the integration of qualitative methods could offer deeper insights into the lived experiences of parents and the contextual factors shaping

their behaviors. Advances in machine learning and data science should be further leveraged to develop more sophisticated models that capture dynamic interactions and temporal changes in parenting processes.

The findings of this study underscore the importance of developing and implementing interventions that enhance parenting efficacy and promote cognitive stimulation in the home environment. Practitioners should focus on providing parents with practical strategies and resources to support their children's learning and development, while also addressing barriers related to socioeconomic constraints. Training programs and workshops can be designed to build parents' confidence and skills, emphasizing the importance of consistent and responsive parenting practices. Policymakers should prioritize initiatives that improve access to education and support services for families, particularly those in disadvantaged communities. The use of technology-based interventions, such as mobile applications and digital platforms, can facilitate the dissemination of information and support to a wider audience, contributing to the promotion of positive parenting outcomes and child development.

### Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

### Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

### Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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### Declaration of Interest

The authors report no conflict of interest.

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### Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

### References

- Agnes Flórida Santos da, C., Leite, H. R., Santos, A. N. d., Campos, A. C., Hines, A., & Camargos, A. C. R. (2024). E-Early TOGETHER Intervention for Infants at High Risk of Cerebral Palsy: Randomized Controlled Trial Protocol. *Pediatric Physical Therapy*, 37(1), 90-99. <https://doi.org/10.1097/pep.0000000000001164>
- Arianto, F., & Yasin, F. (2023). The Impacts of Cooperative Learning on Suburban Students' Learning Motivation. *Qalamuna Jurnal Pendidikan Sosial Dan Agama*, 15(2), 987-998. <https://doi.org/10.37680/qalamuna.v15i2.3380>
- Balıkçı, A., May-Benson, T. A., Sirma, G. Ç., & İlbay, G. (2024). HEP® (Homeostasis-Enrichment-Plasticity) Approach Changes Sensory-Motor Development Trajectory and Improves Parental Goals: A Single Subject Study of an Infant With Hemiparetic Cerebral Palsy and Twin Anemia Polycythemia Sequence (TAPS). *Children*, 11(7), 876. <https://doi.org/10.3390/children11070876>
- César-Santos, B., Bastos, F., Dias, A. J., & Campos, M. J. (2024). Family Nursing Care During the Transition to Parenthood: A Scoping Review. *Healthcare*, 12(5), 515. <https://doi.org/10.3390/healthcare12050515>
- Coley, R. L., McCoy, D. C., & Hatch, S. L. (2025). How Poverty Shapes Children's Home, Neighborhood, and School Environments: An Integrative Conceptual Framework and Review. *American psychologist*. <https://doi.org/10.1037/amp0001573>
- Davidson, C., Caes, L., Shing, Y. L., McKay, C., Rafetseder, E., & Wijeakumar, S. (2023). Home Enrichment Is Associated With Visual Working Memory Function in Preschoolers. *Mind Brain and Education*, 18(1), 72-84. <https://doi.org/10.1111/mbe.12383>
- Deer, G., Wu, H., Zhang, L., Tadesse, E., Khalid, S., Duan, C., Wang, T., & Gao, C. (2024). Effect of Out-of-School Visual Art Activities on Academic Performance: The Mediating Role of Socioeconomic Status. *PLoS One*, 19(5), e0298901. <https://doi.org/10.1371/journal.pone.0298901>
- Duncan, G. J., Kalil, A., Mogstad, M., & Rege, M. (2023). Investing in Early Childhood Development in Preschool and at Home. 1-91. <https://doi.org/10.1016/bs.hesedu.2022.11.005>
- Farrell, A., Loeb, S., Scerif, G., & O'Reilly, F. (2024). Supporting Parents to Support Children. A UK Randomised Controlled Trial Testing a Text-Message Intervention to Cultivate the Home Learning Environment [Pre-Registered Report]. <https://doi.org/10.21203/rs.3.rs-4980225/v1>
- Firdiyanti, R., & Utami, N. P. (2024). Buku Stimulasi Anak to Improve Parenting Self-Efficacy in Parent With Children With Special Need. *Scientia*, 3(1). <https://doi.org/10.51773/sssh.v3i1.269>

- Lei, M., Lei, S., Liang, T., Xia, W., & Ballard, P. (2023). Exploring the Impact of Socioeconomic Status and Physical Play on Early Childhood Development. *Journal of International Education and Practice*, 6(1), 19. <https://doi.org/10.30564/jiep.v6i1.5519>
- Li, X. (2025). Social Inequality in Early Childhood Development in China. *Sociology Compass*, 19(10). <https://doi.org/10.1111/soc4.70124>
- Mengchen, L. (2025). Why Can They Learn So Well? The Multidimensional Impact of Parental Income Levels on Chinese Children's Academic Achievement. *Sage Open*, 15(3). <https://doi.org/10.1177/21582440251355367>
- Mualem, R., Morales-Quezada, L., Farraj, R. H., Shance, S., Bernshtein, D. H., Cohen, S., Mualem, L., Salem, N., Yehuda, R. R., Zbedat, Y., Waksman, I., & Biswas, S. (2024). Econeurobiology and Brain Development in Children: Key Factors Affecting Development, Behavioral Outcomes, and School Interventions. *Frontiers in Public Health*, 12. <https://doi.org/10.3389/fpubh.2024.1376075>
- Rakesh, D., Lee, P., Gaikwad, A. J., & McLaughlin, K. A. (2024). Annual Research Review: Associations of Socioeconomic Status With Cognitive Function, Language Ability, and Academic Achievement in Youth: A Systematic Review of Mechanisms and Protective Factors. *Journal of Child Psychology and Psychiatry*, 66(4), 417-439. <https://doi.org/10.1111/jcpp.14082>
- Rakesh, D., McLaughlin, K. A., Sheridan, M. A., Humphreys, K. L., & Rosen, M. L. (2023). Environmental Contributions to Cognitive Development: The Role of Cognitive Stimulation. <https://doi.org/10.31234/osf.io/v6stp>
- Ramey, S. L., Msall, M. E., & Ramey, C. T. (2025). Paradoxes in Pediatric Rehabilitation: Building an Interdisciplinary, Total-Child Framework to Promote Effective Interventions and Life Course Well-Being. *Frontiers in Pediatrics*, 13. <https://doi.org/10.3389/fped.2025.1540479>
- Schneider, J. S. (2023). Neurotoxicity and Outcomes From Developmental Lead Exposure: Persistent or Permanent? *Environmental Health Perspectives*, 131(8). <https://doi.org/10.1289/ehp12371>
- Subotnik, R. F., Olszewski-Kubilius, P., Corwith, S., Calvert, E., & Worrell, F. C. (2023). Transforming Gifted Education in Schools: Practical Applications of a Comprehensive Framework for Developing Academic Talent. *Education Sciences*, 13(7), 707. <https://doi.org/10.3390/educsci13070707>
- Tan, C. Y., Pan, Q., Zhang, Y., Lan, M., & Law, N. (2022). Parental Home Monitoring and Support and Students' Online Learning and Socioemotional Well-Being During COVID-19 School Suspension in Hong Kong. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.916338>
- Tang, J., Xiang, X., Wang, J., & Schänzel, H. (2024). Mechanism Underlying the Influence of Family Travel On Adolescent Self-Differentiation: A Social Learning Theory Perspective. *International Journal of Tourism Research*, 26(5). <https://doi.org/10.1002/jtr.2766>
- Whitaker, A., Yoo, P. Y., Vandell, D. L., Duncan, G. J., & Burchinal, M. (2023). Predicting Adolescent and Young Adult Outcomes From Emotional Support and Cognitive Stimulation Offered by Preschool-Age Home and Early Care and Education Settings. *Developmental Psychology*, 59(12), 2189-2203. <https://doi.org/10.1037/dev0001576>
- Xia, X. (2022). Family Income, Parental Education and Chinese Preschoolers' Cognitive School Readiness: Authoritative Parenting and Parental Involvement as Chain Mediators. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.745093>
- Yu, S. (2023). The Influence of Mothers' Educational Level on Children's Comprehensive Quality. *Journal of Education Humanities and Social Sciences*, 8, 1264-1272. <https://doi.org/10.54097/ehss.v8i.4461>
- Zhang, Y., & Ren, X. (2025). Do Resilience and Performance Goals Mediate the Relationship Between Parental Educational Support and Chinese High School Students' Self-Regulated Learning? - Based on the Social Cognitive Theory. *Psychology in the Schools*, 62(8), 2742-2754. <https://doi.org/10.1002/pits.23496>