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Early Warning System for the Impact of E-sports on Academics Based on Hybrid Naïve Bayes and Particle Swarm

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Abstract

The integration of e-sports into the lifestyle of high school students in the era of industrial technology 4.0 brings a double dilemma between the development of digital skills and the risk of declining academic performance due to addiction. Previous research has successfully classified the impact of e-sports using the Naïve Bayes algorithm, but the model is static and only provides post-mortem analysis. This study proposes an Early Warning System (EWS) based on a hybrid of Naïve Bayes and Particle Swarm Optimization (PSO) designed to work dynamically and comprehensively. PSO is implemented to heuristically optimize attribute weights to overcome the weakness of the feature independence assumption in the pure Naïve Bayes algorithm. The test was carried out using the 10-fold cross-validation method on 178 student data of Madrasah Aliyah Negeri Rengasdengklok. The algorithm implementation resulted in an accuracy rate of 75.95% and an Area Under Curve (AUC) of 0.792. The main contribution of this research is the transformation from a traditional classification model to a proactive early warning system, where the system real-time monitors playing and studying duration, and then uses a probability threshold (T≥0.6) to trigger mitigation notifications to teachers and parents. In-depth analysis results show that behavioral variables such as playing duration have a much more massive level of significance (weight 1.0) compared to cognitive intelligence level or IQ (weight 0.001) in predicting academic failure. These findings provide a new paradigm for educational institutions in designing intervention strategies focused on time management and student digital literacy.

Keywords: *dynamic classification, early warning system, e-sport, Naïve Bayes, particle swarm optimization*

1. Introduction

Progress technology moment This has touch all over aspect life, including the world of education and daily life students [1]. In addition to making it easier access learning, technology also brings captivating digital entertainment, one of which is *e-sports* [2]. Now *e-sports* No just filler time free time, but rather A trend big lots confiscate time and concentration of teenagers [3].
Impact height intensity play *e-sport* to performance academic now become attention serious in schools. [4]Initial studies at Rengasdengklok State Islamic Senior High School take notes that Of the 178 students, 107 of them experience decline mark related report cards close with online game [5]addiction. Although problem This Once investigated use Naïve Bayes algorithm and *Particle Swarm Optimization* (PSO), the approach Still nature evaluation end (*retrospective)* [6]. This means that detection new done after the semester is over and the grades Already out [7]. This is make school late do prevention, so that guidance from teachers and parents become not enough effective [8].
In the field *Educational Data Mining* (EDM), still There is distance between ability predict and prevent problem since early [9]. System existing predictions generally only focused on results end using rigid data [10]. Therefore that, research This propose A System Early Warning or *Early Warning System* (EWS). System This change Naïve Bayes and PSO algorithms from just historical data testing tool become monitoring system risk decline mark student in a way periodically. Naïve Bayes was chosen because of its efficient [11]calculation process, while PSO is added For give weight best in factors determinant like duration play, duration study, and IQ to cover weakness inherent in Naïve Bayes [12].
Study This aim For test reliability of the combined NB-PSO model in predict risk decline mark using dynamic data. Then build EWS system that can give warning before failure academic happen and analyze connection between intelligence (IQ) with management time (duration) play) against resilience Study students. Hopefully, the school No Again just evaluate value at the end, but Can accompany and prevent decline performance student in a way more proactive

2. Theoretical Basis

Study about Educational Data Mining (EDM) and its impact to performance academic has Lots developed in a number of year last. In the study his predecessor implement optimized Naïve Bayes algorithm with Particle Swarm Optimization (PSO) for classify impact e-sport to

results Study [5]. Although level the resulting accuracy Enough good (75.95%), approach the limited to evaluation post -semester which is static in nature, so that intervention preventive from party school difficult done in a way appropriate time.
In context Early Warning System (EWS), time interval prediction model dynamic for detect at -risk students fail in environment learning online [13]. The EWS system proven capable increase level graduation through notification early [8]. How ever, the main parameters used limited to interaction student with Learning Management System (LMS) and not yet consider variables distraction massive external like addiction online game [2].
In addition, optimization of the prediction model academic use technique heuristics are also supported through evaluation algorithm prediction based Gradient Boosting and metaheuristic [14], concluded that adjustment weight feature weighting is very essential in handling behavioral data cognitive students who tend to be non-linear and non- independent [15].
Study This fill in gap from literature previously with unite framework real-time EWS work [16]and excellence PSO [17] optimization For optimize weakness assumptions independence features in the Naïve Bayes algorithm. In specific, research This focused on mitigation proactive to disruption digital behavior (e-sports) before evaluation final academic accumulated [2], [18]

3. Research Methods

3.1. Stages of EWS – Based Research

Study This develop methodology Modified Cross-Industry Standard Process for Data Mining (CRISP-DM) For need dynamic system. Stages the covering understanding business education, continuous data acquisition, data processing, modeling algorithms, evaluation, up to deployment in form dashboard Early Warning System

3.2. Data Collection and Acquisition

Different with Conventional data collection is done at the end of the semester, the EWS architecture requires data that is updated regularly. periodically [19]. Attributes extracted predictors from 178 respondents shared into two categories:

a. Attributes: Gender, Major (Science/Social Sciences), and IQ Test Score.
b. Attribute Dynamic: Frequency Play E-sports (hours/ week), Activity Organization, and Duration Learn to be independent. Predicted target class (label) is Learning Outcome with nominal value: Decreasing and Increasing.

3.3. Naïve Bayes Classification

Naïve Bayes is algorithm classification based derived probability from Bayes' Theorem [20]. Advantages algorithm This lies in its simplicity which allows computing walking very fast in system real-time [21]. Posterior probability of hypothesis decline mark formulated as following:

$$P(C_k|X) = \frac{P(X|C_k) \times P(C_k)}{P(X)} \tag{1}$$

Information:
$P(C_k|X)$: Probability posterior probability of class C_k(Increasing / Decreasing) with predictor X.
$P(X|C_k)$: Probability predictor X in class C_k (likelihood).
$P(C_k)$: Probability prior from class C_k.
$P(X)$: Probability evidence or proof.

3.4. Optimization Using Particle Swarm Optimization (PSO)

Weakness The main Naïve Bayes is assumptions that all attribute each other free (independent) and have equal weight [22]. In fact, the duration play e-sport confirmed own more influence massive to mark report card compared to type sex student [23]. For cover weakness Particle Swarm Optimization (PSO) was introduced by Kennedy and Eberhart in 1995 as algorithm optimization based behavior flock (like bird or fish) [24].
In research this, PSO works for look for combination weight best attributes (features) in space search dimensionless - D. Update speed (V) and position (X) of each particle for iteration to - (t + 1) calculated use equality mathematical following:

$$V_i(t+1) = w \cdot V_i(t) + c_1 \cdot r_1 \cdot (P_{best,i} - X_i(t)) + c_2 \cdot r_2 \cdot (G_{best} - X_i(t))$$

$$X_i(t+1) = X_i(t) + V_i(t+1) \tag{2}$$

Information:

$V_i(t)$: Speed particle i at time t.
$X_i(t)$: Position particles (representing weight attributes on the model).
c_1, c_2 : Inertia weight (balance) global and local search
w

: Coefficient acceleration cognitive and social
$P_{best,i}$: Position best ever achieved by particles i
G_{best} : Position best ever achieved by all flock

PSO parameters configured on RapidMiner covering size population (swarm size) of 5, iteration maximum 30, inertia weight dynamic 1.0, as well as restrictions weight local and global are 1.0 each.

3.5. Early Warning System Architectural Design

Architecture Early Warning System (EWS) in study This built use draft three - tier architecture system This in a way trace designed For processing input data from users, analyze it through algorithm predictions, and in the end produce output in the form of notification warning early. Workflow architecture system This in a way complete can seen in Figure 1.

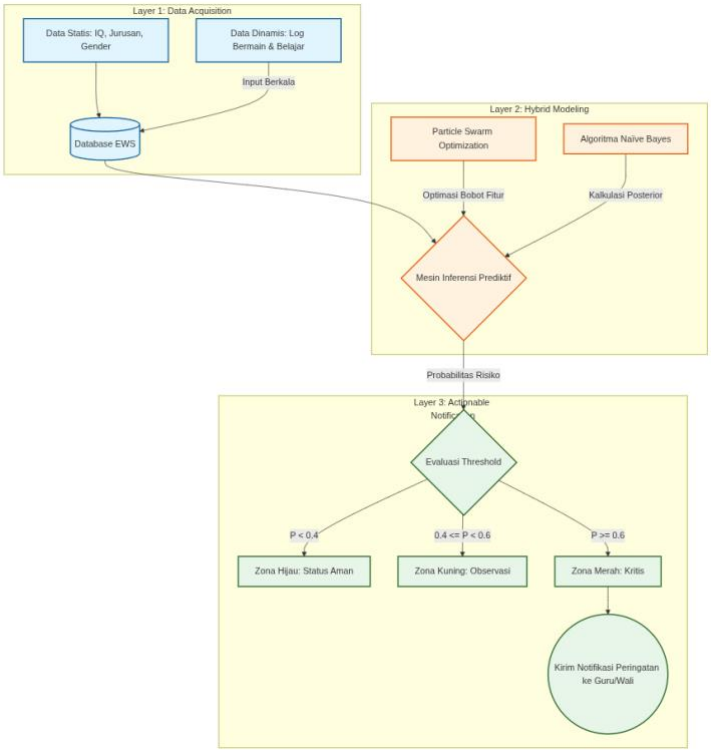

Figure 1 Architectural Flow Early Warning System (EWS)

Following explanation channel mechanism from Architecture Early Warning System (EWS):

1. Layer 1 (Data Acquisition): Is interface data collection where static student data (such as IQ and Gender) is combined with dynamic data (daily logs duration e-sports and learning) which are saved to in EWS Database.
2. Layer 2 (Hybrid Modeling): Layer core computing. The PSO module selects and provides weight on input data (provides weight absolute in duration play), which then continued to Naïve Bayes algorithm for count posterior probability of occurrence decline mark academic.
3. Layer 3 (Actionable Notification): Mitigation logic built with determine threshold against output probability from Layer 2. System will produce action categorized prevention in three risk zones:
   Green Zone (Safe) : If the probability "Decreasing" class < 0.4. Intervention No required.
   Yellow Zone (Warning) : If the probability the "Decreasing" class is between $0.4 \leq T < 0.6$. The system recommend observation.
   Red Zone (Alert) : If the probability 'Decreasing 'class ≥ 0.6. System in a way automatic send notification intervention mitigation to guardian class and BP teacher.

4. Result and Discussion

4.1. Evaluation of Predictive Model Performance

For ensure the model is not experience overfitting (too memorizing training data), evaluation done use method 10-Fold Cross-Validation [25] against the MAN Rengasdengklok student dataset. The success rate This Early Warning System (EWS). Then measured based on results The obtained Confusion Matrix from testing use device RapidMiner software.

Table 1. Confusion Matrix of NB-PSO Classification

Prediction Label	True Downward	True Increase	Class Precision
Pred. Decrease	42	19	68.85%

Pred. Increase	24	52	68.42%
Class Recall	63.63%	73.24%	

In a way Overall, this model reach level accuracy by 75.95%. This figure show that system Already Enough competent in read pattern behavior students and predict the impact to mark academic They. In addition to accuracy, model performance is also evaluated use curve Receiver Operating Characteristic (ROC) which produces mark Area Under Curve (AUC) of 0.792. Referring to the standard evaluation data mining, AUC values in the range of 0.70 to 0.80 are acceptable to in category good classification (Fair Classification).
As A Early Warning System, achievements most important from this model is his abilities detected 42 students (True Decrease) who had the habit play e - sports risky lower mark report card. Success detecting all 42 students This is key main from study this, because they are the ones who will will become target priority For get mentoring from school before the semester ends.

4.2. Weighting Analysis Attribut

The implementation of Particle Swarm Optimization was successful eliminate noise and provide logical weighting in a way academic to the input parameters. Optimization results particle to attribute as following:

Table 2. Weight PSO Optimization Result Attributes

Attributes (Predictors)	Weight Attributes (Weight)	Significance Level
Gender	1.0	Very Significant
Major	1.0	Very Significant
Activity Organization	0.176	Low
Iq Test Score	0.001	Very Low (Ignore)
Frequency Play E-Sport	1.0	Very Significant
Frequency Study	1.0	Very Significant

weighting results in Table 2 show interesting findings. IQ Test Score Attributes turned out to be own very low weight, namely almost approach zero (0.001). On the other hand, the factor habit like Frequency Play E-sports and Frequency Study precisely get weight maximum (1.0).
Findings This brush off assumption general that intelligence high intellectual (IQ) automatic ensure performance good academic performance. In fact, as smart as whatever a person students, their grades still risky down If He No capable share time with good. In the middle the rise trend e-sports, ability management time proven Far more determine. The length of time spent student For playing online games give impact far negative more real to results Study they compared to the IQ level they have have.

4.3. Implementation of Early Warning System (EWS)

the prediction model This can Work in a way dynamic as system monitoring, results calculation probability from algorithm direct connected to dashboard interface as following:

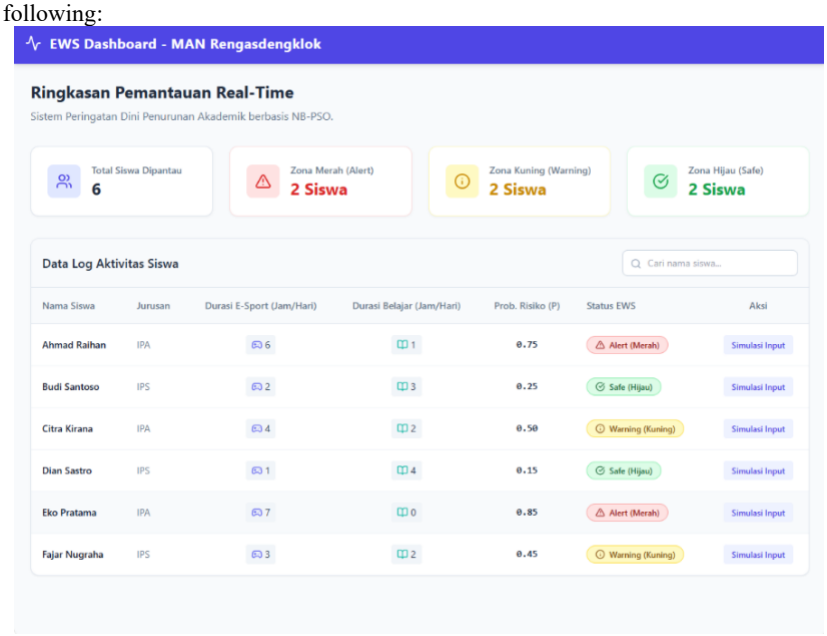

Figure 2: Early Warning System (EWS) dashboard

As illustration, for example There is Student X who is registered play e-sport for 6 hours a day in a way consecutively on week third school term. Because of the attributes duration play own weight highest (1.0) thanks PSO optimization, the Naïve Bayes algorithm will in a way

automatic count repeat opportunity risk student said. Probability for the class label ' Decreasing ' on Student X will be soaring height (eg. reached 0.8). Because the number This Already exceeds the specified safety limit ($T \geq 0.6$), the system will direct emit 'Red Zone' warning.

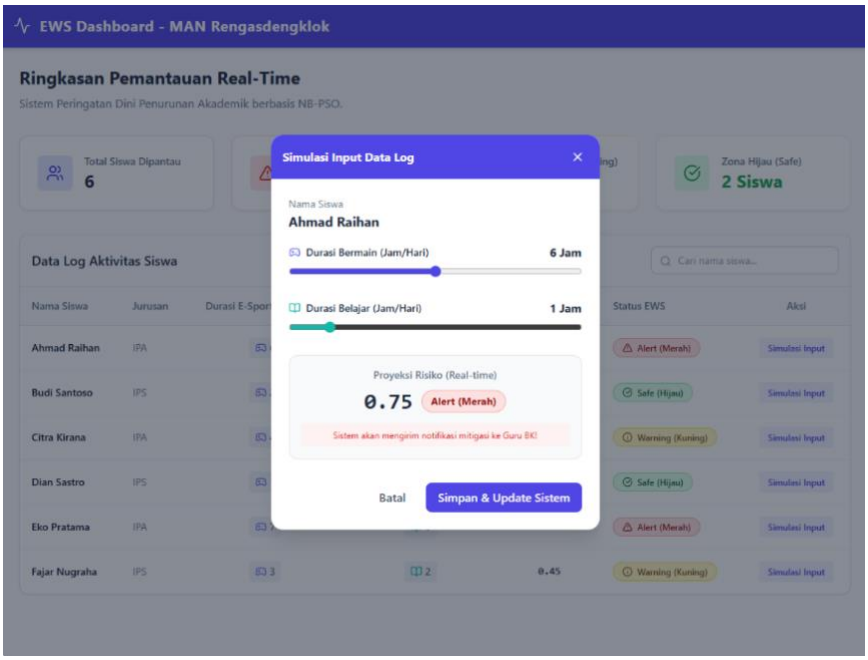

Figure 3: Student Log Data Input Form

Warning This Then appear as notifications on the Guidance teacher dashboard Counseling (BK), which indicates that Student X needs quick called For get guidance related management time playing. The ongoing monitoring and classification process continously in a way real-time this is what it is mark novelty of study this. System No Again just processing passive data, but in a way active help school take action proper prevention time.

5. Conclusion

Based on results analysis and testing that has been conducted, research This conclude that optimized Naïve Bayes algorithm with Particle Swarm Optimization (PSO) is proven effective For developed become Early Warning System (EWS) in the environment school. Combined model This capable reach level accuracy by 75.95% with AUC value of 0.792, so that Enough reliable used as tool help prediction decline mark student.

The novelty value of study This lies in the shift the approach: from the beginning only evaluate the impact of e-sports after semester grades come out, become system prevention active early monitor. With use probability threshold ($T \geq 0.6$), system Can direct detect students who have enter to the vulnerable zone. In addition, the findings most important from research This show that intelligence default or IQ (weight 0.001) it turns out No Lots influential when student Already online game addiction. On the other hand, the ability management time and duration playing e-sports (weight 1.0) instead become determinant main succeed or whether or not student maintain mark academic.

Acknowledgement

For development study Next, the duration data collection play recommended No Again use manual filling of students. This EWS system to in front can integrated via API with feature Digital Wellbeing or recorder Screen Time on smartphone students, so that activity data recorded game play Far more accurate and objective.

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