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Guest Editorial

Decision making in Engineering Education using Learning Analytics

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Introduction to the Special Issue

The use of Information and Communication Technologies (ICTs) to support learning processes is currently a regular practice in every academic institution. ICT systems may act as a mere support to traditional classroom teaching, but they also can facilitate the publication and sharing of educational content, completion of online activities and assignments, exchanges of opinions and experiences, etc. ICT-supported learning has been especially successful and relevant in Engineering Education because students are more familiar with the use of technology. Furthermore, ICTs enable the development of specific educational activities that are hardly affordable or feasible in traditional contexts. An interesting aspect of the use of ICT in educational contexts is that student interactions with digital learning technologies leave a trail of their activity that may be associated with learning evidences. IT-based systems store large amounts of data, and the analysis of those data may be helpful for making decisions in order to improve teaching and learning of Engineering Education.

The analysis of these educational data is the main objective of learning analytics tools and methods [1]. The most accepted definition of learning analytics considers that it comprises *"the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs"* [2]. Learning analytics facilitates discovery of "hidden" knowledge about teaching and learning processes (e.g. [1, 3]), and its application is particularly relevant in Engineering Education, as many learning processes include computer-assisted activities. Therefore, the use of learning analytics allows learners and instructors to obtain and visualize information about student progress, identify at-risk students, assess the suitability of course content and design, observe student, teacher and group interactions, etc.[4]. Institutions and instructors may then use that information to plan interventions and make the necessary changes so as to help students, redesign courses, adapt learning content and methods, etc., in order to improve the whole learning process and experience [5].

Therefore, learning analytics comprises a set of powerful tools to help students improve their learning, assist educational institutions in improving their educational processes, and give instructors additional means to improve their teaching (e.g. [6, 7]). This special issue provides a broad overview of different learning analytics methods, tools and experiences, and success stories and case studies, with emphasis on the impact of application of learning analytics for decision making in the specific context of Engineering Education. The special issue gathers together a total of 13 contributions around the application of learning analytics in Engineering Education covering a large diversity of topics, such as competence-based learning analytics, data visualization, machine learning, instructional design, data sources, or future directions and new paths for learning analytics in Engineering education.

Contents of the Special Issue

This section provides an overview of the different research studies included in this special issue. The contributions pivot around different topics of interest in learning analytics: evaluation of factors affecting the use and success of learning analytics; learning analytics to understand, visualize and predict student behavioral patterns, performance and learning outcomes; peer-assessment, formative assessment and competence-based assessment; and identification of learning problems, with emphasis in student attainment.

Assessment Factors Affecting E-Learning Using Fuzzy Analytic Hierarchy Process and SWARA (Turam) analyzes the application of different methods to explore the factors affecting success of e-learning technologies in engineering education. More specifically, the article explores e-learning applications used in industrial engineering education. With the help of experts, the research identifies five success factors: infrastructure, content, learner interface, quality and techniques, divided into twenty-four sub-factors. Assessment of the relevance of each factor uses analytic hierarchy process (AHP) and step-wise weight assessment ratio analysis (SWARA). The study illustrates how multi-criteria decision-making methods can be used in e-learning applications to evaluate different success factors and identify the importance of the different factors in the application of e-learning technology in Engineering Education.

Hybrid intelligent system to predict the individual academic performance of engineering students (Jove, López-Vázquez, Fernández-Ibáñez, Casteleiro-Roca, & Calvo-Rolle) studies low academic performance in industrial engineering degrees. Their research explores the relation between student admission data and student performance, and builds a model to predict successful course completion. The authors propose a hybrid model based in regression techniques to predict student outcomes based on their choice of courses and when they take those courses. The model achieves a good degree of accuracy, and may be used to help students identify the courses that might be more challenging for them during their studies.

Predicting students' grade based on social and content interactions (Lucero Sánchez López, Díaz-Redondo, & Fernández-Vilas) uses data about student interactions with a learning management system to provide early prediction of students' final grades in Telecommunication Engineering. The research proposes a conceptual framework that includes the definition of five different profiles, reflecting different approaches based on interpersonal interaction and interaction with content. The multiple linear regression analysis of data about student interactions from the Moodle learning management system database shows that prediction on the eighth week provides better results than measures taken at a later time even though the authors warn that the selection of the prediction point should be determined for each course, as it strongly depends on the instructional design of the course.

The Student's Progress Snapshot a hybrid text and visual Learning Analytics Dashboard (Amo, Alier, & Casañ) presents a learning analytics tool that facilitates tracking of student activity in Moodle. The analytics tool may be applied in any educational context that includes the use this popular learning management system. The tool works as software-as-a-service, facilitating its adoption by educational institutions, and provides chart visualizations of students' learning evidence and texts that describe the meaning and interpretation of this charts. The authors test the tool with 30 teachers to validate the results, receiving a positive feedback about the functionalities included.

Learning Process Analysis using Machine Learning Techniques (Fernández-Robles, Alaiz-Moreton, Alfonso-Cendón, Castejón-Limas, & Panizo-Alonso) uses machine learning techniques to evaluate the learning-teaching process in Engineering and Non-Engineering courses. The study uses discriminant analysis and data visualization supported by multidimensional scaling to visually interpret information about student learning behaviors. The authors explore the impact of method changes in blended learning and, upon the data analysis, the research identifies three different learning patterns, with varying degrees of attitudes toward the use of Moodle systems for blended learning processes.

Metrics for Estimating Validity, Reliability and Bias in Peer Assessment (Molina-Carmona, Satorre-Cuerda, Compañ-Rosique, & Llorens-Largo) addresses peer-review assessment in engineering education, and identifies the main problems associated with this assessment method. The study focuses on validity, reliability and bias of individual reviewers. The authors compare how reviewers behave during peer review processes and the operation of an automatic classifier. By doing so, the study translates the results from evaluation of the quality of automatic classifiers to assess the quality of peer review. The research tests this method in an engineering education context, making it possible to identify indicators about how reviewers develop their work and to establish different reviewer profiles. The results of the analysis facilitates the proposal of corrective actions to solve problems associated with peer assessment.

Learning Analytics for Formative Assessment in Engineering Education (Menchaca, Guenaga, & Solabarrieta) uses learning analytics to evaluate competence assessment of engineering students. The research uses two related case studies to show how to perform assessment of the project management competence. The first study compares automatic assessment using learning analytics and manual assessment by instructors, while the second study develops an evaluation model for formative assessment based on data collected from Gantter and Google Docs. The research finds that selection of technological tools that allow student activity data mining is essential for the assessment of competences using learning analytics, and recommends informing students about activity logging and to have their consent to use educational data in order to effectively use learning analytics. Finally the authors advocate for data standardization to facilitate data processing and generalizability of results in other instructional scenarios.

EvalVis: Enriching Formative Assessment with Visual Learning Analytics (Villamañe, Álvarez, & Larrañaga) presents a visualization system (EvalVis) to enhance feedback based on rubric assessment and visual learning analytics of Computer Engineering students. The visualizations in EvalVis follow a design based on the identification of visualization needs of students and teachers. The system provides students with information about their individual learning process and performance, both at individual and group levels. The tool may also be used by instructors to monitor groups of students and compare their evolution and performance. Following a detailed explanation of the design principles and main functionalities of EvalVis, the authors test whether the tool covers the different visual and functional requirements demanded by learners and instructors, finding that the system successfully covers their assessment data visualization requirements, offering them the information they need to reflect about their learning and teaching processes in order to improve them. The preferred visualizations are context-dependent, but visualizations that the users are more familiar with are preferred to the ones containing more information.

Relationship between Specific Professional Competences and Learning Activities of the Building and Construction Engineering Degree Final Project (Peña, Fonseca, Martí, & Ferrándiz) investigates how competences demanded by companies fit with the competences developed by students in their final degree projects (FDP). The study uses academic analytics techniques using information from a Building and Construction Engineering Degree in one Spanish University, complemented by two surveys. The authors study and identify the main variables and learning activities affecting FDP grade. They also present the results of two surveys: an initial one conducted nation-wide, and a replication of the survey applied to a local context. With the help of these surveys, the research identifies the main professional competences of Building Engineering degree students demanded by the labor market, that should be acquired and evidenced by students during their FDP. From the comparative analysis, the authors conclude that there is a need for changes in the current FDP structure, and that more relevance should be given to certain learning activities that help students to develop competences identified as essential by companies.

Using Learning Analytics to Detect Authentic Leadership Characteristics in Engineering Students (Sein-Echaluce, Fidalgo-Blanco, Esteban-Escaño, Gracía-Peñalvo, & Conde) focuses on identifying authentic leadership in teamwork activities. The study analyses the behavior of team members during a teamwork project using a learning analytics tool. The authors complement and validate their analysis with an authentic leadership questionnaire to 78 team members. The results of both instruments show that there is a positive correlation between leadership and student grades. The research also finds that the information collected by the learning analytics tool may be used to predict leadership behavior. Information such as the number of messages correlates with different leadership behaviors: transparency, ethic modal and balanced processing.

Uncovering Flipped-classroom Problems at an Engineering Course on Systems Architecture through Data-driven Learning Design (Estévez-Ayres, Arias Fisteus, Uguina-Gadella, Alario-Hoyos, & Delgado-Kloos) presents a case study of a flipped-classroom undergraduate engineering course. The analysis mixes quantitative data from student opinions and qualitative data extracted from the command-line interface of a simulation tool, C-mulator, and student grades. The findings suggest that delay in the time to complete course activities tends to drive courses towards traditional approaches, but devoting some time to explain the most difficult concepts can help students to be more efficient with their work at the cost of losing some of the spirit of the flipped classroom. The results also suggest that students are strongly mark- and deadline-oriented, and therefore even small grading of activities encourages them to work on the assignments.

Using Bayesian Networks for Learning Analytics in Engineering Education. A Case Study on Computer Science Dropout at UCLM (Lacave & Molina) describes a methodology aiming to lower student dropout in Engineering Education, using Bayesian networks to represent, interpret and contextualize data of a Computer Science Engineering degree. The analysis shows that data heterogeneity translates into poor fit of the model, and suggest that the K2 and PC algorithms provide higher accuracy of results. The results also suggest that gender and admission grade do not affect student dropout, but the number of years of enrolment and access method are related to dropout rates.

Utilisation of Learning Outcome Attainment Data to Drive Continual Quality Improvement of an Engineering Programme: A Case Study of Taylor's University (Namasivayam & Fouladi) explores the role of learning and academic analytics and its application in the design and modeling of Outcome-Based Education, using a case study of three engineering degrees. The research details the use of learning outcome data to inform academic management in order to make decisions to improve academic programmes, and investigates the extent to which Continuous Quality Improvement programs enhance student learning experience, in terms of higher retention rates. The article further describes the methodology and process to generate learning outcome data using an ICT tool developed for this purpose. The results show an overall increase in graduation rates and in the number of modules with students achieving all learning outcomes within a module. The results also seem to confirm that using learning outcome data for CQI processes can improve student learning, measured as graduation rates and pass rates.

Concluding remarks

The articles included in this special issue showcase the current state and advances in learning analytics for decision making in Engineering Education. The variety of the contributions offers a sample of the many different aspects of learning analytics, including institutional design and deployment of learning analytics, development of data extraction/analysis tools and visualization software, predictive algorithms, assessment methods, etc.

It is worth noting that the selection of studies follows the directions proposed by Conde and Hernández-García [8], who gave a wake-up call for researchers about pending issues in the discipline. Nonetheless, the scope of learning analytics is broad, and many other needs and opportunities still need to be addressed by future research [9].

However, it is particularly concerning that, despite the gradual consolidation of learning analytics as a discipline and the initiatives to incorporate these tools and techniques to Engineering Education, it is still being driven mostly from a purely technical approach –i.e. data-mining systems and algorithms, development of software tools, etc. This approach accounts just for one half of what learning analytics is about, leaving out most of the central aspect of learning analytics: learning itself [10].

Therefore, in the spirit of Conde and Hernández-García [8], let this be a new wake-up call to expand the boundaries of learning analytics and incorporate educational researchers to the process. Only working side by side may educational researchers and data scientists make use of all the possibilities of learning analytics, and create powerful tools for the improvement of learning in general, and of Engineering Education in particular. And only acknowledging the importance of **learning** in *learning analytics* will we be able to develop and use effective learning analytics for educational decision-making.

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