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Using Support Vector Machines for Predicting and Mitigating Stunting in Early Childhood Education in Rural Semarang

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Abstract
In 2030, 70% of Indonesia's population will be of productive age (15-64 years), which is a demographic bonus. However, this potential is threatened by the high rate of stunting in children, which threatens future workforce productivity. Early identification of stunting risk is essential for timely intervention. This study develops a stunting prediction model using machine learning with data from early childhood education institutions in rural Semarang. The model used is a Support Vector Machine (SVM) implemented through the RapidMiner framework. The SVM model achieved an accuracy of 97.56%, a precision of 98.97%, a recall of 97.37%, and an AUC of 0.997. The results of the SVM model highlight the importance of physical motor skills and artistic development.

Keywords: *stunting; PAUD; machine learning; SVM.*

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Introduction
Indonesia is poised to become a global economic powerhouse in the coming decades, owing to its stable economic growth and large population. By 2030, 70% of the population is expected to be in the productive age group (15-64 years), which would include 180 million individuals contributing to national economic development (Kementerian Kesehatan, 2018). However, this demographic bonus faces the threat of being undermined by the high prevalence of child stunting. The youth of today, who are key to driving future economic growth, are at risk due to stunting, which has long-term effects on health and productivity (Kementerian Kesehatan, 2023). A decrease in stunting prevalence from 24.4% in 2021 to 21.6% in 2022, as reported by the Indonesian Nutrition Status Survey (SSGI), is a positive development (Kementerian Kesehatan, 2023). Stunting results from chronic malnutrition and infections during critical growth periods, leading to cognitive impairments and reduced productivity later in life (Rambe et al., 2023). Early detection of stunting risks is crucial for timely and effective interventions. Thus, research into developing machine learning models for stunting prediction is necessary.

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Machine learning is a powerful tool for extracting complex patterns from large, diverse datasets (Bitew et al., 2022)(Rozaq & Purnomo, 2022)(Ndagijimana et al., 2023). By utilizing child health, growth, and development data, machine learning models can generate accurate predictions regarding the risk of stunting (Khan et al., 2021). Data from early childhood education institutions shows significant developmental differences between stunted and non-stunted children. The research problem this study aims to address is how to mitigate the effects of stunting on the educational development of early childhood children. The study's objective is to develop a predictive model for early childhood education outcomes among stunted children using machine learning methods. The findings are expected to serve as a basis for recommendations to reduce the educational impact of stunting in early childhood education settings.

The recommendations provided to early childhood education institutions for mitigating the impact of stunting are derived from analyzing the relationship between stunting occurrences and child development data collected from these institutions. This study focuses on predicting stunting in toddlers using a machine learning approach, specifically Support Vector Machine (SVM). Data used for this prediction come from early childhood education institutions in rural areas of Semarang Regency.

Among the machine learning models often used for stunting prediction, Support Vector Machine (SVM) has been identified as a particularly effective tool for classification tasks (Kawo et al., 2024). SVM works by finding the optimal hyperplane that separates different classes—in this case, distinguishing between stunted and non-stunted children—by maximizing the margin between the classes (Ananta et al., 2023).

In this research, the primary goal is to develop a recommendation system for early childhood education institutions. This system is tailored to children identified as being at risk of stunting based on SVM predictions. By identifying these children early, the system aims to prevent developmental delays through targeted interventions. The study integrates both stunting and developmental data to provide insights into how stunting affects educational outcomes and cognitive development in children aged 5-6 years.

Stunting has a significant impact on both the cognitive and non-cognitive development of children. Research indicates that stunted children exhibit lower cognitive abilities, such as deficits in memory, attention, and executive function, which hinder their academic performance, particularly in subjects requiring complex problem-solving skills like mathematics and reading (Beckmann et al., 2021). In addition, stunting is linked to delayed language and motor skill development, which are critical for success during early childhood (Rao et al., 2020). These cognitive impairments are largely driven by malnutrition during the critical early stages of brain development.

Beyond cognitive impacts, stunting also affects non-cognitive development, including social-emotional skills and self-regulation. Stunted children often face difficulties in forming relationships, managing emotions, and adapting to new environments, which may negatively influence classroom behavior and social interactions (Beckmann et al., 2021). Furthermore, reduced social skills and confidence have been noted as key challenges for stunted children, suggesting that the effects of stunting extend beyond academic performance, affecting their overall psychosocial well-being (Rao et al., 2020). These findings underscore the need for early interventions to mitigate the long-term developmental challenges associated with stunting.

Children who experience stunting often struggle to reach their cognitive and academic potential, which may have long-term consequences into adulthood (Duana et al., 2022). Existing research on stunting has increasingly adopted machine learning methods to improve prediction accuracy (Syahrial et al., 2022). Supervised learning models like SVM are particularly suited for this task due to their effectiveness in classification (Darnila et al., 2022).

However, while numerous studies have focused on stunting classification, few have delved into analyzing how stunting affects child development in early education settings. This study addresses this gap by using SVM to analyze both stunting and developmental data,

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offering a more holistic understanding of the challenges stunted children face. The ultimate aim is to use these findings to inform early childhood educators and policymakers, allowing for the design of interventions that better support stunted children in achieving their educational potential.

Methodology

This study aims to develop a stunting prediction model and analyze its impact on the educational development of children aged 5-6 years in early childhood education institutions (PAUD) in rural areas of Semarang Regency. The methodology used in this study includes several main stages as described below:

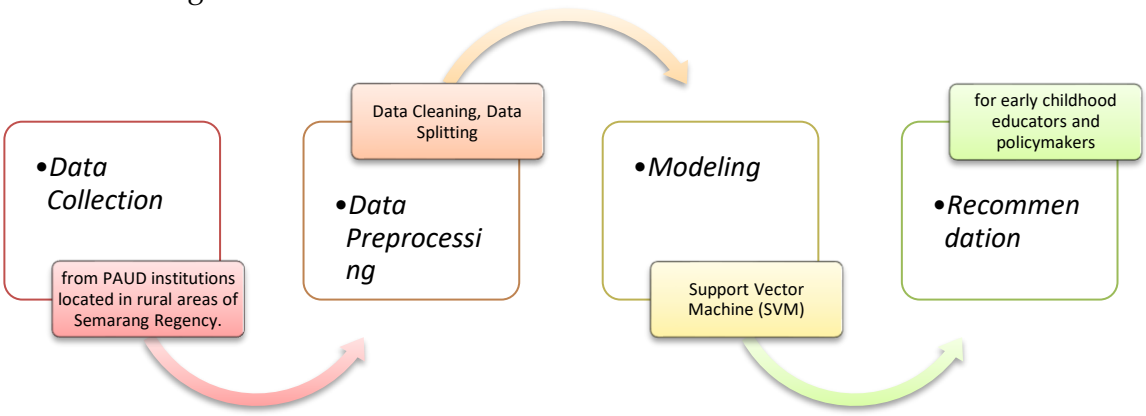

Figure 1. Research Main Stages

Data for this study were collected from PAUD institutions located in rural areas of Semarang Regency. A total of 359 data were collected, consisting of 16 independent variables and 1 dependent variable. Data collection involved anthropometric measurements, such as height and weight, as well as developmental data covering various domains of early childhood growth. These domains include cognitive, motor, language, social emotional, religious, and artistic development, which were assessed over two academic semesters.

The data collection process was comprehensive, ensuring a balanced representation of children with and without stunting. Stunting status was determined based on height-for-age criteria following World Health Organization (WHO) guidelines. Data were collected in coordination with local health and education institutions to ensure accuracy and relevance.

Data preprocessing involved several steps to prepare the data set for analysis. Of the 359 data sets collected, this process yielded 289 data sets that were ready to be modeled in the next stage. The data preprocessing procedures applied were as follows: 1). Data Cleaning: Missing or incomplete data entries were identified and removed to maintain the integrity of the dataset. Inconsistent or erroneous records, particularly in anthropometric measurements, were reviewed and corrected or excluded from further analysis (Palanivinayagam & Damaševičius, 2023). 2). Data Splitting: The cleaned dataset was split into two subsets for model training and testing. For the stunting classification task, 80% of the data was allocated for training and 20% for testing (T R et al., 2023). This approach ensured that model performance could be robustly evaluated using unseen data.

The Support Vector Machine (SVM) algorithm was applied to predict the educational development of children affected by stunting (Ananta et al., 2023). SVM is a supervised learning algorithm that identifies the optimal hyperplane to separate different classes in a feature space by maximizing the margin between them, thus ensuring robust classification performance (Mustafa Abdullah & Mohsin Abdulazeez, 2021). For this study, SVM was implemented using the RapidMiner framework, a widely used tool for machine learning and data analysis. The performance of the SVM model was evaluated based on key metrics such as accuracy, precision, recall, and the AUC (Area Under the Curve) (Valero-Carreras et al.,

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2023). By examining these performance indicators, the study sought to ensure that the SVM model could accurately predict the educational development of children experiencing stunting. Based on the evaluation, the SVM model was selected for further analysis and for generating recommendations aimed at addressing developmental challenges in stunted children.

In addition to predictive modeling, correlation analysis was conducted to explore the relationship between stunting and developmental outcomes in children aged 5-6 years. This analysis aimed to assess the extent to which stunting affects various dimensions of child development, including cognitive, motor, language, social-emotional, religious, and artistic abilities. By identifying these correlations, this study seeks to highlight specific areas of child development that are most impacted by stunting. This information is important for designing targeted interventions and providing recommendations for early childhood educators and policymakers to reduce educational and developmental setbacks associated with stunting.

Results and Discussion

This research examines the relationship between stunting and early childhood education development using the Support Vector Machine (SVM) model with data from 289 children in early childhood education (PAUD) institutions in rural areas of Semarang district. The independent variables include age, height, weight, stunting status, and various child development attributes such as scores in religious and moral education, physical motor skills, cognitive abilities, language, socio-emotional development, and artistic skills. These attributes were measured over two semesters, providing a comprehensive view of the developmental trajectories of children affected by stunting.

Table 1. Description of attributes of the dataset

Atribut	Tipe	Kategori
Umur	Independen	Continuous
TB (Tinggi Badan)	Independen	Continuous
BB (Berat Badan)	Independen	Continuous
Stunting	Independen	0 or 1
P1a (Perkembangan Nilai Agama dan Moral Semester 1)	Independen	1 = BB; 2 = MB; 3 = BSH; 4 = BSB
P1b (Perkembangan Fisik Motorik Semester 1)	Independen	
P1c (Perkembangan Kognitif Semester 1)	Independen	
P1d (Perkembangan Bahasa Semester 1)	Independen	
P1e (Perkembangan Sosial Emosional Semester 1)	Independen	
P1f (Perkembangan Seni Semester 1)	Independen	
P2a (Perkembangan Nilai Agama dan Moral Semester 2)	Independen	
P2b (Perkembangan Fisik Motorik Semester 2)	Independen	
P2c (Perkembangan Kognitif Semester 2)	Independen	
P2d (Perkembangan Bahasa Semester 2)	Independen	
P2e (Perkembangan Sosial Emosional Semester 2)	Independen	
P2f (Perkembangan Seni Semester 2)	Independen	
TK (Tingkat Perkembangan Akhir Tahun)	Dependen	

The table presents the dataset attributes, divided into independent and dependent variables. Independent variables include continuous data like Age (Umur), Height (TB), and Weight (BB), along with a binary stunting variable (0 for non-stunted, 1 for stunted).

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Developmental metrics, measured over two semesters (P1a to P2f), cover areas such as Religious and Moral Education, Physical Motor Skills, Cognitive, Language, Social-Emotional, and Artistic Development. These attributes are categorized into four performance levels: BB (Belum Berkembang), MB (Mulai Berkembang), BSH (Berkembang Sesuai Harapan), and BSB (Berkembang Sangat Baik), allowing detailed analysis of child development, particularly stunting's impact. The Final Year Development Level (TK), the dependent variable, summarizes the children's overall progress using the same performance categories.

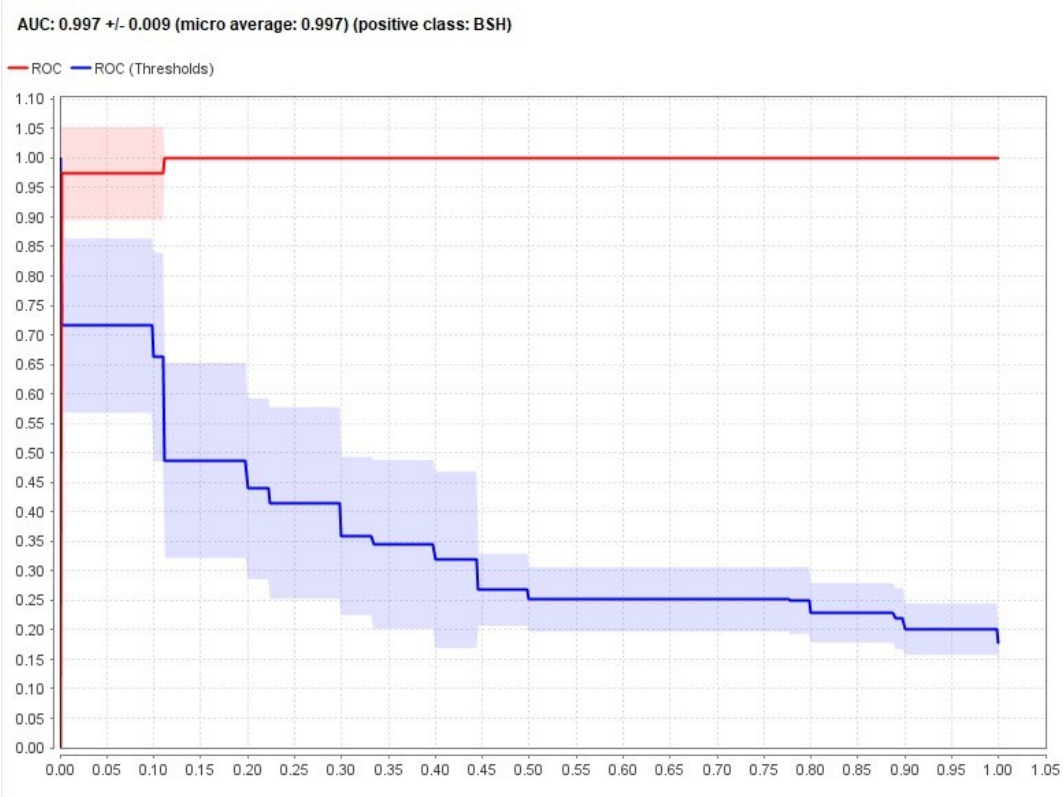

Figure 2. ROC Curve Result

The SVM model achieved an accuracy of 97.56%, precision of 98.97%, recall of 97.37%, and an AUC of 0.997, classifying it as excellent (Tharwat, 2021). It identified 289 support vectors with a bias of 2.004, indicating that many support vectors were needed to distinguish between stunted and non-stunted children, suggesting a relatively complex decision boundary between the two classes. Besides that, the SVM model also exceeds the ROC threshold, as shown in Figure 2.

Table 2 shows the weights of various attributes in the model, highlighting their relative importance in predicting child development. Physical motor skills in Semester 1 (P1b) have the highest influence, followed by artistic (P1f), social-emotional (P1e, P2d), and religious and moral development (P1a, P2a). Cognitive and language skills also contribute, though to a lesser degree, while age and stunting status have minimal or no impact. Notably, attributes from Semester 1 generally weigh more than those from Semester 2, indicating that early development plays a more critical role in the model's predictions.

In Table 2, which is the weighting of the SVM result attributes, physical motor skills in Semester 1 (P1b) emerged as the most influential factor, followed by artistic ability (P1f), social-emotional skills (P1e, P2d), and religious and moral development (P1a, P2a). This hierarchy underscores the important role that motor skills play in early childhood development, in line with the findings of Sudarni and Harun (2023), who highlighted the impact of performing arts on motor and social behavior in children.

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Table 2. Attribute weight results from SVM

Atribut	Bobot (w)
Umur	0.111
Stunting	0
P1a (Perkembangan Nilai Agama dan Moral Semester 1)	0.436
P1b (Perkembangan Fisik Motorik Semester 1)	0.558
P1c (Perkembangan Kognitif Semester 1)	0.195
P1d (Perkembangan Bahasa Semester 1)	0.191
P1e (Perkembangan Sosial Emosional Semester 1)	0.411
P1f (Perkembangan Seni Semester 1)	0.485
P2a (Perkembangan Nilai Agama dan Moral Semester 2)	0.37
P2b (Perkembangan Fisik Motorik Semester 2)	0.049
P2c (Perkembangan Kognitif Semester 2)	0.111
P2d (Perkembangan Bahasa Semester 2)	0.469
P2e (Perkembangan Sosial Emosional Semester 2)	-0.075
P2f (Perkembangan Seni Semester 2)	0.2

The Support Vector Machine (SVM) model used in this analysis provides valuable insights into the relative influence of various developmental attributes. In particular, the SVM model emphasizes the importance of motor skills and artistic abilities in shaping overall development. These results are consistent with previous studies, such as (Pratiwi et al., 2023), who underscore the need to integrate arts learning into educational programs as a means to encourage social-emotional learning. This is in line with the findings of (Ramadhani & Sitorus, 2024) which showed that craft activities can significantly improve artistic skills in children aged 5-6 years.

In addition, stunted children, who often experience obstacles in motor and emotional development, can benefit significantly from interventions targeted at improving motor coordination and emotional stability. Improving Physical Motor Skills. Gross motor skills can be improved through various fun and interactive physical activities. One effective approach is to use traditional games, such as hopscotch, which have been shown to improve children's gross motor skills (Herniawati et al., 2024). In addition, activities such as dance, especially the Tikus Buntung Dance, can also develop gross motor skills while providing positive social experiences (Rahmawati & Pamungkas, 2023). The use of learning methods that involve games, such as relay games, can encourage children to move actively and interact with peers, thereby improving their motor skills (Hasanah & Tangse, 2022). Activities that involve science, such as experiments, also contribute to children's cognitive and motor development (Hasibuan & Suryana, 2022).

To improve the artistic abilities of children aged 5-6 years, craft activities such as weaving can be an interesting choice. Through this activity, children not only learn fine motor skills but also express their creativity (Ramadhani & Sitorus, 2024). In addition, coloring activities have also been shown to be effective in improving children's artistic abilities (Yasmin & Mayar, 2023). The 3M method (drawing, tearing, and sticking) can be implemented to stimulate children's artistic abilities and strengthen their fine motor skills (Suharni & Hasibuan, 2023). Involving music in art activities can also improve children's social and emotional experiences (Ningrum et al., 2022).

Art learning programs can serve as an effective tool in developing children's social emotional skills. Through art, children learn to cooperate, communicate, and express their feelings (Pratiwi et al., 2023). Art activities can also increase independence and social skills, which are important for children's emotional development (Aghniarrahmah et al., 2021).

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Integrating Ramayana dance drama learning and creative dance can improve children's motor skills and social behavior (Sudarni & Harun, 2023). In addition, programs that improve motor skills and creativity, such as dexterity programs, also contribute to children's social development (ELDIASTY et al., 2023)(Khoerunnisa et al., 2023).

By combining various activities that focus on physical motor skills, art, and social emotional skills, children aged 5-6 years can develop holistically, preparing them for future learning challenges, especially for stunted children.

For policymakers and educators, data-driven approaches, such as those demonstrated in this study, can enhance efforts to support the holistic development of stunted children, ensuring better long-term educational and health outcomes. The evidence underscores the need for a collaborative framework involving families, educators, and community programs to create an environment that supports children's growth and development.

Conclusion

This study has successfully developed a predictive model for stunting among children aged 5-6 years in early childhood education institutions (PAUD) in rural Semarang Regency using the Support Vector Machine (SVM) approach. The model achieved remarkable performance metrics, with an accuracy of 97.56%, precision of 98.97%, recall of 97.37%, and an AUC of 0.997, confirming the SVM's effectiveness in distinguishing between stunted and non-stunted children based on various developmental attributes.

The analysis underscores the critical role of early developmental skills, particularly physical motor skills and artistic abilities, in shaping educational outcomes. To address stunting effectively, it is essential to implement targeted interventions within PAUD that enhance motor coordination and emotional development. Stakeholders, including policymakers and educators, should prioritize the development of specific programs that integrate motor skills and arts education into the curriculum. This approach not only aligns with existing research supporting the positive influence of these areas on children's overall growth but also provides practical pathways to improve educational and health outcomes for at-risk populations.

Additionally, future research should explore the application of more complex machine learning methods and expand data collection to include diverse regions, enhancing the model's robustness and generalizability. By fostering a collaborative framework that involves families, educators, and community programs, we can create supportive environments for children. Such a comprehensive strategy is vital to unlocking the developmental potential of stunted children, ultimately leading to better long-term educational and health outcomes. The insights gained from this research lay the groundwork for further investigations into machine learning techniques and their potential applications in addressing developmental challenges among young children.

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