Development of machine learning implementation in engineering education: A literature review

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Abstract. This study has aims to determine the development of implementing machine learning in several engineering majors. The used method was a literature study, and secondary data was used from reputable international journals and published in 2015 to 2019 from each publisher, which is IEEEXplore, Springer Link, Science Direct, ERIC, and Google Scholar. The author was summarized and analysed articles obtained based on the year of publication and the context of the article. Results show that machine learning has been widely applied in engineering education through fourteen contexts, one of which is Prediction Student Academic Performance, which has continuous development from 2013 to 2019. And the total number of engineering majors that are implementing machine learning was 13 majors. This research was expected to be an illustration, reference, and consideration for technicians in engineering education to give more attention and can be applied in schools, universities, and other engineering institutions in Indonesia country.

1. Introduction

Digital revolution 4.0 has been driven a massive transformation in the world of education [1]. That transformation was identified with the elimination of work that considered inefficient, automated, and digitalized [2]. One example, changes can be seen from the tendency of students to learn, which is the selection of teaching media becomes the student's main focus in carrying out their learning activities. Through that statement, digital technology creates new challenges for conventional education, from that primary to higher [3]. That's mean the problem is the production of intelligent systems [4]. That intelligent systems have a technology component in the digital 4.0 revolution, which is big data, cloud computing, data analytics, artificial intelligence, machine learning, IoT systems, adaptive robotics, virtualization, and additive manufacturing [2]. Every component in the digital revolution 4.0 has become a concern for the public, specifically in the element of machine learning [5].

Machine learning is a digital revolution 4.0 technology that can learn without being explicitly programmed [6]. Machine learning has the potential to revolutionize education in the fields of science, technology, engineering, and mathematics [7]. Some of the applications are in the education process, the teacher's role as a mentor, and the automation of all administrative procedures related to education [8].

Since 2018, the discipline of machine learning has been dominated by engineering education in the departments of electrical engineering and computer engineering [2]. However, Dimiduk et al., in his research on perspectives of the machine learning impact, he explained that an engineering practitioner
in the field of engineering education was considered very slow in his involvement in the digital revolution 4.0 [9]. Besides, Onar et al. have been said that in engineering education, several universities have no teaching on the components digital 4.0 revolution curriculum [2]. Moreover, McKinsey & Company has been said that when they surveyed 300 prominent leaders in Southeast Asia, they asked for readiness to face the digital revolution 4.0. In the end, the results showed that 48% said they were ready [10]. That readiness needs to be measured by the evidence or work produced by several researchers related to the application of machine learning in the field of education, specifically in engineering education.

The researchers have further studied machine learning in the field of education through literature studies, including in 2013, 2018, and 2019. Chrysafiadi & Virvou, a literature study was made concerning student modelling [11]. Dalipi et al., a literature review on prediction systems to find out students who were expelled from their schools [12], Bueñaño-Fernandez et al., a literature review on decision-making systems [13]. Bacos, a literature review on quantified self, affective computing, emotional design, and pedagogical agents [14]. Suhaimi et al., a literature review on prediction systems to find out when students graduate from school [15]. And finally, Kučak et al. and Korkmaz & Correia, a literature review on the development of machine learning in education [16,17].

In the end, the author makes concludes that machine learning in the field of education is still developing today. However, specifically, the authors cannot find a significant review of literature that discusses the development of machine learning in engineering education. That knowledge about digital revolution 4.0 technology is still developing until now needs to be known, give an overview for technicians in engineering education, and prepare themselves in the face of the digital revolution 4.0. Therefore, in this study, the authors have aim to determine the development of the implementation of machine learning in several engineering majors from 2015 to 2019 through a literature review.

2. Method

The research method that has been used was a systematic review. And for data analysis, the method was a meta-analysis [18]. In this study, secondary data has been used, which is articles that obtained through search engines in several publisher sources, which is IEEEExplore, SpringerLink, Science Direct, and ERIC, as well as additional assistance, Google Scholar. When searching, the author uses five keywords, including student prediction, student achievement, student performance, machine learning in education engineering, and machine learning in student assessment. The restrictions that are applied when searching articles can be seen in the inclusion criteria in Table 1.

| No | Inclusion |
|----|-----------|
| 1  | Articles type are Journal and indexed by SCOPUS |
| 2  | Articles language is English |
| 3  | Articles not contain a blank page |
| 4  | Concerned with engineering and applying machine learning |
| 5  | Respondents from engineering education |
| 6  | Some articles is “in manuscript form are accepted” |
| 7  | Using machine learning methods |

Generally, the second inclusion criteria were provided limits that articles must be in English. This is related to the paper that the author found in the IEEEExplore database, which is articles not in English language, one example like Amaya et al. [19] article, that article title is in English, but the content is not in English. Then, the third inclusion criteria are the existence of the article found in the IEEEExplore database, which is published as a new year in 2019, one example like Akram et al. article [20] where the article is blank, not contain content, but only abstract. In the number five of inclusion criteria, the authors were expected that in machine learning, articles must be related to engineering, that can see from the respondents [20]. In the number six inclusion criteria, articles were determined
through the discovery of an article, which is sourced from the ScienceDirect database in the form of an Accepted Manuscript [21]. And finally, the number seven of inclusion criteria, the articles were used machine learning method, not an artificial intelligence algorithm method [22]. And then, the exclusion criteria can be seen in Table 2.

Table 2. Exclusion criteria.

| No | Exclusion                                                                 |
|----|---------------------------------------------------------------------------|
| 1  | Articles type are not Journal (For example like Conference Proceeding)     |
| 2  | Articles language is not English                                          |
| 3  | Articles are contain a blank page                                          |
| 4  | Not related to engineering, but applying machine learning                  |
| 5  | Respondents are not from engineering education                             |
| 6  | Some articles are in the form of peer review manuscripts                   |
| 7  | Using the usual intelligence algorithm method                              |

As explained in the exclusion criteria, when the article obtained is an article Conference Proceeding type, not in English, articles only contain title and abstract, not related to engineering, a respondent is not engineering, articles are peer review manuscript, and uses usual algorithm artificial intelligence, that articles should be avoided for download.

3. Results and discussion

Based on the specified keywords, the author detailing articles by four aspects, which are total articles found, a total of articles downloaded, a total of articles that are selected, and a total article was taken. Authors have been downloaded articles, which are having a high significance level for education and machine learning methods. A description of four aspects can be seen in Error! Reference source not found.

Table 3. Number of articles.

| No | Keywords                        | Article Database | Total | Downloaded | Selected | Was taken |
|----|---------------------------------|------------------|-------|------------|----------|----------|
| 1  | Prediction Student              | IEEEXplore       | 115   | 25         | 21       | 4        |
|    |                                 | Springer Link    | 109   | 30         | 28       | 2        |
|    |                                 | IEEEXplore       | 45    | 12         | 12       | 0        |
| 2  | Student Achievement             | Science Direct   | 1681  | 7          | 7        | 0        |
|    |                                 | Springer Link    | 352   | 15         | 11       | 4        |
|    |                                 | IEEEXplore       | 515   | 24         | 20       | 4        |
| 3  | Student Performance             | Science Direct   | 808   | 12         | 12       | 0        |
|    |                                 | Springer Link    | 522   | 26         | 21       | 5        |
|    | Machine Learning In Education   | IEEEXplore       | 606   | 23         | 19       | 4        |
|    | Engineering                     | ERIC              | 25199 | 10         | 6        | 4        |
|    |                                 | Springer Link    | 6     | 3          | 3        | 0        |
|    |                                 | IEEEXplore       | 12    | 6          | 6        | 0        |
| 5  | Machine Learning In Student     | ERIC              | 57375 | 16         | 14       | 2        |
|    | Assessment                      | Springer Link    | 63    | 16         | 15       | 1        |
|    | Total Articles                  |                  | 87408 | 225        | 195      | 30       |

When thirty articles have been taken, seventeen articles have a problem, the problem was respondents. Some respondents were not from engineering education. Besides, and two articles are not indexed by SCOPUS. Authors are known from Scimago Journal & Country Rank site. To anticipate that problem,
authors starting to search again for nineteen articles through Google Scholar with the same keywords. And then, nineteen articles were founded, include from different publishers, which is Semantic Scholar, MDPI, Research Online Goldsmiths in the University of London, ACM Digital Library, and SAGE Journal. However, when the author’s review, in fact, one article was indicated duplicate, three articles were not in the context of machine learning, and three articles were not in the scope of engineering. So, the total articles are 23 articles.

In 2015, the number of articles was one article. That percentage was 4,347%. Then, in 2016, the number of articles was three articles. That percentage was 13.04347826%. In 2017 until 2018, the number of articles had an increase, which was initially five articles in 2017 to seven articles in 2019. That percentage was 21.73913043% to 30.43478261%. Meanwhile, in 2018 until 2019, there was no increase. The authors were made four categories for each context consisting of prediction, academic, automation, and others. Here are four categories:

3.1. Prediction
The context that contains predictions was included Student Action (1 article) in the Department of Forestry Engineering, Student Academic Performance (10 articles) in the Department of Engineering, Electrical Engineering, Mechanical, and Aerospace Engineering, Computer Engineering, Information Technology, Vocational Student, Student Placement (1 article ) in the Engineering department using the WEKA (Waikato Environment for Knowledge Analysis) dataset, and Educational Institution (1 article) in the Technical And Vocational Institutions. A total number of articles in the prediction category is 13 articles.

3.2. Academic
The context that contains academic was included Academic Decision (1 article) in the Industrial, Systems, Electronic, Electric, and Cadastral Engineering majors, and Academic Guidance (1 article) in the Engineering Sciences major. A total number of articles in the academic category is two articles.

3.3. Automation
The context that contains automation was included Machine Assessment (1 article) in the Software Engineering department, Automatic Analysis (1 article) in the Engineering Department, and Automatic Scoring (1 article) in the Chemical, Electrical and Computer Science Engineering department. The total number of articles in the automation category is three articles.

3.4. Others
The context that contains about others was included Mining Data (1 article) in the Engineering department, Multimodal Learning Analytics (1 article) in the Engineering Department, Machine Learning Education (1 article) in the Engineering Department in STEM Education, Ethics in Machine Learning (1 article) is majoring in Engineering and Student Collaborative (1 article) in the Department of Engineering. The total number of articles in the automation category is five articles.

To know which articles are published based on a certain year, the authors regroup each context of the article based on the year of publication. Here are the groupings:

- 2015: student academic performance
- 2016: student academic performance, student action, mining data
- 2017: student academic performance (3 articles), automated scoring, multimodal learning analytics
- 2018: machine assessment, academic decision, academic guidance, educational institution, student academic performance, student placement, student collaboration
- 2019: student academic performance(4 articles), automated analysis, machine learning education, ethics in machine learning

As we have seen, most of the research context regarding predicting student academic performance, especially in 2019. Korkmaz & Correia [17], his research was in education, explained that predicting
student academic performance has been starting and carried out from 2013. Another research was conducted by Yildiz et al. [23], which is used as a fuzzy logic method to predict the academic performance students. That accuracy obtained by using fuzzy logic was 72%.

To be known, fuzzy logic was not a machine learning method. Therefore, in 2014, authors cannot found an article that reviews the literature, including the context of predicting student academic performance. So, authors still believe that the development of machine learning implementation in predicting student academic performance still starting between 2015 until 2019. As explained before in the literature review by Kucak et al., the principle in predicting student performance is to study weakness students using technology and then suggest a step to improve student performance [16]. One of the articles that the author found was Yagci & Cevik to predict the academic performance of vocational high school students in Johor Bahru, Malaysia, and Karaman, Turkey, the subjects in Physics, Chemistry, and Biology. A total respondent was 1,972 students, and the method was Artificial Neural Networks. Results show that 98% of the system can be predicted accurately [24].

4. Conclusion
Fourteen contexts have been obtained through a reviewed process of twenty-six articles, which were included Prediction Student Action, Prediction Student Academic Performance, Prediction Student Placement, Prediction Educational Institution, Academic Decision, Academic Guidance, Machine Assessment, Automatic Analysis, Automatic Scoring, Mining Data, Multimodal Learning Analytics, Machine Learning Education, Ethics in Machine Learning, and Student Collaborative. Based on the percentage in 2019, which is 30.43478261%, most of the developing context is Prediction Student Academic Performance, with a total of ten articles.

The total number of engineering majors is thirteen majors, including Forestry Engineering, Electrical Engineering, Electronic Engineering, Mechanical Engineering, Aerospace Engineering, Computer Engineering, Industrial Engineering, Systems Engineering, Cadastral Engineering, Sciences Engineering, Software Engineering, Chemical Engineering, and Computer Science Engineering. And in engineering institutions such as Information Technology, Vocational Student, Technical and Vocational Institutions. Seven studies were not explicitly mentioned in which engineering department. And for the Prediction Student Academic Performance context, four articles were not explicitly mentioned too, which is the engineering department.

In the context of Prediction Student Academic Performance, one article has high accuracy using the Artificial Neural Network method with an accuracy of 98% compared to the non-machine learning method, which is fuzzy logic with an accuracy of 72%. So, the context and the method are expected to be considered by technicians in engineering education to pay more attention to applied in schools, universities, and other engineering institutions in the country of Indonesia.

Reference
[1] Birch C 2011 Rethinking Education in the Age of Technology: The Digital Revolution and Schooling in America by Allan Collins and Richard Halverson Am. J. Educ. 117(3) 433–436, 2011.
[2] Onar S C, Ustundag A, Kadaifci Ç and Oztaysi B 2018 The changing role of engineering education in industry 4.0 Era In Industry 4.0: Managing The Digital Transformation 137-151
[3] Larasati A, Hajji A M and Handayani A N 2019 Preferences Analysis of Engineering Students on Choosing Learning Media using Support Vector Machine (SVM) Model In 2nd International Conference on Vocational Education and Training (ICOVET 2018)
[4] Baygin M, Yetis H, Karakose M and Akin E 2016 An effect analysis of industry 4.0 to higher education In 2016 15th international conference on information technology based higher education and training (ITHET)
[5] Jiang Y, Baker R S, Paquette L, San Pedro M and Heffernan N T 2015 Learning, moment-by-moment and over the long term In International Conference on Artificial Intelligence in
[6] Samuel A L 1959 Some studies in machine learning using the game of checkers *IBM Journal of research and development* 3(3) 210-229

[7] Uskov V L, Bakken J P, Byerly A and Shah A 2019 Machine Learning-based Predictive Analytics of Student Academic Performance in STEM Education *In 2019 IEEE Global Engineering Education Conference (EDUCON)* 1370-1376

[8] Habib M K 2019 Revolutionizing Education in the Age of AI and Machine Learning” *Revolutionizing Education in the Age of AI and Machine Learning*

[9] Dimiduk D M, Holm E A and Niezgoda S R 2018 Perspectives on the impact of machine learning, deep learning, and artificial intelligence on materials, processes, and structures *Engineering Integrating Materials and Manufacturing Innovation* 7(3) 157-172

[10] Indriani F 2019 Sudahkah Indonesia Siap Menghadapi Revolusi Industri 4.0? [Online] Available: https://www.kompasiana.com/frisiliab5/2cd1d76750657559e751d03/sudahkah-indonesia-siap-menghadapi-revolusi-industri-4-0?page=all. [Accessed: 23-Dec-2019].

[11] Chrysafiadi K and Virvou M 2013 Student modeling approaches: A literature review for the last decade *Expert Systems with Applications* 40(11), 4715-4729.

[12] Dalipi F, Imran A S and Kastrati Z 2018 MOOC dropout prediction using machine learning techniques: Review and research challenges *In 2018 IEEE Global Engineering Education Conference (EDUCON)* 1007-1014

[13] Buenaño-Fernandez D, Villegas-CH W and Luján-Mora S 2019 The use of tools of data mining to decision making in engineering education—A systematic mapping study *Computer Applications in Engineering Education* 27 (3) 744-758

[14] Bacos C A 2018 *Machine Learning and Education in the Human Age: A Review of Emerging Technologies* (Springer International Publishing)

[15] Nuraffiah M S, Abdul-Rahman S, Mutaib S, Hamid N H A and Ab Malik A M 2019 Review on predicting students’ graduation time using machine learning algorithms *International Journal of Modern Education and Computer Science* 11(7) 1

[16] Kučak D, Jurićić V and Đambić G 2018 MACHINE LEARNING IN EDUCATION-A SURVEY OF CURRENT RESEARCH TRENDS *Annals of DAAAM & Proceedings* 29

[17] Korkmaz C and Correia A P 2019 A review of research on machine learning in educational technology *Educational Media International* 56(3) 250-267

[18] Lau F and Kuziemsky C 2016 *Chapter 9 Methods for Literature Reviews in Handbook of eHealth Evaluation: An Evidence-based Approach* (Canada: University of Victoria)

[19] Heredia D, Amaya Y and Barrientos E 2015 Student dropout predictive model using data mining techniques *IEEE Latin America Transactions* 13(9) 3127-3134

[20] Passey D 2017 Computer science (CS) in the compulsory education curriculum: Implications for future research *Education and Information Technologies* 22(2) 421-443

[21] Asif R, Merceron A, Ali S A and Haider N G 2017 Analyzing undergraduate students’ performance using educational data mining *Computers & Education* 113 177-194

[22] Pribadi F S, Permanasari A E and Adjji T B 2018 Short answer scoring system using automatic reference answer generation and geometric average normalized-longest common subsequence (GAN-LCS) *Education and Information Technologies* 23(6) 2855-2866

[23] Yıldız O, Bal A and Gulsecen S 2013 Improved fuzzy modelling to predict the academic performance of distance education students *The international review of research in open and distributed learning* 14(5)

[24] Yağcı A and Çevik M 2019 Prediction of academic achievements of vocational and technical high school (VTS) students in science courses through artificial neural networks (comparison of Turkey and Malaysia) *Education and Information Technologies* 24(5) 2741-2761