Reproducibility of Published Educational Recommendation Systems: Systematic Review

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Abstract. The purpose of this paper is to conduct a systematic review of the available literature on explainable recommendation systems in education and their reproducibility, particularly when recommendations are integrated as part of learning management systems. The first part of the paper's methodology employs an NLP-powered toolkit that automates a large portion of the review process by automatically analyzing articles indexed in the IEEE Xplore, PubMed, Springer, Elsevier, and MDPI digital libraries. A quantitative review of all available literature is carried, followed by a qualitative review of the few selected articles that do indeed focus on the explainability approach when implementing recommendation systems. The relevant articles are thoroughly analyzed and compared based on a variety of indicators such as the purpose of the recommendations, tools and techniques used, and whether the research is easy or hard to reproduce. The findings show that, while the amount of available research is increasing and new learning management systems are continuously being developed in recent years, the explainability of the machine learning techniques used in recommendation systems isn't a primary focus among researchers and developers, and the scope of the available literature is quite limited.

Keywords: LMS · recommendation systems · explainable recommendation systems · reproducible recommendation algorithms · systematic review.

1 Introduction

Many educational institutions have used online, remote, and distance learning since the Internet's stability and availability enabled it. Many online learning platforms have emerged in the last ten years, with some gaining massive popularity and being used on a daily basis by millions of people (students, educators, etc.). Udemy, EdX, Codecademy, Pluralsight, and Brilliant are a few examples.

The recent global pandemic forced all schools around the world to close their doors and all students and teachers to stay at home. This not only increased the number of people navigating toward some of the previously mentioned digital learning platforms to acquire new skills and knowledge, but it also resulted in the appearance of numerous new platforms. Some are designed for a global audience, while others are designed exclusively for educational institutions' students. These new platforms provide entirely new ways and possibilities than what people have been doing for centuries. These new educational approaches are still to be evaluated for long-term effectiveness as today's students become the driving force of the working society. However, because everything students do in an online environment can and frequently is measured, various insights and conclusions are frequently published. We now have a much better understanding of what works best in these digital platforms, how students and teachers react to certain features, and how achievement and satisfaction of both reflected the shift from offline to online education than we did just two years ago, before the pandemic.

Because the number of courses, materials, and activities available in these online learning platforms is massive, and no single student can possibly complete everything, these platforms frequently include some kind of guidance. The guidance is most commonly implemented in the form of recommendation systems, which constantly recommend what the next step in the learning process should be based on the student's interests, past activities, and community trends. These recommendation systems are frequently "black boxes," which means they are implemented using various machine learning techniques and it is impossible to determine why a particular activity is recommended to a specific student [25]. This is problematic because, in order to be beneficial, recommended content must be tailored to each individual user. In recent years, there has been a shift away from traditional recommendation systems toward the creation of explainable recommendations. Explainable recommendation systems are powered by algorithms that allow for the backtracking of why a specific activity is being recommended - whether it is similar to other activities, whether it is a neighbor-driven decision, and which user's activities lead to the recommendation.

This paper will present a review of all published research in the last 12 years on explainable recommendation systems as part of learning management systems. Explainable machine learning can be used in a variety of contexts, and the purpose of this paper is to examine its application in the educational setting, with the goal of improving students' learning process and experience. This paper is organized into four sections. The first section is an introduction, which outlines the motivations for this topic. The methodology section follows, in which we explain the process and tools we used to gather the necessary information, as well as the research approach we chose. Section 3 will summarize the findings. First, a quantitative analysis of all relevant articles found on our topic of interest in the previous 12 years is presented, followed by a qualitative analysis of the most relevant articles. Finally, in section 4, we summarize our findings and discuss the future work we will be able to do as a result of this research.

2 Methodology

To identify the work that has already been completed on our topic of interest, we will use an NLP toolkit designed for automating systematic, scoping, and rapid reviews [24]. This tool requires a structured input of data consisting of keywords, properties, property groups, required relevance, included sources, and beginning and ending years. Keywords, as input parameters, serve as search terms for the available libraries. The properties are words or phrases that must appear in the article's title, abstract, and keywords. They are organized into property groups to address synonyms and variants of the same phrase (i.e. recommender systems and recommendation systems). Each property group must be represented in the title or abstract of the paper for it to be included in the results. In this manner, the properties serve as a secondary filter for discovering relevant articles. Relevance is configured using a dedicated input parameter, which is an integer that specifies the minimum number of occurrences of each property group for an article to be considered relevant. In our case, the relevance setting was set to 2. This means that words or phrases from at least 2 property groups must be presents in the article's title or abstract for it to be considered relevant. The parameter value of 2 has shown to be the most accurate one from multiple reasons. Relevance 2 means that at least 2 of the provided properties need to be found in the article's title and/or abstract for it to be considered relevant. Lowering this parameter's value to 1 results with a huge amount of papers included in the result set which are totally irrelevant and just happened to contain some of the provided keywords. Rising the value to 3 and more is just too big restriction and the number of articles included in the result set is very low, if any. The scope of the returned articles is also constrained by the required input parameters: beginning and ending years. There is a comprehensive description of all input parameters in the original paper [24]. The toolkit first connects to the WordNet application to find synonyms for all input parameters, allowing for a more thorough analysis and ensuring that no papers are overlooked. The toolkit then conducts a search of the selected libraries, such as IEEE Xplore, PubMed, Springer, Elsevier, and MDPI. Each of these libraries has a maximum number of retrievable articles. Springer provides a minimum of 1000 articles or 50 pages of results, whichever comes first, all of which are sorted by relevance. Other libraries have a cut-off ranging from 2,000 articles to all existing articles, meaning that the analysis includes all relevant articles on the searched topic.

PRISMA, the "Preferred reporting items for systematic reviews and meta-analyses - PRISMA statement" [17], [18] is the methodology used for selecting and processing the articles. The PRISMA methodology aims to standardize these types of surveys. It begins by collecting articles based on a particular criterion (such as a keyword), then removes duplicates and discards irrelevant articles (invalid publication period, missing meta-data, inaccessible abstracts, etc.). The utilized NLP toolkit eliminates duplicates by comparing the DOI number of the article, so that the same article available in multiple libraries is only considered once. Our search criteria yielded a total of 29912 results from the toolkit. It was discovered that there were 3455 duplicates throughout the various libraries.

Another 8613 articles were found and removed from consideration because they lacked the necessary data or accessibility. Following the application of the remaining filters, including date, property groups, and relevance, an additional 17480 articles were removed from consideration. In the end, the result from using the NLP toolkit produced a total of 364 research papers and articles that were pertinent to further investigation. The comprehensive PRISMA workflow regarding the present research topic is depicted in Fig. 1.

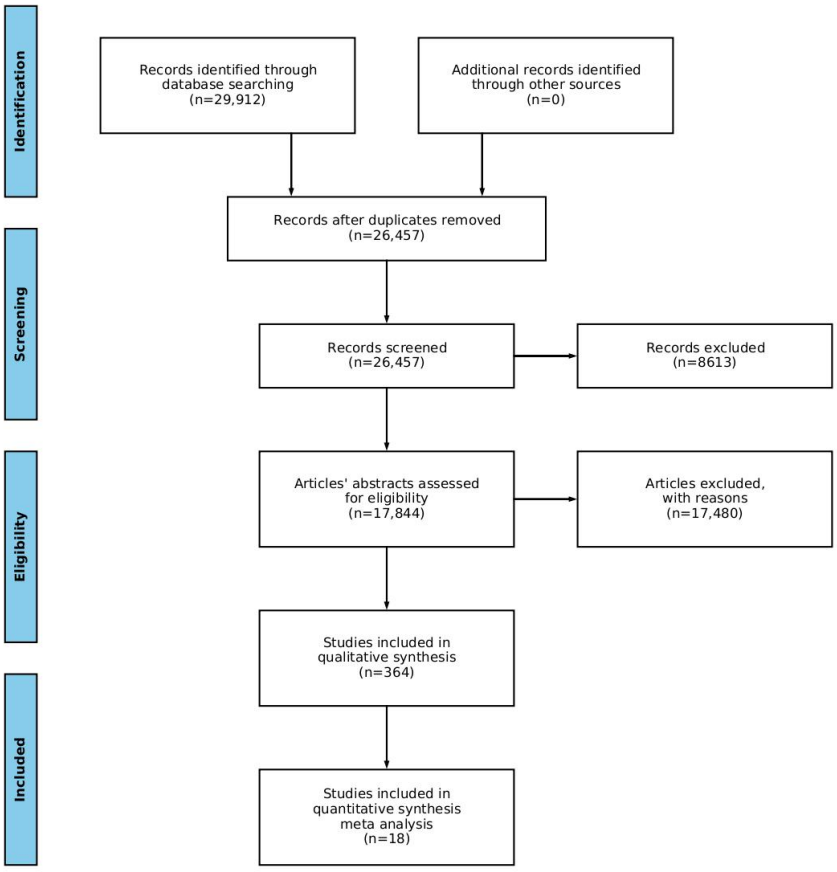

Fig. 1. Workflow of the PRISMA statement for the current research topic.

These articles served as the starting ground for a quantitative analysis of the existing body of research on explainable and reproducible recommendation algorithms that was carried out. In order to get a better idea of the trends that are currently being followed by researchers working in this area, we conducted a

research about the number of articles that have been discovered over the years and which contain particular keywords. In the next section, graphs are used to illustrate the findings. After this was finished, a qualitative investigation of a subset of the 364 articles was carried out. We wanted to ascertain whether or not the research presented in the articles was pertinent to educational recommendation systems and whether or not the methodologies described in the paper are both explicable and reproducible. Articles were included in the qualitative analysis after manual inspection of their relevance to the topic. This manual process of filtering out the articles that are not relevant consisted of reading through each of the 364 article's abstracts and deciding whether each one of them is relevant to the topic of this research or not. There were a total of only 18 articles that were relevant after this operation was finished. In the results section, a synopsis of these 18 articles can be found. For the purpose of conducting the qualitative analysis we looked for certain correlations between the articles, to find our whether certain parameters influence some others or how certain criteria is influenced by certain article's metadata. Interesting finding emerged and is presented in the Result section.

The result of the NLP toolkit used in this paper emerges with the production of multiple files. These files include the visualization of the results as charts in vector PDF files, CSV files that contain all of the articles that have been filtered, files containing only articles segmented by different properties and property groups, as well as a BibTeX file that contains all of the article data and helps to simplify the process of citing sources. The charts that are obtained provide a summary of the findings according to a variety of metrics, including the number of articles by country, the number of articles per keyword, the number of articles per year, and the number of articles per source (library). More charts can be easily generated from the data included in the CSV result files, since these files contain the complete data for each provided article, such as publisher, publication year and place, authors, their affiliations, origin countries and emails, the relevance factor for each included articles, number of citations, DOI numbers and other soft data.

Reproducibility of each paper is graded on 5-point Likert scale. Grading is done based on the ease of replicating the results outlined in the paper, the data accessibility and the clarity of the implemented algorithms. A 5 point reproducibility score means that the research is performed on publicly available dataset, its results can easily be replicated in our own environment and the results verified. A 4 point score means that the research is thorough and clear, but the dataset was not included and is not publicly accessible. A 3 point grade means that the dataset is not included and the explanation is vague but relies on popular concepts and can easily be assembled using common knowledge of ML techniques. Repdocibility score 2 means that data is missing and used techniques are not well explained, but the research can be reproduced although the process would be very hard and much guessing would be needed. Finally, a reproducibility score of 1 means that the research process is impossible to be replicated with the given data and information.

3 Results

In this section, both qualitative and quantitative analysis will be performed. The selection of the articles eligible for qualitative analysis was performed manually, by reading the abstracts of all 364 articles found by the NLP toolkit. After the initial 18 articles were identified, a detailed reading of all of them was performed. It turned out that 1 of the articles, although promising, did not include anything regarding reproducing or explaining recommendations [14], yet it is still included in the results section as it reflects the methodology used in this paper.

3.1 Quantitative analysis

Fig. 2 shows a comparison of the total number of articles that the NLP toolkit considered worthy of inclusion in the final results, by publisher and by year. It should not come as a surprise that the amount of research that is currently available steadily rises until it reaches its highest point in 2021. The occurrence of this phenomenon was discussed at length in the introduction. It is anticipated that the number of articles that are available will increase over the course of the upcoming years as all parties involved in the process of educating people around the world continue to implement new strategies for online learning and evaluate the effects of the ones that are already in place. Interesting result is that the largest amount of relevant articles in 2021 comes from PubMed whose main topic is biomedical literature. This unexpected finding is most probably consequence of the global Covid pandemic, which encouraged implementation of recommendation systems in various domains, for example recommending medicines and therapy to infected patients, and even using the recommendation algorithms to detect possible suspects or alarm people which may have had contact with an infected person [19].

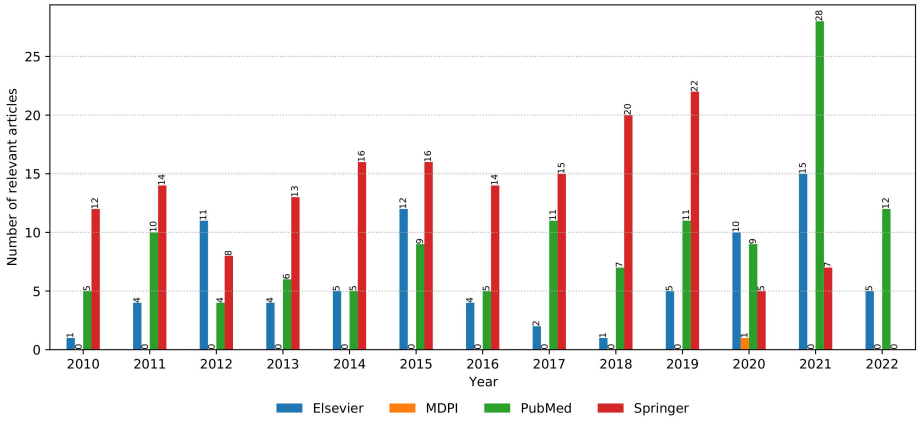

Fig. 2. Number of articles by publisher per year.

LMS, which stands for Learning Management Systems, is one of the most frequently mentioned topics in every of the analyzed articles. A learning management system is, by definition, "the framework that handles all aspects of the learning process." [22]. It consists of managing curriculum content, assessing students, tracking students' progress, collecting data, and enhancing the overall experience of students and teachers. Gilhooly [13] would add to that that LMSs should handle even more logistics like course registration, skill gap analysis, tracking and reporting various activities. Similar to the previous graph, in Fig. 3 we can see that the available literature on LMSs has been increasing steadily over the past few years and reached its peak in 2021. Other keywords such as recommendation systems in education are also on the rise. Although there always were more articles about LMS than articles about recommendation systems in LMS, in 2021 this number was equal, as shown in Fig. 3. The amount of data available in online learning management systems is huge and implementing recommendation systems to guide the students in their education presents an obligatory feature for the LMS to be used by the affected parties.

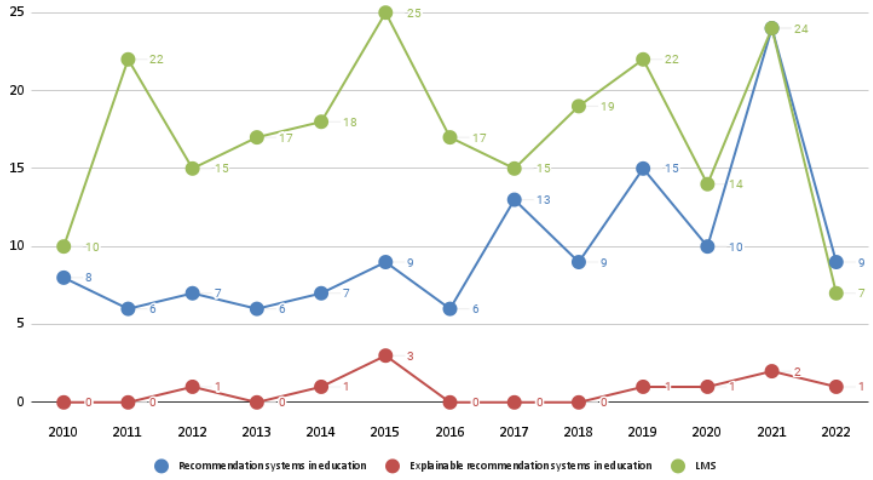

Fig. 3. Number of articles by year divided by used search criteria.

Fig. 3, also shows that explainability of recommendation systems used for educational purposes still proves to be immature and the number of articles talking about this concept is scarce. Following the latest trends in machine learning, like explainable artificial intelligence (xAI), we anticipate this number to increase in the coming years. A comprehensive systematic review of explainable artificial intelligence has been performed by Arietta et al. in 2020 [6].

3.2 Qualitative analysis

As stated, 18 articles were selected manually from the 364 available for qualitative analysis. Table 1 and Table 2 contain a summary of the 18 articles. The tables contain information about the article's title (along with its citation), the machine learning techniques used, whether it is reproducible and the application domain (content recommendation, feedback generation, test recommendation, etc.). Despite the fact that the articles were hand-picked and all promised to tackle explainability, the table and summary reveal that some of the articles fail to meet this promise. The reproducibility score is described in he methodology section. A short justification about each grade lower than 5 is provided. Articles in the two tables are sorted in descending order by ease of reproduction.

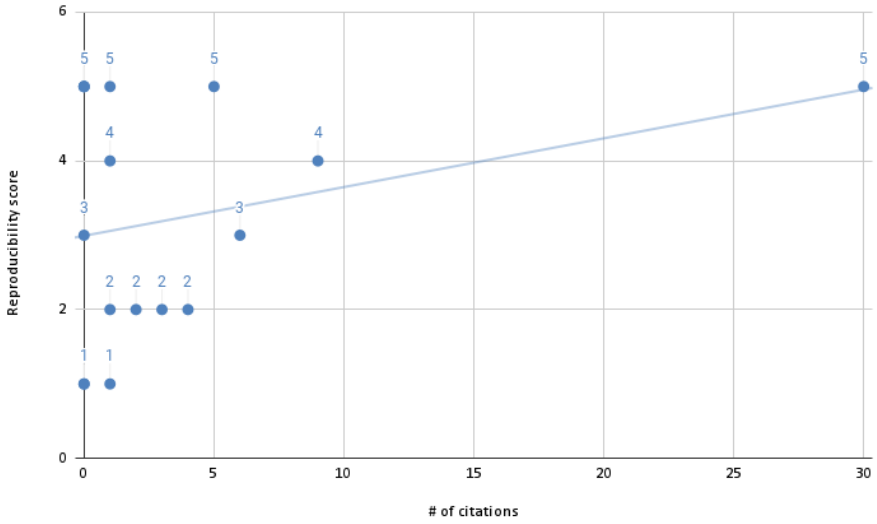

Fig. 4. Correlation between the number of article citations and the reproducibility score of each article.

When we compared the number of citations that each of the chosen articles has with the given reproducibility score, we made a discovery that was both interesting and remarkable. It would appear that the likelihood of an article being cited by others increases in proportion to the degree to which it provides a detailed description and is simple to reproduce. The trend line in Fig. 4 illustrates exactly this point. Despite the fact that the articles were only recently published and did not have sufficient time to gather a large number of citations, this result unquestionably presents a meaningful finding that contributes to the process of working on articles with methodology that is transparent and relatively simple to reproduce.

Table 1. Qualitative analysis of relevant research - part 1

Paper	Field	Machine learning techniques	Reproducibility
A Multi-agent and Content-Based Course Recommender System for University E-learning Platforms [4]	Content recommendation	TF-IDF scores, cosine-similarity	5 - public dataset, well-known algorithms
Explainable Attentional Neural Recommendations for Personalized Social Learning [16]	Content recommendation	Attention-based models	4 - easy to reproduce, lacks data set
Enabling recommendation system architecture in virtualized environment for e-learning [2]	Content recommendation	K-nearest machine learning algorithm, Semantic recommendation	4 - easy to reproduce, lacks data set
Explainable AI for Data-Driven Feedback and Intelligent Action Recommendations to Support Students Self-Regulation [1]	Feedback generation and activity recommendation	logistic regression (LR), k-nearest neighbours (KNN), support vector machine (SVM), random forest (RF), multi-layer perceptron (MLP), and BayesNet	4 - easy to reproduce, lacks data set
A personalized recommendation system with combinational algorithm for onl ine learning [23]	Content recommendation	Association rules, content filtering, collaborative filtering	4 - easy to reproduce, lacks dataset
An efficient personalized trust based hybrid recommendation (TBHR) strategy for e-learning system in cloud computing [8]	Content recommendation	Trust-based hybrid (collaborative and content-based) algorithm, AprioriAll for sequential patterns mining	4 - easy to reproduce, lacks data set
MoodleREC: A recommendation system for creating courses using the moodle e-learning platform [10]	Curriculum creation	content based filtering, collaborative filtering apprach. Not integrated, end-users sees 2 lists of recommendations. Tf-Idf for ordering of the results set.	4 - easy to reproduce, lacks data set
Reciprocal Recommender System for Learners in Massive Open Online Courses (MOOCs) [20]	Student recommendation	Matrix factorization	4 - would be relatively easy. No dataset is provided, but the underlying concepts are well explained
Personalized recommender system for e-Learning environment [7]	Content recommendation	Cold Start Hybrid Taxonomy Recommender	3 - vague explanation of the preferences used

Table 2. Qualitative analysis of relevant research - part 2

Paper	Field	Machine learning techniques	Reproducibility
A type-2 fuzzy logic recommendation system for adaptive teaching [3]	Approach to teaching	Type-2 fuzzy-based model	3 - will be hard due to the lack of technical data
StudyAdvisor: A Context-Aware Recommendation Application in e-Learning Environment [11]	Course recommendation, questions recommendation	Context-aware collaborative filtering	2 - it would be hard to reproduce with the amount of provided information
A Recommender System for Learning Goals [9]	Content recommendation	Collaborative based recommendation, matrix factorization	2 - theoretical data, very little is said about the implementation
Toward a New Recommender System Based on Multi-criteria Hybrid Information Filtering [26]	Content recommendation	Hybrid filtering (collaborative + content-based filtering)	2 - no data provided and no specific algorithm was mentioned
An Improved Recommender System for E-Learning Environments to Enhance Learning Capabilities of Learners [12]	Content recommendation	Content-based filtering	2 - although a dataset snapshot is provided, the whole research doesn't explicitly focus on explaining the context in which it is used
Recommender Systems for an Enhanced Mobile e-Learning [21]	Activity recommendation	Collaborative Filtering, K-mean and Apriori algorithm	1 - lack of dataset explanation, only covers the topic of recommendation techniques
Research and Design of Personalized Recommendation System Model for Course Learning Based on Deep Learning in Grid Environment [15]	Content recommendation	Collaborative-based filtering	1 - no data provided and no description of used techniques and algorithms
Hybrid Fuzzy Recommendation System for Enhanced E-learning [5]	Content recommendation	Collaborative Sequential Map Filtering Algorithm and Hybrid Fuzzy-based Matching Recommendation Algorithm	1 - not reproducible with the given information.
Personalization in Education Using Recommendation System: An Overview [14]	Not applicable	Not applicable	Not applicable

When a recommendation system is mentioned, it is quite common to think of a way to recommend content to the end user, no matter whether it is recommending courses, movies, songs, people or any other asset or activity. By doing the qualitative analysis, we have seen some rather interesting scenarios for implementing recommendation systems in educational context, despite course recommendation. There are papers recommending different teaching styles to teachers for different students (A type-2 fuzzy logic recommendation system for adaptive teaching [3]), systems built for recommending materials to teachers to assist them in the curriculum creation (MoodleREC: A recommendation system for creating courses using the moodle e-learning platform [10]), systems for recommending students to each other, a concept borrowed from dating apps in order to enhance peer learning possibilities (Reciprocal Recommendation System for Learners [20]), and systems for generating automatic feedback (StudyAdvisor: A Context-Aware Recommendation Application in e-Learning Environment [11]).

4 Conclusion

When starting the research process, we expected to see a growing number of learning management systems and techniques for enhancing student achievement in online environments in the last decade. This indeed was the case, and is a direct consequence of complete shift to online and distant learning in the past two years. The research showed that the existence of recommendation algorithms as a part of learning management platforms is starting to be a requirement following the vast amount of content usually accessible in these learning management systems.

An interested finding that emerged from this research is the correlation between the number of citations certain research paper has and the ease of reproducing the same paper. It turns out that researchers prefer citing papers which can be easily understood and which are suitable for reproducing in the own research process. Having access to a publicly accessible dataset when reproducing certain research can prove crucial for replicating the results.

What is common to all the analyzed research papers is that they all contribute toward making e-learning a better and more personalized process. They all help combat the one-size-fits-all model, which works well in physical classrooms but can be improved in online settings. As previously stated in this paper, we anticipate that the amount of research on this topic will increase in the future as a result of the global adoption of online learning in the preceding years. On a daily basis, new strategies for bringing online classes closer to students and making them more enjoyable for instructors are developed as existing techniques are evaluated and adapted to better meet the needs of students and instructors. As a result, we can conclude that the review provided in this paper is a good snapshot of the current state of learning management systems and their accompanying recommendation algorithms, as well as a good starting point for determining how the complete transition to online education will affect this segment in the coming years.

References

1. Afzaal, M., Nouri, J., Zia, A., Papapetrou, P., Fors, U., Wu, Y., Li, X., Weegar, R.: Explainable ai for data-driven feedback and intelligent action recommendations to support students self-regulation. Frontiers in Artificial Intelligence **4** (2021)
2. Ali, S., Hafeez, Y., Humayun, M., Jamail, N.S.M., Aqib, M., Nawaz, A.: Enabling recommendation system architecture in virtualized environment for e-learning. Egyptian Informatics Journal **23**(1), 33–45 (2022)
3. Almohammadi, K., Hagras, H., Yao, B., Alzahrani, A., Alghazzawi, D., Aldabbagh, G.: A type-2 fuzzy logic recommendation system for adaptive teaching. Soft Computing **21**(4), 965–979 (2017)
4. Amane, M., Aissaoui, K., Berrada, M.: A multi-agent and content-based course recommender system for university e-learning platforms. In: International Conference on Digital Technologies and Applications. pp. 663–672. Springer (2021)
5. Appalla, P., Selvaraj, R., Kuthadi, V.M., Marwala, T.: Hybrid fuzzy recommendation system for enhanced e-learning. In: Advances in Systems, Control and Automation, pp. 21–32. Springer (2018)
6. Arrieta, A.B., Díaz-Rodríguez, N., Del Ser, J., Bennetot, A., Tabik, S., Barbado, A., García, S., Gil-López, S., Molina, D., Benjamins, R., et al.: Explainable artificial intelligence (xai): Concepts, taxonomies, opportunities and challenges toward responsible ai. Information fusion **58**, 82–115 (2020)
7. Benhamdi, S., Babouri, A., Chiky, R.: Personalized recommender system for e-learning environment. Education and Information Technologies **22**(4), 1455–1477 (2017)
8. Bhaskaran, S., Santhi, B.: An efficient personalized trust based hybrid recommendation (tbhr) strategy for e-learning system in cloud computing. Cluster Computing **22**(1), 1137–1149 (2019)
9. Capuano, N., Iannone, R., Gaeta, M., Miranda, S., Ritrovato, P., Salerno, S.: A recommender system for learning goals. In: World Summit on Knowledge Society. pp. 515–521. Springer (2011)
10. De Medio, C., Limongelli, C., Sciarrone, F., Temperini, M.: Moodlerec: A recommendation system for creating courses using the moodle e-learning platform. Computers in Human Behavior **104**, 106168 (2020)
11. Do, P., Le, H., Nguyen, V.T., Dung, T.N.: Studyadvisor: a context-aware recommendation application in e-learning environment. In: Advanced approaches to intelligent information and database systems, pp. 119–128. Springer (2014)
12. Doja, M., et al.: An improved recommender system for e-learning environments to enhance learning capabilities of learners. In: Proceedings of ICETIT 2019, pp. 604–612. Springer (2020)
13. Gilhooly, K.: Making e-learning effective. Computerworld **35**(29), 52–53 (2001)
14. Kundu, S.S., Sarkar, D., Jana, P., Kole, D.K.: Personalization in education using recommendation system: An overview. Computational Intelligence in Digital Pedagogy pp. 85–111 (2021)
15. Liu, F., Guo, W.: Research and design of personalized recommendation system model for course learning based on deep learning in grid environment. In: Innovative Computing, pp. 1707–1716. Springer (2020)
16. Marconi, L., Aragon, R.A.M., Zoppis, I., Manzoni, S., Mauri, G., Epifania, F.: Explainable attentional neural recommendations for personalized social learning. In: International Conference of the Italian Association for Artificial Intelligence. pp. 67–79. Springer (2020)

17. Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., Group*, P.: Preferred reporting items for systematic reviews and meta-analyses: the prisma statement. Annals of internal medicine **151**(4), 264–269 (2009)
18. Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L.A.: Preferred reporting items for systematic review and meta-analysis protocols (prisma-p) 2015 statement. Systematic reviews **4**(1), 1–9 (2015)
19. Organization, W.H., et al.: Public health surveillance for covid-19: interim guidance, 7 august 2020. Tech. rep., World Health Organization (2020)
20. Prabhakar, S., Spanakis, G., Zaiane, O.: Reciprocal recommender system for learners in massive open online courses (moocs). In: International Conference on Web-Based Learning. pp. 157–167. Springer (2017)
21. Vélez-Langs, O., Caicedo-Castro, I.: Recommender systems for an enhanced mobile e-learning. In: International Conference on Human-Computer Interaction. pp. 357–365. Springer (2019)
22. Watson, W., Watson, S.L.: An argument for clarity: What are learning management systems, what are they not, and what should they become. (2007)
23. Xiao, J., Wang, M., Jiang, B., Li, J.: A personalized recommendation system with combinational algorithm for online learning. Journal of Ambient Intelligence and Humanized Computing **9**(3), 667–677 (2018)
24. Zdravevski, E., Lameski, P., Trajkovik, V., Chorbev, I., Goleva, R., Pombo, N., Garcia, N.M.: Automation in systematic, scoping and rapid reviews by an nlp toolkit: a case study in enhanced living environments. Enhanced living environments pp. 1–18 (2019)
25. Zhang, Y., Chen, X., et al.: Explainable recommendation: A survey and new perspectives. Foundations and Trends® in Information Retrieval **14**(1), 1–101 (2020)
26. Zitouni, H., Nouali, O., Meshoul, S.: Toward a new recommender system based on multi-criteria hybrid information filtering. In: IFIP International Conference on Computer Science and its Applications. pp. 328–339. Springer (2015)