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Prediction and Comparative Analysis of Factors Affecting the Mathematical Achievement of Gifted Students With Machine Learning Models

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ABSTRACT

This study aims to determine the factors affecting the mathematical achievement of gifted students studying at science and art centers in Bursa province and to predict this achievement using various machine learning models. In the study, variables, such as demographic information, family structure, study habits, motivation level, technology use, and social activities were analyzed in line with the data collected from 151 students. Methods, such as decision trees, support vector machines, and artificial neural networks, were used by utilizing the fields of educational data mining and learning analytics. The results obtained showed that some variables significantly affected the mathematical achievement of students. The study provides important findings in terms of developing educational policies and individualized teaching strategies.

KEYWORDS

Educational Data Mining, Giftedness, Machine Learning, Mathematics Achievement, SAC, Science and Art Centers

INTRODUCTION

The mathematical success of gifted students is of critical importance for both their individual development and their future academic and professional success. An accurate and comprehensive understanding of the factors that affect success in this area enables the development of effective educational strategies for these students to achieve their full potential. Machine learning stands out as a unique tool for analyzing the multidimensional factors that affect the mathematical success of gifted students, thanks to its ability to extract meaningful patterns from large and complex datasets. Thus, it has the potential to go beyond traditional methods and offer more personalized and data-driven educational solutions (Hodges & Mohan, 2019).

The education of gifted students is one of the important challenges faced by education systems both nationally and internationally (Alkan & Mertol, 2019; Renzulli, 2012). In order for these students to fully develop their high cognitive capacity, educational programs that are suitable for

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their special needs must be designed. The universal language of mathematics and its central role in today's technological world make it especially important to support the success and development of gifted students in mathematics (Sheffield, 2017). In order to design such environments, both the individual characteristics of the students and the environmental factors affecting the educational process must be analyzed in detail.

Science and art centers (SACs), established for the education of gifted students in Turkey, support the learning needs of these students that cannot be met within the general education system. However, comprehensive research is needed on which factors affect the mathematics success of students in these centers, as well as how this success can be optimized (Sak, 2016).

The increasing amount of data in the field of education offers researchers new opportunities to analyze educational processes and outcomes (Baker & Yacef, 2009). Machine learning techniques emerge as powerful tools in discovering patterns in large and complex datasets and creating predictive models (Baker & Inventado, 2014). Fields, such as educational data mining and learning analytics, which are developed especially for the analysis of educational data, offer important opportunities in determining the factors affecting student performance and predicting success (Romero & Ventura, 2020). The main purpose of this study is to determine the factors affecting the mathematical success of gifted students studying at SACs in Bursa and to examine to what extent these factors can predict mathematical success through various machine learning models. The sub-objectives of the research can be listed as follows:

1. to determine the demographic, familial, educational and socioeconomic factors affecting the mathematics achievement of gifted students;
2. to analyze the importance levels of the factors affecting mathematics achievement using machine learning techniques;
3. to compare the performances of different machine learning algorithms, i.e., logistic regression (Hosmer & Lemeshow, 2000), decision trees, support vector machines (SVM), random forest (RF), gradient boosting (Friedman, 2001), and deep neural networks, in predicting mathematics achievement;
4. to determine the model(s) that provide the highest prediction accuracy and to evaluate the interpretability of these models; and
5. in light of the findings, to make educational recommendations to increase the mathematics achievement of gifted students.

This study aims to analyze and predict the factors affecting the mathematical success of 151 gifted students studying at SACs in Bursa province using various machine learning techniques. The effects of many factors, such as students' demographic characteristics, family structures, study habits, motivations, technology use, and social activities, on mathematical success will be examined.

This study brings an important innovation to the literature by examining the factors affecting the mathematical success of gifted students for the first time using machine learning and deep learning techniques. While existing studies are generally limited to classical statistical methods, this study reveals deeper and nonlinear relationships with advanced models, such as extreme gradient boosting (XGBoost), RF, gradient boosting, and multilayer artificial neural networks. In particular, weighting the relative importance levels of motivational, cognitive, social, and behavioral factors with machine learning algorithms offers original contributions both methodologically and practically. In addition, the fact that the sample consists of gifted students studying in private educational institutions, such as SACs, fills an important gap in the literature in terms of the findings being for a unique group.