Collaborative Learning Platform Using Learning Optimized Algorithms

Beatriz Flamia Azevedo[1,2(✉)], Yahia Amoura[1], Gauhar Kantayeva[3], Maria F. Pacheco[1,4], Ana I. Pereira[1,2], and Florbela P. Fernandes[1]

[1] Research Centre in Digitalization and Intelligent Robotics (CeDRI), Instituto Politécnico de Bragança, 5300-252 Bragança, Portugal
{beatrizflamia,yahia,pacheco,apereira,fflor}@ipb.pt
[2] Algoritmi Research Centre, University of Minho, Campus Azurém, 4800-058 Guimarães, Portugal
[3] Kaunas University of Technology, 44249 Kaunas, Lithuania
m306563@ipb.pt
[4] Center for Research & Development in Mathematics and Applications CIDMA, University of Aveiro, Aveiro, Portugal

Abstract. Aware that the lack of mathematical knowledge and skills is a major problem for the development of a modern, inclusive and informed society, the MathE partnership has developed a tool that is aimed at bridging the gap that moves students away from courses that rely on a mathematical core. The MathE collaborative learning platform offers higher education students a package of scientific and pedagogical resources that allow them to be active agents in their learning pathway, by self-managing their study. The MathE platform is currently being used by a significant number of users, from all over the world, as a tool to support and engage students, ensuring new and creative ways to encourage them to improve their mathematical skills and therefore increasing their confidence and capacities. In order to enhance this platform, a visual representation of the performance of the students is already implemented, based on the recorded performance historic data for each student. This paper contains a literature review about the implementation of data mining techniques in education, followed by a description of the features of the MathE learning system and suggestions of data parameters to support the improvement of the students' performance. Future work includes the application of optimization and learning algorithms so that the MathE platform will have a dynamical structure and act as a virtual tutor for the users.

Keywords: Pedagogical innovation · E-learning platforms · Learning algorithms · Collaborative learning

1 Introduction

In an era when the Internet and digital resources in general are forcing all levels of the teaching system to reinvent themselves, it becomes necessary and urgent

A. I. Pereira et al. (Eds.): OL2A 2021, CCIS 1488, pp. 691–702, 2021.
https://doi.org/10.1007/978-3-030-91885-9_52

to implement changes in teaching and learning processes [18], namely in what concerns Mathematics. In fact, taking into account the demands of our rapidly changing technological society, Mathematics is considered a fundamental area for the construction of a sustainable knowledge economy, one of the great societal challenges of our time.

It is well known that, on their arrival to university, a significant number of students lack the basic skills to effectively follow their courses in areas that rely on a strong mathematical background [15].

In order to engage and motivate those students (actually, all students), it is vital to innovate pedagogical methodologies and improve the quality of lessons that are usually taught in a conventional manner.

The MathE platform aims to make a step forward and provide all agents of the higher education system with an opportunity to reinvent some aspects of teaching and learning, offering them the possibility of building individual study pathways, suited to the specific skills and features of each student, teaching each of them to manage their learning. Aware of the importance of understanding students' individual types and needs, the MathE consortium is focused on the promotion of student-centered learning, providing a database of resources and a dynamical pool of tests that allow students to organize their study of mathematics at their own pace. In this way, MathE moves from a standard approach to tailored academic paths that fit the individual needs of the students.

Another asset of MathE is the possibility to offer free online learning to students in developing countries, without access to on-site classes, allowing them to gain new expertise. As a free personalised tool for distance learning or a complement for tradicional classroom dynamics, MathE contributes to improve distance learning and suplement live instruction, thus helping to reduce dropout rates in higher education and enabling empowering, equity-focused alternatives to students who are marginalized by race, income, language, home country or other factors.

An additional perspective that is worth reflexion has to do with the pandemic that the whole world is facing. The disruptions created by COVID 19, in all areas of life, require new approaches: values have shifted as a result of the pandemic and institutions were forced to adapt to the circumstances and conditions it dictated. It is expected that digitalisation expands, forcing people to rethink, innovate, acquire new skills and develop new strategies. The transition to digital in higher education was immediate and MathE can work as a valuable contribution to its consistency and sustainability over time.

This paper intents to present the trends in higher education involving learning and optimization algorithms to identify the personalized learning paths and identify some strategies to be applied on MathE platform.

The rest of this paper is organized as follows. In Sect. 2, a review about learning algorithms in the educational field is presented and, in Sect. 3, the collaborative educational platform MathE is briefly described. In Sect. 4, some enhanced features of the MathE system are presented and, finally, Sect. 5 rounds-up the paper.

2 Application of Data Mining in the Educational Field

For a constructive, fulfilling life project, education represents the main tool that enables the development of individuals' life with excellence. Furthermore, it is considered a fundamental commitment to promote self-confidence and create the necessary conditions to full participation and citizenship in today's world. Meanwhile, different methods of teaching are proposed to enhance learning quality in education. Starting from the fact that computers and mobile devices are used in all stages of daily life, those latter can be a way for student integration with Information and Communications Technologies (ICTs); such tools influence the development of teaching and learning processes by promoting innovative pedagogical actions and creating new learning environments [5,23]. Through a self proper assessment of abilities, an intelligent tutoring system (ITS) helps the students to perform better in their education and brings remarkable satisfaction in the advancement of their competencies, as proven by the study presented in [20]. For instance, an online adaptive learning tool for mathematics titled Mathematics Adaptive Platform PAM (Plataforma Adaptativa de Matemáticas) has been adopted by the Uruguayan educational system. In this context, an empirical strategy relying on some assumptions has been employed to recognize the impact of PAM use on the test score gain in mathematics. Based on longitudinal data from a sample of primary school students, this study reported that the platform has a positive effect on the scores of math test scores.

Furthermore, to enhance the student's performances, data mining techniques were widely employed in education, giving emergence to the concept of educational data mining (EDM). Many studies of EDM have focused on the data mining algorithms related to the prediction of student performances; for this purpose, three main tasks are employed, including classification, regression, and density estimation.

The classifier arranges the class label of the unknown data. The classification is a supervised learning technique consisting of two phases: a learning phase and a classification phase. For this assignment, several algorithms were applied in order to predict the student's performance, as Bayesian Classifier on [8,10], Decision Trees on [3], Support Vector Machine on [12], K-Nearest Neighbor on [22], Artificial Neural Network on [2].

Regression or clustering is one of the statistical methodologies commonly used for educational student performances prediction in which the aim is to achieve a function of independent variables allowing the computation of the conditional expectation of a dependent variable for prediction, based on the reduction of a certain amount of error via an iterative procedure. CART (classification and regression trees) is an example of algorithm that can be applied in this context [25].

Density estimation, another methodology, includes the estimation of probability scores, joint densities, conditional densities, and univariate densities. Among the density estimation techniques used for performance prediction in education are inference, pattern mining, or outlier detection [13].

Table 1 compares some research based on the predictive accuracy using the techniques listed above.

Table 1. Comparison between some EDM techniques in terms of prediction accuracy.

Ref	Methods	Accuracy obtained
[16]	Bayesian Classifier	98.86%
[24]	Support Vector Machine	97.98%
[11]	Artificial Neural Network	96.00%
[24]	k-Nearest Neighbor	84.04%
[21]	Classification and Regression Trees	98.30%

Educational data mining has become an evolving discipline, which focuses on developing methodologies for exploring large data sets from educational situations and then using these methodologies to better understand students' competencies.

Although educational data may be derived from learners' use of an interactive or computer-based collaborative learning experience or from data collected administratively from schools and universities, it usually has several levels of hierarchization, usually identified by the properties of the data itself, rather than in advance of it. Matters of time, sequence and background also play an important role in the study of educational data.

The evolution of the Web and communication technologies has increasingly attracted e-learning platforms and the massive storage of educational data. The notion of "big data" describes a large scale of information-rich data in various types of media, networks and other supports. In particular, education big data is a subarea of big data, which refers to data in education. However, analyzing and effectively using all the data to improve the online educational quality is an issue in the field of big data in education (BDE); indeed educational data mining (EDM) is an efficient and practical method and a way to perform BDE. Figure 1 illustrates the principle of the EDM in e-learning platforms based on BDE.

Formerly, educational data mining algorithms were not just being employed for the prediction of student performances, but rather, the EDM was used for: a survey of the instructor's performance [1], engineering education [4], physical education [26], English language education [14]. Some data mining studies have highlighted the impact of e-learning activities on the students' learning development in mathematics [9].

In order to achieve efficient e-learning in mathematics, an adapted software and well-known learning concepts and theories are required so that the right mathematical content to satisfy the learners' needs and the teachers' overall intentions is created. Among the identified mathematics e-learning platforms, the Mumie toolkit [7], is an example of a free platform for mathematics and

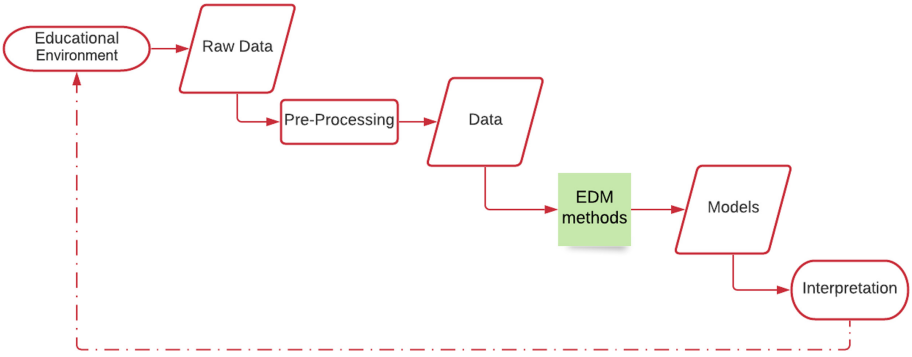

Fig. 1. EDM in e-learning platforms based on big data.

computer science education and teaching for higher education that integrates students, lectures and tutors. Another example is the platform Assessment and Learning in Knowledge Spaces (ALEKS) [6], a payed web-based assessment and learning system based on machine learning; ALEKS uses interactive quizzes to quickly and carefully determine what a student understands and does not understand in a course.

3 The Particular Case of the MathE Platform

The MathE platform is a free collaborative e-learning platform (mathe.pixel-online.org) with an associated YouTube channel called MathE Project, where students and teachers can have access to many valuable resources related to several mathematical areas taught in higher education courses. The MathE platform was created with the aim of encouraging the implementation of innovative methodologies through digital tools and to offer teachers and students a new way to teach and learn mathematics presented in higher education courses. The main goal of the platform is to provide a stimulating and engaging environment for the students to learn and practice mathematics outside or inside the classroom, with or without the presence of the teacher, whenever they wish and at their individual pace [17]. Next, the platform will be briefly described and the features and experiences from the users point of view will be deepened.

3.1 The MathE Platform Features

MathE was initially developed and implemented by a consortium of seven institutional partners: Polytechnic Institute of Bragança (Portugal), Limerick Institute of Technology (Italy), University of Genova, Pixel (Italy), Kaunas University of Technology (Lithuania), Technical University of Iasi (Romania) and EuroED (Romania) [19]. However, nowadays the platform has the collaboration of many other institutions around the world, more precisely 21 institutions from 12 countries. It is important to remark that, besides the users registered in the MathE

portal, there are more users from countries like India, Philippines and Egypt taking into account the information obtained from the YouTube channel.

Currently the platform covers the fourteen most classical mathematical topics addressed in graduation courses: Analytic Geometry, Complex Numbers, Differential Equations, Differentiation (including 3 subtopics: Derivatives, Partial Differentiation, Implicit Differentiation and Chain Rule), Fundamental Mathematics (2 subtopics: Elementary Geometry and Expressions and Equations), Graph Theory, Integration (2 subtopics: Integration Techniques and Double Integration), Linear Algebra (5 subtopics: Matrices and Determinants, Eigenvalues and Eigenvectors, Linear Systems, Vector Spaces and Linear Transformations), Optimization (2 subtopics: Linear Optimization and Nonlinear Optimization), Probability, Real Functions of a Single Variable (2 subtopics: Limits and Continuity and Domain, Image and Graphics), Real Functions of Several Variables (1 subtopic: Limits, Continuity, Domain and Image) and Statistics.

The MathE platform is organized into three main sections: *Student's Assessment*, *MathE Library* and *Community of Practice*, as presented in Fig. 2.

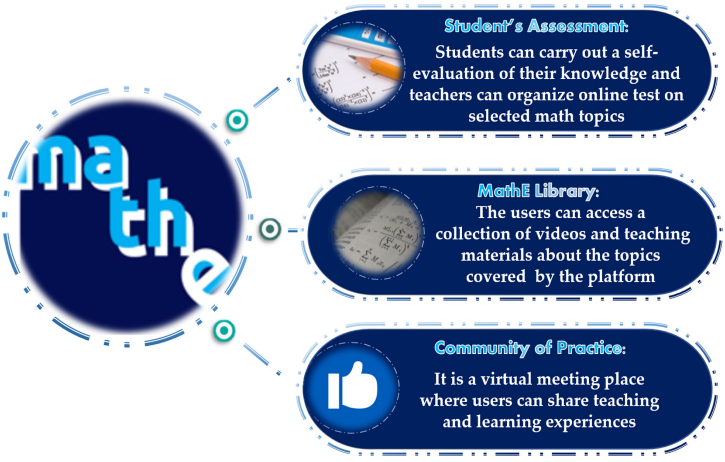

Fig. 2. Sections available on the MathE platform

The section *Student's Assessment*, is composed of multiple choice questions divided into topics, with two difficulty levels (basic and advanced); students can practice and self-assess their skills on the *Self Need Assessment*, and teachers can evaluate the students performance on the *Final Assessment*. The main goal of the Student's Assessment section is to provide the student with an opportunity to practice a certain topic that he/she enrolled; after that, the teachers can evaluate if this topic was effectively understood by the student.

In the section *MathE Library*, the users have access to valuable and diversified materials related to the topics and subtopics covered by the platform, such as videos, lessons, exercises, training tests and other formats [17]. All the resources

make a point of being concise, appealing and having the ability to help students and teachers to focus on particular aspects of the covered subjects.

Finally, the section *Community of Practice* provides a place where teachers and students have the opportunity to interact on an ongoing basis, sharing common concerns, problems and interests, coming together to fulfill their common goals, thus consolidating a strong network community.

Through digital interactive technologies, the MathE platform offers a different way to encourage students to develop effective learning strategies, more dynamic and at the same time less exhaustive than traditional methods. The platform is permanently available, enabling autonomous and distance study, whenever the users wish to use it.

3.2 MathE End Users

The MathE end users are mainly students and teachers. The main goal of the platform is to help students improve knowledge in the field of mathematics while providing the teachers with a virtual space where they can share methodologies, ideas and strategies to improve the way they teach mathematics.

Inside the platform it is possible to have two different types of end users' profiles. Registering as student, the user has access to all the features mentioned above, related with the practice of a certain topic. For users registered as teachers, two situations can occur:

- rely on the portal only to evaluate the students;
- be a contributor to the MathE portal with questions, videos or written resources.

Under this profile, the users (teachers) have access to all the features: the ones that student can access, as well as the parts that students do not have access to.

So far, the MathE portal has almost a thousand registered users under student profile as well as one hundred as teachers.

In terms of impact of this project, it can be said that a large number of questions were already answered by the students, meaning that the platform is actively being used. Also, taking into account the information given by YouTube, the MathE Project channel linked to the MathE platform, has more than 1800 views corresponding to a total time of more than 46 h of visualization. The fact that almost all the materials available in the platform are in English is a big asset to the project since more people outside the consortium and around the world can use all the available resources in their study and benefit from it. In fact, users from countries like Brazil, India, Phillipines or Egypt (outside EU and from three continents) are relying on the MathE resources.

4 Using Data to Obtain a Better Performance

The MathE platform is implemented in such a way that each student has his/her private area. Inside this area the user can check the grades obtained in Final

Assessment for a small period of time, but in the Self Need Assessment (SNA) the student has the grade only right after he/she finished the exam. After this moment, the students do not have access to the grade or to the exam they performed. This is due to the fact that the questions in the SNA can appear more than one time if the student repeat the test about one topic. Therefore, the information grade about the exams is not saved. Since SNA plays a very important role in the MathE portal – the questions in SNA are linked with all the related resources – it is important that the students have a way to check their performance when they use this feature of MathE. Awareness of their previous performance allows the students to make an informed judgment about what they should do next, in their study.

Considering all the previous arguments, a way to check the performance of the users' performances when using MathE platform is now implemented. Based on recorded data about each test taken, the progress of the student, by topic, can be visualized. In Fig. 3 hypothetical data about a student's pathway is shown.

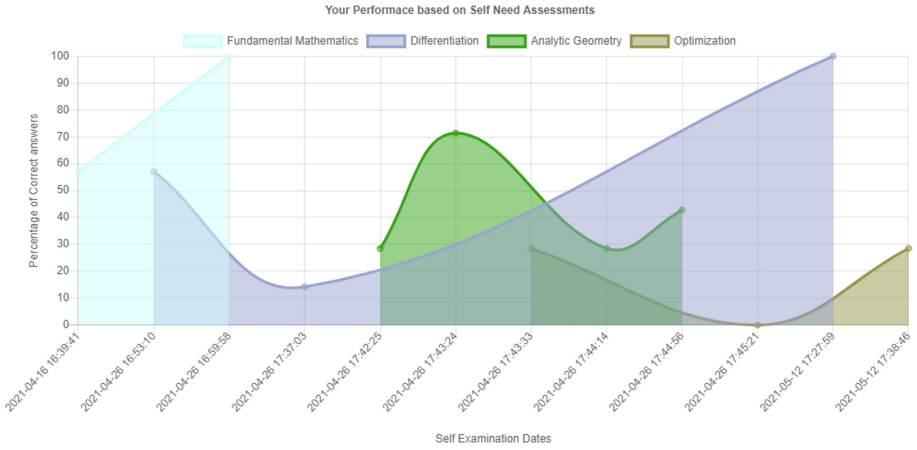

Fig. 3. Student's performance based on Self Need Assessments, per topic.

The results obtained in tests are delivered to the students on the same day the test was performed, so that the students can know whether a certain subject should be further deepened or if the results show a good performance, therefore assuring good comprehension of the topic.

Moreover, the student can track his/her previous overall performance or just one topic each time (see Fig. 4).

The main idea of this implementation is to show the performance in each topic individually, if the student wants to focus on one topic, or to show all the topics and the history data of the student as a whole, to have a global perception of his/her performance. In this way, and looking at the past, the students have one tool that will help them decide what to study next.

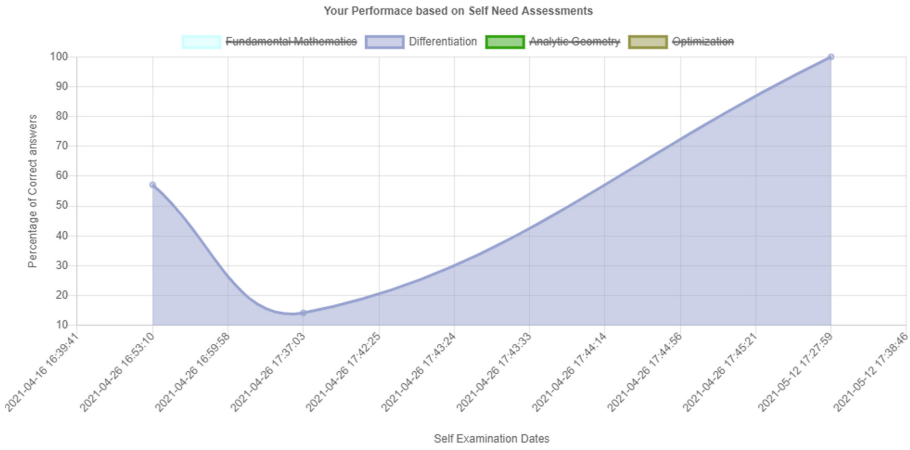

Fig. 4. Student's performance based on Self Need Assessments on one topic.

The MathE is a leap forward with respect to distance education in mathematics but it has a drawback – it is a static platform where the resources are interconnected but it is up to the student to choose their best study pathway. The previous implementation is already an improvement of the initial version of the MathE platform. From the above disadvantage of MathE arises the idea of giving this learning system a dynamical perspective, going further than being a mere repository of videos, written materials and questions but, instead, acting in a proactive way, helping and advising the students in a personalized way.

In a near future, all the MathE materials and questions will have a mark associated to the students community behavior, i.e., if a given question has a higher number of correct answers that means that the question is easily answered by the students community. Therefore, the question level have a dynamic mark according to the students performance on that question. If a given material is analyzed by the majority of the students, that can indicate that the material is useful for the students, in that specify topic. Correlations between corrected answers and teaching/video material can be analyzed. Suggestion of future questions can be performed.

At this moment, this idea is taking form and some previous studies about optimization and learning algorithms are being carried out, the main areas upon which a new intelligent learning system supported on MathE will be developed.

Others indicators will be collected from the student's performance.

5 Conclusion and Future Work

The MathE platform is an educational online system that aims to help students who struggle to learn college mathematics as well as students who want to deepen their knowledge on mathematical topics, at their own pace.

The users have access to written and spoken resources on 15 topics from classical higher education curricula on mathematics as well as a section for self assessment, where the students can test their knowledge.

Besides that, a way to visualize the performance of the student in this self assessment, along time, is already implemented. The objective of this visualization tool is to give the students information on which they can rely in order to optimize the management of their study.

This platform behaves statically since it does not orient the students in a personalized way. In order to overcome this weakness of the MathE system, and as future work, methods and techniques from optimization and learning will be overviewed and applied in the educational data mining context; the platform will serve as a virtual tutor that will advise the student about the steps he/she should take to pursue the best possible learning path, taking into account his/her individual characteristics.

E-learning has already operated a transformation in higher education and software platforms such as MathE are an opportunity to make learning more accessible, deepen student engagement and allow teachers to shift to a student-centered pedagogical model.

Acknowledgements. This work has been supported by FCT - Fundação para a Ciência e Tecnologia within the Project Scope: UIDB/05757/2020 and Erasmus+ Programme project n. 2018-1-PT01-KA203-047361.

References

1. Agaoglu, M.: Predicting instructor performance using data mining techniques in higher education. IEEE Access **4**, 2379–2387 (2016). https://doi.org/10.1109/access.2016.2568756
2. Amrieh, E.A., Hamtini, T., Aljarah, I.: Mining educational data to predict student's academic performance using ensemble methods. Int. J. Database Theory Appl. **9**(8), 119–136 (2016). https://doi.org/10.14257/ijdta.2016.9.8.13
3. Asif, R., Hina, S., Haque, S.I.: Predicting student academic performance using data mining methods. Int. J. Comput. Sci. Network Secur. **17**(5), 187–191 (2017). https://doi.org/10.1109/iccons.2018.8663197
4. Buenaño-Fernandez, D., Villegas-CH, W., Luján-Mora, S.: The use of tools of data mining to decision making in engineering education—a systematic mapping study. Comput. Appl. Eng. Educ. **27**(3), 744–758 (2019). https://doi.org/10.1002/cae.22100
5. Bulman, G., Fairlie, R.W.: Technology and education: computers, software, and the internet. In: Handbook of the Economics of Education, vol. 5, pp. 239–280. Elsevier (2016). https://doi.org/10.3386/w22237
6. Craig, S.D., et al.: Learning with aleks: the impact of students' attendance in a mathematics after-school program. In: International Conference on Artificial Intelligence in Education, pp. 435–437. Springer (2011). https://doi.org/10.1007/978-3-642-21869-961
7. Dahlmann, N., Jeschke, S., Rassy, T., Seiler, R., Sinha, U.: Mumie: Platform and authoring environment for mathematics. Europ. J. Open Distance E-Learning (EURODL) (2005). https://doi.org/10.1007/0-306-47532-47

8. Devasia, T., Vinushree, T., Hegde, V.: Prediction of students performance using educational data mining. In: International Conference on Data Mining and Advanced Computing (SAPIENCE), pp. 91–95. IEEE (2016). https://doi.org/10.1109/sapience.2016.7684167
9. Falakmasir, M.H., Habibi, J.: Using educational data mining methods to study the impact of virtual classroom in e-learning. In: Educational Data Mining 2010. ERIC (2010). 10.18297/etd/2758
10. Galván, P.: Educational evaluation and prediction of school performance through data mining and genetic algorithms. In: Future Technologies Conference (FTC), pp. 245–249. IEEE (2016). https://doi.org/10.1109/ftc.2016.7821617
11. Hooshyar, D., Pedaste, M., Yang, Y.: Mining educational data to predict students' performance through procrastination behavior. Entropy **22**(1), 12 (2020). https://doi.org/10.3390/e22010012
12. Kadambande, A., Thakur, S., Mohol, A., Ingole, A.: Predict student performance by utilizing data mining technique and support vector machine. Int. Res. J. Eng. Technol. **4**, 2818–2821 (2017). https://doi.org/10.1142/9789813229693_0017
13. Kumar, A.D., Selvam, R.P., Kumar, K.S.: Review on prediction algorithms in educational data mining. Int. J. Pure Appl. Math. **118**(8), 531–537 (2018). https://doi.org/10.5373/jardcs/v12sp7/20202265
14. Lu, M.: Predicting college students English performance using education data mining. J. Comput. Theor. Nanosci. **14**(1), 225–229 (2017). https://doi.org/10.1166/jctn.2017.6152
15. N.S.F.: Enough with the lecturing (2014). https://nsf.gov/news/. National Science Foundation - accessed May, 2021
16. Nurhachita, N., Negara, E.S.: A comparison between naïve bayes and the k-means clustering algorithm for the application of data mining on the admission of new students. Jurnal Intelektualita: Keislaman, Sosial dan Sains **9**(1), 51–62 (2020). https://doi.org/10.35940/ijeat.c5414.029320
17. Pacheco, M.F., Pereira, A.I., Fernandes, F.: Mathe - improve mathematical skills in higher education. In: Proceedings of the 2019 8th International Conference on Educational and Information Technology (ICET2019), pp. 173–176. United Kingdom (2019). https://doi.org/10.1145/3318396.3320116
18. Pedró, S., Rivas, V.: Artificial intelligence in education: challenges and opportunities for sustainable development. UNESCODOC Digital Library (2019). https://unesdoc.unesco.org/ark:/48223/pf0000366994. Accessed May 2021
19. Pereira, A.I., et al.: Developing tools for the e-learning platform mathe. In: Conference Proceedings of the 10th International Conference The Future of Education, pp. 327–332. Virtual Edition (2020)
20. Perera, M., Aboal, D.: The impact of a mathematics computer-assisted learning platform on students' mathematics test scores. Merit working papers, United Nations University - Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT) (2018)
21. Saheed, Y., Oladele, T., Akanni, A., Ibrahim, W.: Student performance prediction based on data mining classification techniques. Niger. J. Technol. **37**(4), 1087–1091 (2018). https://doi.org/10.4314/njt.v37i4.31
22. Sajadin, S.: Zarlis: prediction of student performance by an application of data mining techniques. In: International Conference on Management and Artificial Intelligence, vol. 6. ICMAAI (2011). https://doi.org/10.1109/aimsec.2011.6010697

23. Sung, Y.T., Chang, K.E., Liu, T.C.: The effects of integrating mobile devices with teaching and learning on students' learning performance: a meta-analysis and research synthesis. Comput. Educ. **94**, 252–275 (2016). https://doi.org/10.1016/j.compedu.2015.11.008
24. Tekin, A.: Early prediction of students' grade point averages at graduation: a data mining approach. Eurasian J. Educ. Res. **54**, 207–226 (2014). https://doi.org/10.14689/ejer.2014.54.12
25. Waheed, H., Hassan, S.U., Aljohani, N.R., Hardman, J., Alelyani, S., Nawaz, R.: Predicting academic performance of students from vle big data using deep learning models. Comput. Hum. Behav. **104**, 106189 (2020). https://doi.org/10.1016/j.chb.2019.106189
26. Zhu, S.: Research on data mining of education technical ability training for physical education students based on Apriori algorithm. Clust. Comput. **22**(6), 14811–14818 (2018). https://doi.org/10.1007/s10586-018-2420-8