Journal of Engineering Science and Technology
20th EURECA 2023 Special Issue October (2024) 93 - 106

DEEP LEARNING APPLIED IN EDUCATION: SCOPING REVIEW

NISA AULIA SAPUTRA[1], IDA HAMIDAH[1,*], AGUS SETIAWAN[1], LALA SEPTEM RIZA[1], ASEP BAYU DANI NANDIYANTO[1], INDRIYANI RACHMAN[2], TORU MATSUMOTO[2]

[1]Universitas Pendidikan Indonesia, Jl Setiabudhi No. 229, Bandung Indonesia
[2]The University of Kitakyushu, 1-1 Hibikino, Wakamatsu-ku, Kitakyushu, Japan
*Corresponding Author: idahamidah@upi.edu

Abstract

The reliability of Deep Learning (DL) technology in processing all types of data makes the technology widely used in various fields, including the field of Education. The functions of DL algorithms provide a multitude of advantages in the field of education. The objective of this paper is to offer an analysis of the potential and impact of DL in transforming education, therefore fostering a more efficient and effective learning environment. The research method in this review is the prism method using Scopus data. The results show that DL is widely used for the benefit of Education. Some of them are used as learning media that function to help students understand learning and master competencies according to their level. The use of DL is finally able to make the quality of education increase. A potential area for future research involves enhancing both student and teacher digital skills for seamless adaptability in utilizing technology-based deep learning. Furthermore, it is recommended that future research endeavours include more extensive comparative analyses between deep learning (DL) and conventional techniques of learning.

Keywords: Classification and analysis, Data-driven modelling, Decision-making, Educational tool, Prediction.

1. Introduction

Technological breakthroughs, such as the Internet of Things (IoT), Cloud Computing, Big Data, robots, Artificial Intelligence (AI), machine vision, and machine learning, have had a profound impact on all aspects of modern society, including the education sector [1, 2]. In the era of Industry 4.0, education has become a key sector that actively adapts, learns, and develops technology. Among the various 4.0 technologies utilized in education, AI and its algorithms, such as Machine Learning (ML), and Deep Learning (DL), have gained significant prominence. AI, a form of artificial intelligence that emulates human intelligence, finds applications in developing learning tools and problem-solving within the education sector [3]. ML, on the other hand, harnesses knowledge or information to draw conclusions and establish connections with data [4]. DL, a subset of ML, employs multi-layer neural networks (MLPNN) to tackle problems involving nonlinear data and provides an overview of the data [5, 6].

The respective functions of AI algorithms offer numerous benefits for education. They contribute to the development of more engaging and interactive learning media and models, aid in foreign language tasks, facilitate predictive student achievement analysis, and support the regulation of administrative systems within the education sector. Moreover, deep learning exhibits numerous advantages when compared to traditional methodologies.

In the traditional approach, education takes place within a teacher-centred environment, resulting in a diminished development of students' analytical skills and their ability to effectively solve complex and productive problems. In traditional instructional approaches, it is common for students to generate inquiries that are intended to be posed directly to the teacher [7]. Incorporating the use of DL in the educational process enhances student engagement and interactivity, leading to the development of analytical and critical thinking abilities [7]. Additionally, DL enables students to engage in focused group discussions, facilitating problem-solving and collaborative learning [7].

The analysis of the importance of incorporating deep learning (DL) in the field of education is a crucial endeavour. The objective of this systematic literature review is to provide a comprehensive overview of the implementation of DL in the education sector. The article is organized into several parts: the introduction, research methodology, results, and conclusion. The purpose of this review is to provide insight into the potential and influence of DL in revolutionizing education, thereby cultivating a learning environment that is more streamlined and efficacious.

2. Methodology

2.1. Review stages

Review articles begin by defining the research question. Research questions are formed to facilitate the search for article topics. After the research question is created, the database is used to search for documents. The database used in this study is the Scopus database. It brings together publishers such as Science Direct, Springer, IEEE, MDPI, Sage, Taylor and Francis, iJET, SOLAR, Nature Research, BOP Universitätsbibliothek Bern, and SIAM Review. Furthermore, screening of documents by exclusion and

inclusion criteria was carried out [8]. The pertinent documents meeting the inclusion criteria were methodically identified and synthesized.

The first stage, forming a research question. The research question in this review was formed by looking at the gaps that occur in DL issues. Research questions were also developed, and the results were used as the basis for creating a review protocol. This is done to see at the beginning whether the review protocol created is possible or not.

The second stage is to carry out the selection, identification, and synthesis of documents. Documents that have been successfully collected through the database are identified and reviewed such as journal name, publisher, document title, research objectives, research methods, important results, and conclusions. After the identification and review process is complete, the next step is to synthesize and compile article reviews.

The purpose of this study is to see the picture of DL implementation that is applied in education. In addition, this article looks at the extent of the development of DL in the education sector. The research questions in this review literature are:

- Research Question 1: How has the DL trend in Education evolved over the past ten years?
- Research Question 2: What are some educational themes that can benefit from DL?

The many uses of DL today make research on DL widely found. Not only DL research is carried out in the field of education, but in various fields, there are also many found. The searches carried out must be researched and selected properly to match the search point we want. The search is performed automatically using the Scopus database. The keywords searched will be seen based on the abstract, title, and keywords. The search input we use is "deep learning" OR "deep learning algorithm" AND education.

Exclusion criteria are determined to filter out documents that do not fit the topic. This is done so that the analysis process is carried out effectively and precisely. The exclusion criteria in this study are as follows.

The first exclusion criteria of the document were published before 2013. Second, the document type is a systematic type of review or not a journal article. Third, the document has been downloaded more than once. Fourth, non-English documents. Fifth, the document is not available as an open-access file, therefore, it cannot be downloaded automatically. Sixth, the document does not correspond to the topic and data sought. The prism method is also illustrated in Fig. 1.

3. Results

3.1. Article distribution analysis

The distribution of articles is carried out to see the publication trend of DL applications in the world of education every year. The large amount of research on the application of DL makes it interesting to see if there is an increase or not. Figure 2 shows the number of DL articles in education over the past ten years. Search results with the keywords “deep learning" OR "deep learning algorithm" AND education returned 6,393 documents.

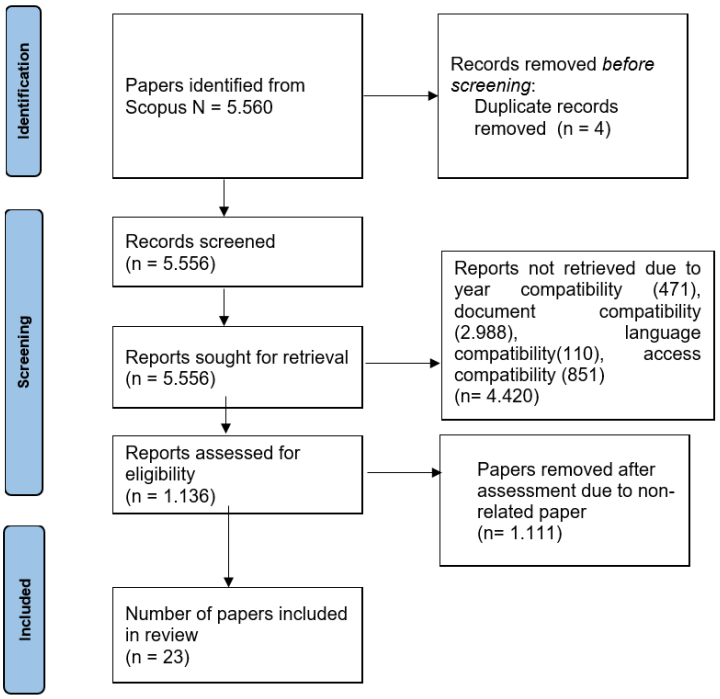

Fig. 1. Prism method.

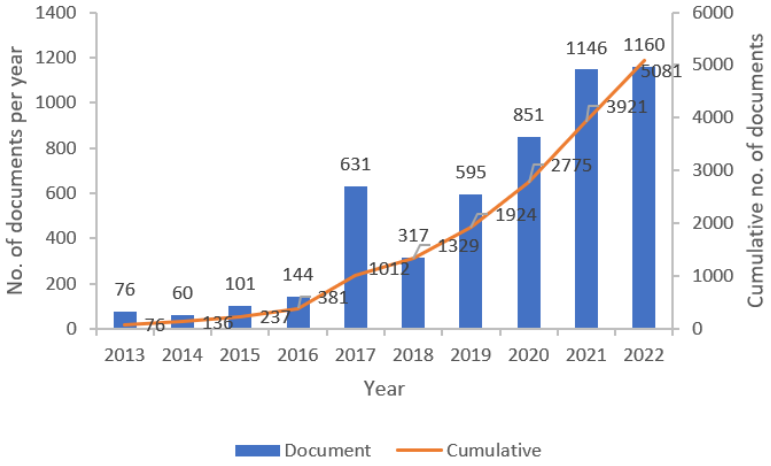

Fig. 2. Distribution of DL articles in education over the past ten years.

In Fig. 2, it can be seen that the growth of articles about the application of DL in the world of education increases every year. Research related to deep learning in the world of Education in the last ten years has been rife. However, the number of articles starting from 2013-2020 is still very volatile. Evidenced by the number of articles that increased dramatically in 2017 to 631 with a cumulative total of 1,012 (0.19%) articles, then in 2018 experienced a decrease in the number of articles to

317 (0.26%) articles before finally increasing again in 2019 with a total number of articles 595 (0.37%) articles. The peak of article publication is in 2022 with a total number of articles of 1,160 articles. Furthermore, the recently conducted research related to DL in education will be shown in Table 1.

Table 1. The latest research related to DL in education.

Title	Analysis aspects	Reference
Early prediction of learners at risk in self-paced education: A neural network approach	Analyse students' ability to study in independent programs. DL helps predict student success and performance in carrying out independent learning using technology.	[9]
The development system of local music teaching materials based on deep learning	DL-based system used to develop local music teaching material. The development of this DL-based system can be used to create learning materials such as textbooks for local music learning.	[10]
Enabling Remote School Education using Knowledge Graphs and Deep Learning Techniques	Research on the design of an automated question-answering system used to increase student understanding in online learning.	[11]

3.2. Thematic analysis

Table 2 provides an explanation of the thematic analysis obtained in this review. Overall, these themes are applications of DL. From this theme, future research gaps concerning the advancement of DL in the field of education can be identified.

Table 2. Theme definition.

Theme Name	Definition
Learning Media	This theme describes the ability of DL as a tool that can help learning or as a learning system. In addition, DL as an educational tool is also used as a learning medium.
Prediction	This theme provides an overview of DL as a tool that can predict student achievement and performance.
Classification and Analysis	This theme describes DL's ability to analyse factors or variables and classify images, semantic data, and sentiments related to learning.

As DL becomes more prevalent in the field of education, it is implemented in an array of formats. As depicted in Fig. 3, the article we obtained identifies several overarching themes concerning the application of DL in education. The review frequently revisits recurring themes such as "performance prediction", "classification and analysis", and "learning media". With a total of ten articles, the theme of classification and analysis possesses the greatest quantity of articles. This theme includes DL as an instrument and system for analysing multiple variables extracted from an image or video. Due to the diversity of classification and analysis variables in learning, the educational instrument theme contains the most articles. The learning media theme has the smallest quantity of articles, comprising a total of six articles per theme.

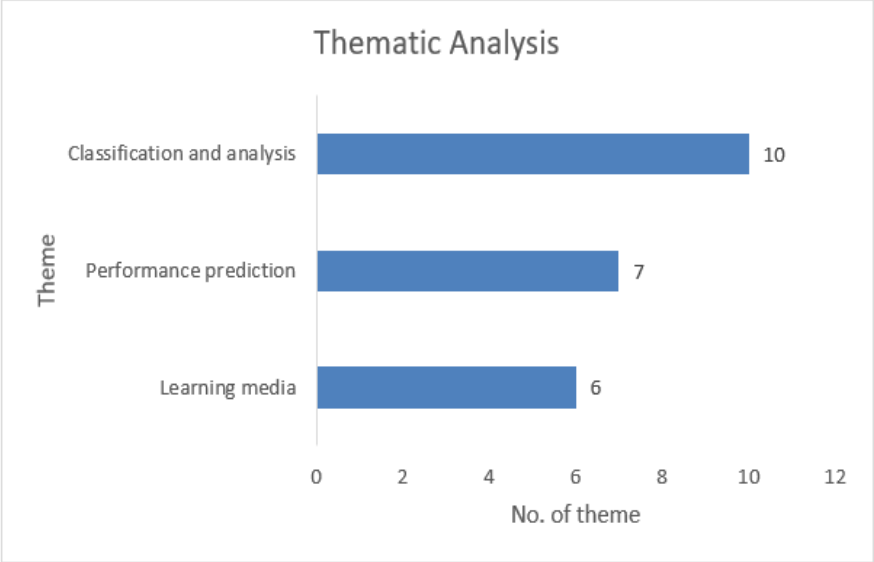

Fig. 3. Thematic analysis of DL in education.

3.3. DL in education

3.3.1. Learning media

In the realm of educational digital tools, various categories exist, encompassing Massive Online Open Courses (MOOCs), Mind Mapping, Interactive Tools, Web Conferencing, Info Graphics, Research Visibility Tools, Web-based Content Management Systems, etc. [12]. These tools are grouped into eight main categories, each serving a unique purpose in enhancing the educational experience. However, despite the promising potential of these digital tools, their widespread adoption faces certain challenges.

One significant barrier is the issue of adoption itself, as educators and institutions need to embrace and integrate these tools into their teaching practices effectively. Additionally, technical concerns, such as internet connectivity and the availability of necessary equipment for access, can hinder the seamless implementation of online instructional resources [12].

To address these challenges, the education community must work collaboratively to overcome barriers and maximize the benefits of these digital tools. Proper training and support for educators can boost their confidence and competence in using these technologies. Simultaneously, efforts to improve internet infrastructure and provide access to necessary equipment can bridge the digital divide and ensure equitable opportunities for all learners.

Table 3 exemplifies the use of Deep Learning (DL) as an educational tool, demonstrating its potential to revolutionize teaching and learning in the educational landscape. As technology continues to advance, it is essential to embrace these tools thoughtfully and strategically, leveraging their capabilities to create an enriched and inclusive learning environment for learners of all backgrounds.

Table 3. DL apps for educational tools.

Title	Overview	References
DeepXDE: A Deep Learning Library for Solving Differential Equations	The new library on DL is DeepXDE which is able to help computational learning for data in the form of physical information. DL is able to calculate and process physical data by the expected results.	[13]
Learning laparoscopic video shot classification for gynaecological surgery	DL is used as a system to classify anatomical structures and surgical procedures based on surgical videos of endometriosis treatment and myoma resection	[14]
CNN EXPLAINER: Learning Convolutional Neural Networks with Interactive Visualization	DL-based tools are used to help people who are not experts in computing or programming learn the CNN network.	[15]
Recurrent Neural Network to Deep Learn Conversation in Indonesian	DL is used as a system capable of analysing words in Indonesian to produce synonyms of identified words.	[16]
Rock Classification from Field Image Patches Analysed Using a Deep Convolutional Neural Network	The DL algorithm is used to classify rock types.	[17]

3.3.2. Performance prediction

Schools and colleges commonly employ predictive methods to assess students' academic performance and determine their potential for successful completion of their education. A method for forecasting the initial performance of pupils entails the utilization of assessment systems and the examination of their test scores or diplomas. However, an alternative method, as presented by Pereira et al. [18], involves extracting essential information from student log data and incorporating this data as features in machine-learning algorithms. This approach allows for early prediction of student outcomes.

Several studies have utilized log data to understand how students handle various aspects of their learning process, such as dealing with mistakes, meeting deadlines, attempting tasks, ensuring correctness, analysing code statically, and examining typing patterns, among others. To achieve this, researchers have employed an evolutionary algorithm to automatically develop and optimize the machine learning pipeline, eliminating the need for a data science professional.

Pereira et al. [18] gathered log data from a custom-made online judge tailored for novice programmers. The evolutionary algorithm systematically explored multiple combinations of feature selection strategies, machine learning algorithms, and hyperparameter tuning to identify the most effective predictive models. As a result, this approach emerged as a highly competitive technique. In a related context, Table 4 demonstrates the use of Deep Learning (DL) for performance prediction in the field of education.

Table 4. DL apps to predict student achievement.

Title	Overview	References
Deep learning goes to school: toward a relational understanding of AI in education	Predict aspects of educational performance by analysing online learning environments, learning forms, flawed data, and computational methods that are difficult to understand.	[19]
Transfer Learning from Deep Neural Networks for Predicting Student Performance	Predict student learning outcomes in higher education through transfer learning conducted by DL networks.	[20]
Predicting At-Risk Students Using Clickstream Data in the Virtual Learning Environment	DL is a system to predict student learning success with input data in the form of student involvement in learning every week. DL will also estimate what kind of student behaviour increases the risk of failure in education.	[21]
Utilizing Student Time Series Behaviour in Learning Management Systems for Early Prediction of Course Performance	DL algorithms predict student performance in online learning based on their analysis of students' online temporal behaviour.	[22]
Deep LMS: a deep learning predictive model for supporting online learning in the Covid-19 era	Predict student behaviour in online learning environments.	[23]
Examining the Factors Influencing the Mobile Learning Usage During COVID-19 Pandemic: An Integrated SEM-ANN Method	DL is tasked with predicting the type of fear faced by teachers and students. DL will predict this through facial expression detection.	[24]
Predicting the academic performance of students from VLE big data using deep learning models	DL is a continuous decision-making system in higher education. The system can provide decisions about which students have indications of intervening and have problems.	[25]

3.3.3. Classification and analysis

Artificial neural networks (ANNs) represent a prominent subset of machine learning (ML) often associated with the term "machine learning." ANNs leverage deep learning techniques to analyse unstructured data. In supervised learning, specific ground truth goals, such as diagnostic labels, outcomes, or reference image measurements, are essential for the algorithm to optimize its performance during training [26]. Supervised learning encompasses two subcategories: classification and regression. Classification techniques yield categorical outputs, assigning inputs to specific categories like "red," "blue," "illness," or "nondisease" (e.g., predicting the probability of a diagnosis). Common algorithms used for classification include deep learning, decision trees, support vector machines (SVM), and others, while regression approaches provide continuous outputs representing the predicted quantity. Logistic and linear regressions are frequently employed for regression tasks [26].

On the other hand, unsupervised learning algorithms work with unlabelled examples and aim to discover key patterns or similarities within the data. These patterns may relate to various illness manifestations, different phenotypes within a specific disease, or diverse temporal evolutions. Unsupervised learning serves as an

exploratory tool, with the end goal often emerging from the study of the results. The two subcategories of unsupervised learning techniques are dimensionality reduction and clustering. Clustering algorithms like K-means and Gaussian mixture models are used for grouping data points, while traditional dimensionality reduction approaches, such as principal component analysis and linear discriminant analysis, help in reducing the number of features in the data [26]. In summary, supervised learning is preferred when the desired outcome is known at the outset of the learning process, while unsupervised learning is used for exploratory purposes, with the ultimate goal typically emerging from the analysis of the results. Table 5 illustrates the application of deep learning as a classification tool in the field of education.

Table 5. DL applications for classification and analysis.

Title	Overview	References
Deep-Learning-Based Agile Teaching Framework of Software Development Courses in Computer Science Education	Assess and evaluate students' abilities automatically using DL. Assessment is carried out based on general ability and in particular.	[27]
Weakly Supervised Framework for Aspect-Based Sentiment Analysis on Students' Reviews of MOOCs	DL is tasked with identifying important variables that affect the effectiveness of MOOCs.	[28]
Sentiment Analysis and Topic Modelling on Tweets about Online Education during COVID-19	Analyse student sentiment using DL to see the effectiveness of e-learning.	[29]
UTiLearn: A Personalised Ubiquitous Teaching and Learning System for Smart Societies	DL, IoT, and big data collaborate to create improved quality of learning, development, management, and delivery.	[30]
A Convolution-LSTM-Based Deep Neural Network for Cross-Domain MOOC Forum Post Classification	DL is a system that functions to identify reactions, classify sentiments, and also determine urgency in the MOOC process.	[31]
Intelligent Teaching Evaluation System Integrating Facial Expression and Behaviour Recognition in Teaching Video	Evaluation tools are used to see the effectiveness of learning methods used by teachers in the form of audio and video on student interests and habits.	[32]
Detecting Task Difficulty of Learners in Colonoscopy: Evidence from Eye-Tracking	DL as a tool to assess the focus of medical students in colonoscopy learning practice. Focus is assessed through eye movement detection by DL.	[33]
Towards Emotionally Aware AI Smart Classroom: Current Issues and Directions for Engineering and Education	DL learns expression patterns and also student body gestures when presenting. This will provide real-time feedback to students about the quality of their presentation delivery.	[34]
Application of Deep Learning on Student Engagement in e-learning environments	DL system as a shortener for student interaction in digital learning in long class hours. DL studies students' expression patterns (fear, happiness, anger, sadness, or surprise) in real time to find out student interactions during class.	[35]
Web Explainer for Children's Education with Image Recognition Based on Deep Learning	DL is a child education system that is able to assess and make decisions when children answer questions. Students will be given true or false answers by DL when doing virtual game-based learning.	[36]

4. Discussion

4.1. Advantages of using DL in education

Deep learning's application in education represents a promising frontier that has the potential to revolutionize the way students learn, and educators teach. The integration of deep learning techniques in educational settings offers numerous opportunities to enhance learning experiences, personalize instruction, and improve educational outcomes. One of the key advantages of deep learning in education is its ability to provide personalized learning experiences. By leveraging vast amounts of student data, deep learning algorithms can analyse individual learning patterns, preferences, and strengths [36]. This enables the creation of adaptive learning platforms that tailor instructional content and pace to meet the unique needs of each student. As a result, students can engage in self-directed learning, progress at their own pace, and focus on areas that require more attention. This personalized approach not only boosts student motivation and engagement but also fosters a deeper understanding of the subject matter.

Deep learning also holds great promise in the development of Intelligent Tutoring Systems (ITS). These systems can provide real-time feedback, diagnose student misconceptions, and offer personalized remediation. By analysing student interactions with the system, ITS can identify areas where learners may be struggling and provide targeted support [16]. This level of individualized guidance empowers students to address their weaknesses, leading to more effective learning outcomes. Language learning is another area where deep learning has shown significant potential. Natural Language Processing (NLP) models can facilitate language understanding, pronunciation assessment, and even automatic translation [34]. Through interactive language learning platforms, students can improve their language skills with immersive and contextually relevant content, ultimately enhancing their communication abilities [11]. Automated assessment and grading powered by deep learning algorithms are streamlining the evaluation process in education. By analysing student responses, these systems can provide timely and consistent feedback to students and educators. Automated grading not only saves educators valuable time but also ensures objective evaluation, minimizing potential biases.

4.2. Challenges of using DL in education

Despite the considerable potential of deep learning in the field of education, it is imperative to acknowledge and tackle several obstacles and ethical problems associated with its implementation. Data privacy is a crucial concern when implementing deep learning algorithms, as student data is utilized for personalization and assessment. It is essential to prioritize data security and comply with data protection regulations to safeguard sensitive information. Algorithmic bias is another critical ethical consideration. Deep learning models are only as unbiased as the data on which they are trained. If the data used to develop these models contains biases, it can perpetuate inequalities and reinforce existing stereotypes in educational settings [9]. Efforts must be made to ensure that deep learning models are fair and equitable, avoiding any unintentional discrimination.

Moreover, the successful integration of deep learning in education requires a collaborative effort between educators, researchers, and technologists. Teachers need to be empowered with the necessary digital literacy skills to effectively utilize

deep learning tools in their classrooms. Furthermore, investments in technology infrastructure are essential to provide seamless access to these educational innovations for all students. In conclusion, deep learning applied in education offers a transformative pathway to create a student-centric and adaptive learning environment. Through personalized instruction, intelligent tutoring systems, and automated assessment, deep learning has the potential to optimize learning outcomes and empower students to reach their full potential. While there are challenges and ethical considerations that need to be addressed, the benefits of deep learning in education outweigh the obstacles. By embracing this technological advancement responsibly, educators can equip students with the skills and knowledge they need to thrive in the dynamic digital era.

4.3. Future directions of incorporating DL methodologies in educational settings

The utilization of deep learning techniques has the capacity to greatly augment educational settings. It enables the seamless integration of educational systems to provide more accurate and regulated results. In the context of education, pupils have the ability to independently employ critical thinking and analysis by utilizing deep learning systems [14]. These technologies demonstrate proficiency in reproducing intricate educational materials, effectively connecting the divide between theoretical concepts and practical comprehension, regardless of whether they are implemented in physical or virtual environments [37].

Furthermore, the integration of deep learning (DL) with classroom cameras contributes to the cultivation of an environment that is more conducive to learning and driven by specific educational objectives [38]. The integration of deep learning directly into these cameras facilitates the observation and analysis of students' facial expressions, actions, and speech intonations, thus enabling the prediction of their academic achievements [38]. The aforementioned examples illustrate the potential of deep learning to be efficiently and suitably utilized in educational environments.

5. Conclusions

The reliability of Deep Learning (DL) technology in processing all types of data has led to its widespread application in numerous disciplines, including Education. This article examines the application of DL in the field of Education. In this review, the research technique is the prism method with Scopus data.

Results indicate that DL is extensively utilized for the advancement of Education. Some of them are used as learning media that help students comprehend learning and master level-appropriate competencies. DL is also used as a system to predict student achievement and performance, classify learning content, discern patterns of expression or gestures to evaluate student interaction during learning and make wrong/right decisions.

The application of DL is ultimately able to improve the quality of education.

Acknowledgement

This research was funded by a grant from the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia (051/E5/PG.02.00.PL/2023).

References

1. Javaid, M.; Haleem, A.; Singh, R.P.; Rab, S.; and Suman, R. (2022). Exploring impact and features of machine vision for progressive industry 4.0 culture. *Sensors International*, 3, 100132.
2. de Assis, D.J.; Néstor, A.F.; and Alejandro, F.G. (2022). Smart working in industry 4.0: How digital technologies enhance manufacturing workers' activities. *Computers and Industrial Engineering*, 163, 107804.
3. Shinde, P.P.; and Shah, S. (2018). A review of machine learning and deep learning applications. *Proceedings of the Fourth international conference on computing communication control and automation* (*ICCUBEA,* 2018), Pune, India, 1-6.
4. Wedel, F.; and Marx, S. (2022). Application of machine learning methods on real bridge monitoring data. *Engineering Structures*, 250, 113365.
5. Bui, D.T.; Tsangaratos, P.; Nguyen, V.-T.; Liem, N.V.; and Trinh, P.T. (2020). Comparing the prediction performance of a Deep Learning Neural Network model with conventional machine learning models in landslide susceptibility assessment. *Catena*, 188, 104426.
6. Chauhan, D. et al. (2022). Comparison of machine learning and deep learning for view identification from cardiac magnetic resonance images. *Clinical Imaging*, 82, 121-126.
7. Teoh, S.C.; Ch'ng, C.K.; and Zaibidi, N.Z. (2019). ICT versus conventional teaching and learning approach in education: An overview of advantages and disadvantages. *Proceeding of the* 2*nd Young Researchers' Quantitative Symposium*, Sintok, Malaysia.
8. van Klompenburg, T.; Kassahun, A.; and Catal, C. (2020). Crop yield prediction using machine learning: A systematic literature review. *Computers and Electronics in Agriculture*, 177, 105709.
9. Waheed, H. et al. (2023). Early prediction of learners at risk in self-paced education: A neural network approach. *Expert Systems with Applications*, 213, 118868.
10. Zhou, W. (2023). The development system of local music teaching materials based on deep learning. *Optik*, 273, 170421.
11. Nair, L.S.; Shivani, M.K.; and Cheriyan, J. (2022). Enabling remote school education using knowledge graphs and deep learning techniques. *Procedia Computer Science*, 215, 618-625.
12. Sundar, N. (2022). No boundaries on educational technology tools for teaching, learning and research. *Social Science Research Network* (*SSRN*), 2(2), 8-14.
13. Lu, L.; Meng, X.; Mao, Z.; and Karniadakis, G.E. (2021). DeepXDE: A deep learning library for solving differential equations. *SIAM Review*, 63(1), 208-228.
14. Petscharnig, S.; and Schöffmann, K. (2018). Learning laparoscopic video shot classification for gynecological surgery. *Multimedia Tools and Applications*, 77, 8061-8079.
15. Wang, Z.J. et al. (2020). CNN explainer: Learning convolutional neural networks with interactive visualization. *IEEE Transactions on Visualization and Computer Graphics*, 27(2), 1396-1406.

16. Chowanda, A.; and Chowanda, A.D. (2017). Recurrent neural network to deep learn conversation in Indonesian. *Procedia Computer Science*, 116, 579-586.
17. Han, Z.; and Xu, A. (2021). Ecological evolution path of smart education platform based on deep learning and image detection. *Microprocessors and Microsystems*, 80, 103343.
18. Pereira, F.D. et al. (2020). Deep learning for early performance prediction of introductory programming students: A comparative and explanatory study. *Brazilian Journal of Computers in Education*, 28, 723-748.
19. Perrotta, C.; and Selwyn, N. (2020). Deep learning goes to school: Toward a relational understanding of AI in education. *Learning, Media and Technology*, 45(3), 251-269.
20. Tsiakmaki, M.; Kostopoulos, G.; Kotsiantis, S.; and Ragos, O. (2020). Transfer learning from deep neural networks for predicting student performance. *Applied Sciences*, 10(6), 2145.
21. Aljohani, N.R.; Fayoumi, A.; and Hassan, S.-U. (2019). Predicting at-risk students using clickstream data in the virtual learning environment. *Sustainability*, 11(24), 7238.
22. Chen, F.; and Cui, Y. (2020). Utilizing student time series behaviour in learning management systems for early prediction of course performance. *Journal of Learning Analytics*, 7(2), 1-17.
23. Dias, S.B.; Hadjileontiadou, S.J.; Diniz, J.; and Hadjileontiadis, L.J. (2020). DeepLMS: A deep learning predictive model for supporting online learning in the COVID-19 era. *Scientific Reports*, 10(1), 19888.
24. Alhumaid, K.; Habes, M.; and Salloum, S.A. (2021). Examining the factors influencing the mobile learning usage during COVID-19 pandemic: An integrated SEM-ANN method. *IEEE Access*, 9, 102567-102578.
25. Waheed, H. et al. (2020). Predicting academic performance of students from VLE big data using deep learning models. *Computers in Human Behavior*, 104, 106189.
26. Garcia-Canadilla, P.; Sanchez-Martinez, S.; Crispi, F.; and Bijnens, B. (2020). Machine learning in fetal cardiology: What to expect. *Fetal Diagnosis and Therapy*, 47(5), 363-372.
27. Yang, J.; Zhang, X.L.; and Su, P. (2019). Deep-learning-based agile teaching framework of software development courses in computer science education. *Procedia Computer Science*, 154, 137-145.
28. Kastrati, Z.; Imran, A.S.; and Kurti, A. (2020). Weakly supervised framework for aspect-based sentiment analysis on students' reviews of MOOCs. *IEEE Access*, 8, 106799-106810.
29. Mujahid, M. et al. (2021). Sentiment analysis and topic modelling on tweets about online education during COVID-19. *Applied Sciences*, 11(18), 8438.
30. Mehmood, R. et al. (2017). UTiLearn: A personalised ubiquitous teaching and learning system for smart societies. *IEEE Access*, 5, 2615-2635.
31. Wei, X.; Lin, H.; Yang, L.; and Yu, Y. (2017). A convolution-LSTM-based deep neural network for cross-domain MOOC forum post classification. *Information*, 8(3), 92.

32. Chen, Z.; Liang, M.; Yu, W.; Huang, Y.; and Wang, X. (2021). Intelligent teaching evaluation system integrating facial expression and behaviour recognition in teaching video. *Proceedings of the IEEE International Conference on Big Data and Smart Computing* (*BigComp,* 2021), Jeju Island, Korea (South), 52-59.
33. Xin, L. et al. (2021). Detecting task difficulty of learners in colonoscopy: Evidence from eye-tracking. *Journal of Eye Movement Research*, 14(2), 1-13.
34. Kim, Y.; Soyata, T.; and Behnagh, R.F. (2018). Towards emotionally aware AI smart classroom: Current issues and directions for engineering and education. *IEEE Access*, 6, 5308-5331.
35. Bhardwaj, P. et al. (2021). Application of deep learning on student engagement in e-learning environments. *Computers & Electrical Engineering*, 93, 107277.
36. Risal, M.F.; Sukaridhoto, S.; and Rante, H. (2019). Web explainer for children's education with image recognition based on deep learning. *Proceedings of International Electronics Symposium* (*IES,* 2019), Surabaya, Indonesia, 406-410.
37. Ahmed, S.F. et al. (2023). Deep learning modelling techniques: Current progress, applications, advantages, and challenges. *Artificial Intelligence Review*, 56(11), 13521-13617.
38. Kuppusamy, P.; and Joseph, S.K. (2020). A Deep Learning Model to Smart Education System. *Proceedings of E-Conference on Artificial Intelligence and Machine Learning* (*EC-AI ML*, 2020), Mumbai, India, 77-83.