Journal Basic Education 8[19]1-7: e5819107
Article

Identification of priority cases for attention to the academic performance of students by subject

Identificación de casos prioritarios para atención en el desempeño académico de los estudiantes por asignatura

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CONAHCYT classification:

Area: Engineering
Field: Technological sciences
Discipline: Information technology
Sub-discipline: Artificial Intelligence

https://doi.org/10.35429/JBE.2024.8.19.5.1.7
History of the article:
Received: September 05, 2024
Accepted: December 30, 2024

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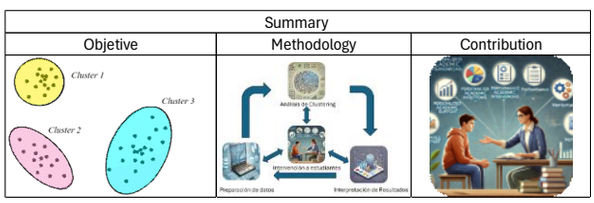
Abstract

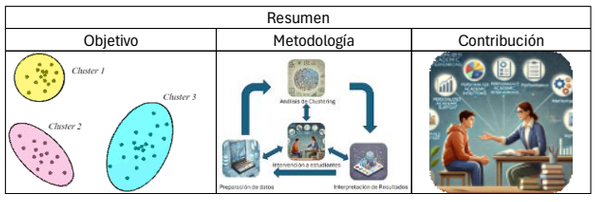
Identifying priority cases to improve students' academic performance by subject has gained relevance in modern education, and artificial intelligence (AI) emerges as a fundamental tool to achieve this. Through cluster analysis, an unsupervised learning technique, it is possible to group students according to specific performance patterns and needs. This allows educational institutions to quickly recognize which cases require priority attention and focus their resources efficiently. Cluster analysis makes it possible to identify segments of students with similar characteristics in their academic performance, revealing aspects such as recurring difficulties in certain subjects, learning patterns, and factors that affect performance. With these defined groups, teachers and administrators can establish personalized and effective intervention strategies. For example, specific support programs can be developed for students facing problems in mathematics or science, rather than applying general solutions. AI applied in this context not only helps to categorize students, but also allows for a more accurate prediction of who may need additional support in the short and long term. Furthermore, by identifying common factors within each cluster, it is possible to improve teaching methods and design curricula that are more adapted to the real needs of students. This practice not only promotes inclusive and student-centered education, but also optimizes the use of academic resources by focusing efforts on the most urgent cases. The application of cluster analysis in the identification of priority cases for academic attention represents a key innovation in the educational sector, allowing for more personalized, inclusive and effective education, supported by artificial intelligence.



Artificial Intelligence, Cluster Analysis, Academic Performance

Resumen

La identificación de casos prioritarios para mejorar el desempeño académico de los estudiantes por asignatura ha cobrado relevancia en la educación moderna, y la inteligencia artificial (IA) emerge como una herramienta fundamental para lograrlo. A través del análisis de clúster, una técnica de aprendizaje no supervisado, es posible agrupar a los estudiantes según patrones específicos de rendimiento y necesidades. Esto permite que las instituciones educativas reconozcan rápidamente cuáles son los casos que requieren una atención prioritaria y enfoquen sus recursos de manera eficiente. El análisis de clúster permite identificar segmentos de estudiantes con características similares en su desempeño académico, revelando aspectos como las dificultades recurrentes en ciertas asignaturas, patrones de aprendizaje y factores que afectan el rendimiento. Con estos grupos definidos, los docentes y administradores pueden establecer estrategias de intervención personalizadas y efectivas. Por ejemplo, se pueden desarrollar programas de apoyo específicos para los estudiantes que enfrentan problemas en matemáticas o ciencias, en lugar de aplicar soluciones generales. La IA aplicada en este contexto no solo ayuda a categorizar a los estudiantes, sino que también permite una predicción más precisa de quiénes pueden necesitar apoyo adicional a corto y largo plazo. Además, al identificar los factores comunes dentro de cada clúster, es posible mejorar los métodos de enseñanza y diseñar currículos más adaptados a las necesidades reales de los alumnos. Esta práctica no solo promueve una educación inclusiva y centrada en el estudiante, sino que también optimiza el uso de los recursos académicos al focalizar los esfuerzos en los casos más urgentes. La aplicación del análisis de clúster en la identificación de casos prioritarios de atención académica representa una innovación clave en el sector educativo, permitiendo una educación más personalizada, inclusiva y efectiva, con el respaldo de la inteligencia artificial.



Inteligencia Artificial, Análisis de Cluster, Desempeño académico

Citation: Fernández-Mena, Ana Laura, Torres-Magaña, María Patricia, Hernández-De La Rosa, Francisco Alberto and Rodríguez-Fernández, Manuel Antonio. Identification of priority cases for attention to the academic performance of students by subject. Journal Basic Education. 8[19]1-7: e5819107.

Introduction

Today, identifying students at academic risk has become a priority for educational institutions seeking to improve educational outcomes and quality. With the rise of artificial intelligence (AI), advanced data analysis techniques, such as cluster analysis, have proven to be powerful tools for detecting patterns of underachievement that would otherwise go unnoticed in traditional education (García-Martínez *et al*., 2023). This type of analysis allows students to be segmented into groups with similar characteristics and needs, thus facilitating the identification of priority cases that require immediate intervention to improve their performance in different subjects.

The application of cluster analysis in education offers an innovative perspective for understanding academic behaviour and the factors that influence student performance. This approach, powered by AI algorithms, allows not only to classify students, but also to tailor interventions and support strategies to their specific needs. The methodology is based on the collection of detailed data on performance in each subject, the normalisation and selection of key variables, and the application of clustering techniques to group and prioritise cases (Kulik & Fletcher, 2015).

The early identification of students at academic risk has gained relevance in recent years due to its impact on student success and the efficiency of educational institutions. Artificial intelligence (AI) techniques, specifically cluster analysis, have emerged as effective methods for segmenting and prioritising student cases that require immediate attention. These tools can identify patterns in academic data and provide personalised interventions, optimising institutional resources and improving the educational experience. Studies have shown that cluster analysis can significantly improve accuracy in classifying and predicting academic performance compared to conventional methods (Adelson & McMullin, 2017).

Early studies in this area focused on the use of traditional statistical methods for the identification of at-risk students. However, with the advancement of AI technologies, a more dynamic and accurate approach has been achieved.

For example, McLaren *et al*. (2017) demonstrated how intelligent tutoring systems, integrated with data analytics, can significantly improve learning in specific areas of mathematics and science. These systems, based on algorithms that detect patterns of behaviour and performance, offer more effective and targeted interventions, and their application has spread rapidly in different educational contexts.

Recent studies, such as that of García-Martínez *et al*. (2023), have gone a step further by employing cluster analysis methods to segment students according to critical performance factors. This approach, supported by AI techniques, allows students to be classified into homogeneous groups, facilitating the implementation of personalised support plans that are tailored to the specific needs of each group. In contrast to previous studies, this work combines cluster analysis with increased data processing power, allowing large volumes of information to be assessed in real time and to respond quickly to changes in academic performance.

This study explores how cluster analysis, in combination with artificial intelligence, can transform the way academic support is addressed, ensuring that the most at-risk students receive personalised and effective attention. The implementation of these analytical techniques allows not only to improve educational quality, but also to optimise the use of resources in academic institutions, focusing efforts on those students who need it most.

Methodology

Development of the Methodology:

In the methodology to be followed in the research was carried out under a descriptive approach as it is key to accurately document the data, describes in detail the patterns of student performance, the interpretation resulting from cluster analysis and preparation methods, knowledge, ways to structure strategies for intervention with students.

To address the problem of identifying priority cases in students' academic performance by subject using artificial intelligence techniques and cluster analysis, the following methodology is proposed:

ISSN: 2523-2452
RENIECYT-CONAHCYT: 1702902

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1. Data Collection:

– Academic Data: Collect detailed information on students' grades in each subject, including midterm grades, final exams and practical work.
– Behavioural Data: Record class attendance, participation in extracurricular activities and use of educational platforms.

2. Data Preprocessing:

– Data Cleaning: Eliminate incomplete or inconsistent records.
– Normalisation: Standardise variables to facilitate analysis.
– Coding: Transforming categorical variables into numerical ones.

3. Variable Selection:

– Identify the most relevant variables that influence academic performance, using statistical and machine learning methods to determine their significance.

4. Cluster Analysis:

– Application of Algorithms: Use clustering algorithms, such as K-means or DBSCAN, to group students according to similar patterns in their academic performance.
– Determining the Number of Clusters: Use methods such as the elbow method or the silhouette score to identify the optimal number of clusters.

5. Interpretation of Results:

– Cluster Profiling: Analyse the characteristics of each cluster to understand differences in performance and associated factors.
– Identification of Priority Cases: Detect clusters that represent students with low performance or academic risk, prioritising their attention.

6. Implementation of Interventions:

– Strategy Design: Develop specific action plans for each identified cluster, such as personalised tutoring, study skills workshops or psychological support.
– Monitoring and Evaluation: Establish indicators to measure the effectiveness of interventions and make adjustments as needed.
– Feedback and Continuous Improvement: Use the results obtained to refine the analysis model and intervention strategies, ensuring constant improvement in the identification and attention of priority cases.

Results

The implementation of a cluster analysis supported by artificial intelligence in the educational field seeks to identify and classify priority cases for intervention in the academic performance of students, according to their performance in different subjects. It is expected that this tool will enable educational institutions to:

1. Identify patterns of performance: using advanced grouping techniques, it is expected to detect groups of students with similar characteristics in their performance, which will facilitate specific and targeted intervention.

2. Improve the effectiveness of interventions: By targeting efforts to the students who need it most, an increase in the effectiveness of academic support programmes is expected.

3. Optimise resources: By prioritising critical cases of academic performance, resources can be focused on the areas and students with the greatest needs, maximising the impact of educational strategies.

4. Narrow the learning gap: Personalisation of teaching strategies will help to narrow the achievement gap between students, creating a more inclusive learning environment.

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Cluster analysis has become an essential tool in education to identify patterns of student behaviour and performance. Three scientific investigations that apply clustering techniques in education are summarised below:

1. Cluster Analysis in Educational Data: A Quantitative Study of Responses to an Open-Ended Questionnaire 2.

Battaglia, Di Paola and Fazio (2015) explored the consistency of student responses in various educational contexts. They applied cluster analysis methods to group students according to similarities in their responses, without prior knowledge about the formation of these groups. The results allowed them to identify intellectually similar subgroups, providing a deeper understanding of student reasoning patterns.

2. Machine Learning Methodology for the Classification and Prediction of Users in Virtual Learning Environments.

De-La-Hoz, De-La-Hoz and Fontalvo (2019) developed a methodology for classifying and predicting user behaviour in educational virtual environments. They used machine learning tools, such as principal component analysis and clustering, to study students' interaction with the platform and their performance in exams. The methodology allowed them to identify categories of users and apply machine learning algorithms to classify students according to their level of knowledge, achieving 91% accuracy in predictions.

3. Unsupervised Cluster Analysis Based on Online Learner Behavioural Data.

Peach, Yaliraki, Lefevre, and Barahona (2019) introduced a mathematical framework for analysing time series of student online participation. They used a dynamic temporal alignment kernel combined with an unsupervised multiscale graph clustering algorithm to identify groups of students with similar behavioural patterns. The study revealed different patterns of engagement, from distributed to concentrated learning, and highlighted the methodology's ability to identify low-performing students more accurately than traditional classification methods.

This research shows how cluster analysis with artificial intelligence can be a powerful tool for improving academic performance through targeted and personalised interventions.

Conclusions:

The use of artificial intelligence through cluster analysis in education offers an innovative and efficient approach to improving academic performance. This tool allows educational institutions to identify, with high precision, priority cases that require intervention, thus achieving a more effective allocation of resources and a timely response to the needs of each student.

By segmenting students into groups with similar performance and behavioural characteristics, teachers can design personalised interventions that enhance learning, increase retention and reduce achievement gaps.

In addition, this approach allows for anticipation of learning problems and facilitates informed decision-making based on real data and specific patterns that might otherwise go unnoticed. By implementing this model, institutions also foster an inclusive educational environment, where every student receives the attention they need to develop their skills and reach their full potential.

Artificial intelligence and cluster analysis not only transform the way priority cases are identified, but also put education on a path towards personalisation of learning, benefiting both students and educators. This represents a significant step forward in the commitment to quality, learner-centred education adapted to current educational demands.

Potential for improvement

One possibility for improvement in the process of identifying and addressing priority cases in academic performance could be the integration of real-time feedback to students and teachers. By implementing continuous reporting and analysis systems, both students and teachers would receive early alerts on academic performance and progress in each subject.

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This would allow students to take proactive measures and access additional resources at the moment they face difficulties, rather than waiting for later interventions.

Furthermore, teachers would be able to adapt their methodology based on real-time data, applying differentiated strategies according to the individual needs of the group. This improvement would facilitate a more agile intervention, encourage self-assessment and autonomous learning, and contribute to a more dynamic learning environment that is more responsive to the academic challenges of each student.

Medium-term benefits

1. Improved academic performance: Timely intervention in priority cases will help students overcome specific difficulties in certain subjects, tangibly improving their performance in the short and medium term.

2. Optimisation of educational resources: By identifying and addressing critical areas, the institution will be able to focus resources and efforts on the students who need them most, optimising the use of staff, time and educational materials.

3. Increased student retention: Students who receive support and attention when they need it most are more likely to remain in the education system, reducing dropout rates.

4. Motivation and confidence in students: By receiving personalised attention and seeing results in their performance, students gain confidence in their abilities and maintain a positive attitude towards learning.

Long-term benefits

1. Development of autonomous and self-assessment skills: Constant exposure to a feedback system will enable students to develop self-assessment and self-management skills, valuable for their continuous learning and professional life.

2. Improved institutional reputation: Implementing advanced technology for educational support will strengthen the image of the institution as innovative and committed to the academic success of its students.

3. Reducing the learning gap: Attention to priority cases helps to level the performance of the student group, promoting inclusive learning that reduces differences in academic achievement.

4. Contribution to educational research: The data collection and results obtained from this project will serve as a basis for future research, driving new artificial intelligence initiatives in education and contributing to global knowledge on personalised learning.

Implementing this project not only has the potential to transform learning today, but also to lay a solid foundation for a more equitable and efficient education system in the long term.

Strengthening partnerships

This project offers an excellent opportunity to strengthen strategic partnerships with a variety of entities. Some ways in which this can be achieved include:

1. Collaboration with technology companies: establishing partnerships with companies specialising in artificial intelligence and data analytics will allow the institution to access cutting-edge technologies, receive expert advice and jointly explore new educational applications. These collaborations can also open doors for students and teachers to participate in training and joint projects, broadening their knowledge in the use of advanced tools.

2. Linking with universities and research institutions: Working hand in hand with other academic institutions will allow for the exchange of knowledge, methodologies and experiences on the use of artificial intelligence in education.

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These partnerships can lead to joint research, academic publications and the development of best practices that benefit both parties and ultimately the entire education community.

3. Partnership with governmental and educational bodies: By demonstrating the positive impact of the project, the institution can attract the attention of educational authorities and governmental bodies interested in promoting technology in education. This can translate into financial support, access to educational innovation programmes and opportunities to expand the project to a regional or national level, benefiting more students and communities.

4. Engaging with parents and student associations: Involving parents and student associations in the project can strengthen community engagement in students' education. By communicating the benefits of the project and the progress made, a bond of trust and collaboration is created that drives the success of the project and motivates students to make the most of these opportunities.

5. Connections with non-governmental organisations (NGOs) and educational foundations: Often interested in supporting inclusive education and bridging gaps, NGOs can provide financial or in-kind support to ensure the continuity of the project. In addition, NGOs often have educational resources and intervention expertise that can enrich and strengthen the implementation of the cluster analysis in the institution.

Strengthening these partnerships will allow the institution to expand the impact of this project, improve its technological and pedagogical capacities.

Authors' contribution

The authors made the following contributions to the article:

Fernández-Mena, Ana Laura: was responsible for the analysis of artificial intelligence algorithms that can be applied to the academic area, ensuring their suitability to the educational context and accuracy in identifying patterns of academic performance.

Torres-Magaña, María Patricia: led the overall coordination of the project, ensuring the effective integration of the various stages of the research.

Hernández-De la Rosa, Francisco Alberto: contributed to data collection and analysis, establishing the criteria for the selection of relevant variables and ensuring the quality and consistency of the relevant information in the study.

Rodríguez Fernández, Manuel Antonio: participated in the interpretation of the results obtained from the cluster analysis research, collaborating in the elaboration of conclusions and practical recommendations for their implementation.

These joint contributions made it possible to develop an innovative methodology that will allow us to detect and efficiently address the academic needs of students, optimising educational resources and improving performance in various subjects.

Acknowledgements

We are deeply grateful to the TecNM Campus Villahermosa for their vision and commitment to academic excellence by allowing us to research advanced artificial intelligence technologies in the analysis of student performance. Their support and dedication to the continuous improvement of education has allowed this project to be conceptualised, seeking to benefit not only students, but also teachers and the community in general. Thanks to their support, we have been able to analyse cluster analysis techniques to identify and prioritise the needs of students in each subject, promoting more inclusive, personalised and effective learning.

Your leadership in embracing research in technological innovations is an inspiration to all of us in education, and demonstrates a strong commitment to quality and the well-being of every student.

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We are grateful for their trust and unwavering support, which have been essential to the success of this initiative, and hope that together we can continue to build a more equitable educational future tailored to the individual needs of each student.

Abbreviations

TecNM	Tecnológico Nacional de México
AI	Artificial Intelligence
AI	Artificial intelligence
NGO	non-governmental organisation

References

Background

McLaren, B. M., Adams, D. M., Mayer, R. E., & Forlizzi, J. (2017). A computer-based game that promotes mathematics learning more than a conventional approach. International Journal of Game-Based Learning, 7(1), 36-56.

Kulik, James & Fletcher, J. D. (2015). Effectiveness of Intelligent Tutoring Systems: A Meta-Analytic Review. Review of Educational Research. 86.

De-La-Hoz, Enrique J., De-La-Hoz, Efraín J., & Fontalvo, Tomás J.. (2019). Methodology of Machine Learning for the classification and Prediction of users in Virtual Education Environments. *Información tecnológica*, *30*(1), 247-254.

Basics

García-Martínez, I., Fernández-Batanero, J. M., Fernández-Cerero, J., & León, S. P. (2023). Analysing the impact of artificial intelligence and computational sciences on student performance: Systematic review and meta-analysis. Journal of New Approaches in Educational Research, 12(1), 1-15.

Barcia Cedeño, E. I., Tambaco Quintero, A. R., Angulo Quiñónez, O. G., Prado Zamora, M. E., & Valverde Prado, N. G. (2024). Análisis de tendencias y futuro de la Inteligencia Artificial en la Educación Superior: perspectivas y desafíos. Ciencia Latina Revista Científica Multidisciplinar, 8(1), 3061-3076.

Parra-Sánchez, J. (2022). Potencialidades de la Inteligencia Artificial en Educación Superior: Un Enfoque desde la Personalización. Revista Tecnológica-Educativa Docentes 2.0, 14(1), 19-27.

European Commission: Joint Research Centre, Tuomi, I., Punie, Y., Vuorikari, R., & Cabrera, M. (2018). The impact of Artificial Intelligence on learning, teaching, and education, (Y.Punie,editor,R.Vuorikari,editor,M.Cabrera,edito) Publications Office.

Support

Castrillón, Omar D., Sarache, William, & Ruiz-Herrera, Santiago. (2020). Predicción del rendimiento académico por medio de técnicas de inteligencia artificial. Formación universitaria, 13(1), 93-102.

Peach, R. L., Yaliraki, S. N., Lefevre, D., & Barahona, M. (2019). Data-driven unsupervised clustering of online learner behaviour. arXiv preprint arXiv:1902.04047.

De-La-Hoz, E. J., De-La-Hoz, E. J., & Fontalvo, T. J. (2019). Metodología de Aprendizaje Automático para la Clasificación y Predicción de Usuarios en Ambientes Virtuales de Educación. Información tecnológica, 30(1), 247-256.

Battaglia, O. R., Di Paola, B., & Fazio, C. (2015). Cluster Analysis of Educational Data: an Example of Quantitative Study on the answers to an Open-Ended Questionnaire. arXiv preprint arXiv:1512.08998.

Salles, I., Mejia-Domenzain, P., Swamy, V., Blackwell, J., & Käser, T. (2024). Interpret3C: Interpretable Student Clustering Through Individualized Feature Selection. arXiv

Bravo, M., Salvo S. & Muñoz, C. (2015), Profiles of Chilean students according to academic performance inmathematics: An exploratory study using classification trees and random forests, Studies in Educational Evaluation, 44, 50-59

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