

Adaptive Learning Systems in Maritime Education: A Systematic Review of Artificial Intelligence, Deep Learning, and Competency-Based Training Approaches

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Abstract

Maritime education plays a crucial role in developing competent seafarers capable of meeting the operational, safety, and regulatory requirements of the global shipping industry. Traditional maritime training systems generally adopt a uniform teaching and assessment approach, providing identical learning content and evaluation methods to all cadets regardless of their individual learning abilities and competency levels. Recent advancements in Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Educational Data Mining (EDM), and Learning Analytics have enabled the development of adaptive learning systems that can personalize educational experiences based on learner characteristics and performance. This study presents a systematic review of existing research on adaptive learning systems, AI-driven educational technologies, deep learning models for student performance prediction, ensemble learning techniques, and competency-based training approaches relevant to maritime education. A comprehensive review of literature published between 2019 and 2026 was conducted using major academic databases, including Scopus, Web of Science, Springer, ScienceDirect, IEEE Xplore, and ACM Digital Library.

The findings indicate that most existing adaptive learning frameworks are designed for general educational environments and primarily focus on academic performance prediction rather than competency development. Furthermore, the application of hybrid deep learning models, ensemble intelligence techniques, and personalized learning pathways within maritime education remains limited. Current maritime training systems largely rely on traditional learning management systems, simulator-based training, and static assessment methods, with minimal support for individualized learning and competency forecasting. The review identifies significant research gaps and

highlights the need for an intelligent maritime-specific adaptive learning framework. Based on these observations, the study establishes the foundation for the development of MARITAS (Maritime Training and Adaptive Skills System), a competency-driven adaptive learning framework that integrates predictive analytics, personalized recommendations, and advanced AI techniques to enhance maritime education and training outcomes.

Keywords: Maritime Education, Adaptive Learning, Artificial Intelligence, Deep Learning, Ensemble Learning, Learning Analytics, Competency-Based Training, Personalized Learning, MARITAS.

1. Introduction

Maritime education is a specialized domain that aims to develop competent maritime professionals capable of operating safely and efficiently in the global shipping industry. Maritime institutions are responsible for equipping cadets with theoretical knowledge, practical skills, and professional competencies in accordance with the Standards of Training, Certification and Watchkeeping (STCW) prescribed by the International Maritime Organization (IMO). Traditionally, maritime education relies on classroom teaching, computer-based training, simulator exercises, practical demonstrations, and periodic assessments to evaluate cadet performance. While these approaches have contributed significantly to maritime training, they often follow a standardized instructional model that treats all learners similarly regardless of their individual learning abilities, strengths, weaknesses, and competency levels.

In recent years, rapid advancements in Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Educational Data Mining (EDM), and Learning Analytics have transformed the educational landscape. Adaptive learning systems have emerged as intelligent educational solutions capable of personalizing learning experiences based on learner behavior, performance patterns, and cognitive characteristics. These systems dynamically adjust learning content, assessment difficulty, and instructional pathways to meet the unique needs of individual learners. Studies have reported that adaptive learning approaches can improve student engagement, knowledge retention, learning efficiency, and academic outcomes across various educational disciplines.

Despite the growing adoption of adaptive learning technologies in general education, their application within maritime education remains limited. Most existing maritime learning platforms focus primarily on delivering course content, conducting assessments, and supporting simulator-based training. These systems provide limited support for personalized learning, competency forecasting, and intelligent recommendation mechanisms. Furthermore, many existing studies concentrate on predicting academic performance rather than evaluating competency development, which is a critical requirement in maritime education where operational safety and professional competence are of paramount importance.

Recent research has demonstrated the effectiveness of deep learning models such as Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Long Short-Term Memory (LSTM), and Gated Recurrent Units (GRU) for educational data analysis and student performance prediction. Similarly, ensemble learning techniques including Random Forest, XGBoost, AdaBoost, Voting, and Stacking have shown promising results in improving prediction accuracy and model robustness. However, limited studies have investigated the integration of these advanced techniques within maritime education environments to support adaptive learning and competency-based training.

Therefore, there is a growing need to systematically examine the current state of adaptive learning systems, AI-driven educational technologies, deep learning models, ensemble learning approaches, and competency-based training frameworks relevant to maritime education. Understanding existing developments, limitations, and research gaps is essential for designing intelligent educational systems capable of addressing the unique requirements of maritime cadets.

This study presents a systematic review of the literature related to adaptive learning systems in maritime education, focusing on Artificial Intelligence, Deep Learning, Ensemble Learning, Learning Analytics, and Competency-Based Training. The review aims to identify current research trends, analyze existing methodologies, evaluate their strengths and limitations, and establish future research directions. The findings of this review provide the foundation for the development of MARITAS (Maritime Training and Adaptive Skills System), an intelligent adaptive learning framework designed to enhance maritime competency development through predictive analytics, personalized learning pathways, and advanced AI-driven decision support mechanisms.

2. Research Objectives

The primary objective of this study is to systematically review the existing literature on adaptive learning systems, Artificial Intelligence (AI), Deep Learning (DL), Ensemble Learning, Learning Analytics, and competency-based training approaches relevant to maritime education. The review aims to examine current technological advancements, identify prevailing research trends, and evaluate their applicability in developing intelligent educational systems for maritime cadets.

The specific objectives of this study are as follows:

1. To examine the current state of adaptive learning systems and personalized learning approaches in educational environments.
2. To investigate the application of Artificial Intelligence, Machine Learning, and Deep Learning techniques in student performance prediction and learning analytics.

3. To analyze the effectiveness of ensemble learning techniques in improving prediction accuracy and educational decision-making.
4. To review existing competency-based training frameworks and assessment methodologies used in maritime education.
5. To identify the strengths, limitations, and research gaps in current adaptive learning systems and maritime training platforms.
6. To evaluate the potential of integrating hybrid deep learning models, ensemble intelligence, and adaptive learning strategies for competency development in maritime education.
7. To establish the need for an intelligent maritime-specific adaptive learning framework capable of providing personalized learning pathways and competency-driven recommendations.
8. To provide a research foundation for the development of MARITAS (Maritime Training and Adaptive Skills System), an AI-driven adaptive learning framework for maritime education.

3. Research Questions

The rapid advancement of Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Learning Analytics, and Adaptive Learning technologies has significantly influenced modern educational practices. Numerous studies have investigated the application of these technologies in enhancing personalized learning, student performance prediction, and educational decision-making. However, the extent to which these approaches have been applied within maritime education remains unclear. To systematically examine the existing body of knowledge and identify potential research gaps, a set of research questions was formulated to guide this review.

The first research question investigates the major adaptive learning approaches and personalized learning strategies currently employed in educational systems. This question aims to understand how adaptive learning technologies are designed and implemented to address diverse learner needs. The second research question examines the utilization of Artificial Intelligence, Machine Learning, and Deep Learning techniques for student performance prediction and learning analytics. Understanding the effectiveness of these techniques is essential for identifying suitable methodologies for adaptive educational environments.

The third research question focuses on the role of ensemble learning techniques in educational applications and their contribution toward improving prediction accuracy and decision-making capabilities. Since ensemble methods have demonstrated superior performance in various prediction tasks, their applicability within adaptive learning environments warrants further investigation. The fourth research question explores existing competency-based training and assessment frameworks adopted in maritime education and training institutions. This analysis is important because competency development forms the foundation of professional maritime training and certification requirements.

The fifth research question seeks to identify the major limitations, challenges, and research gaps present in existing adaptive learning systems, particularly those related to maritime education and competency development. Finally, the sixth research question investigates how adaptive learning approaches, hybrid deep learning models, ensemble intelligence techniques, and competency-based educational frameworks can be integrated to develop intelligent maritime learning systems. Collectively, these research questions provide a structured framework for reviewing the literature, identifying emerging trends, and establishing the necessity for developing MARITAS (Maritime Training and Adaptive Skills System), an intelligent adaptive learning framework specifically designed to support competency enhancement and personalized learning in maritime education.

4. Research Methodology

This study adopts a systematic literature review approach to investigate the application of adaptive learning systems, Artificial Intelligence (AI), Deep Learning (DL), Ensemble Learning, Learning Analytics, and competency-based training methodologies in maritime education. A systematic review methodology was selected to ensure a comprehensive, transparent, and reproducible analysis of existing research studies. The review process was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which provide a structured framework for identifying, screening, evaluating, and synthesizing relevant literature.

To collect relevant studies, a comprehensive search was performed across major academic databases, including Scopus, Web of Science, SpringerLink, ScienceDirect, IEEE Xplore, ACM Digital Library, and Google Scholar. The literature search focused on publications released between 2019 and 2026 to capture recent developments in adaptive learning technologies and maritime education. Several search keywords and keyword combinations were utilized, including “Adaptive Learning Systems,” “Maritime Education,” “Artificial Intelligence in Education,” “Deep Learning for Student Performance Prediction,” “Ensemble Learning,” “Learning Analytics,” “Educational Data Mining,” “Competency-Based Training,” “Personalized Learning,” and “Maritime Training Systems.”

To ensure the quality and relevance of the reviewed studies, specific inclusion and exclusion criteria were established. The inclusion criteria considered peer-reviewed journal articles, conference papers, review articles, and scholarly publications written in English that addressed adaptive learning, artificial intelligence, machine learning, deep learning, learning analytics, competency assessment, or maritime education. Studies published outside the selected time period, duplicate records, non-peer-reviewed publications, editorials, and articles lacking sufficient methodological details were excluded from the review process.

Following the initial database search, all identified articles were screened based on their titles, abstracts, and keywords. Relevant studies were then subjected to full-text assessment to determine their suitability for inclusion in

the review. Information from the selected studies was systematically extracted and categorized according to research objectives, methodologies, technologies employed, datasets used, major findings, limitations, and identified research gaps. The collected data were subsequently analyzed and synthesized to identify prevailing research trends, technological advancements, challenges, and future research opportunities related to adaptive learning systems in maritime education.

The systematic review process enables a comprehensive understanding of the current state of research while providing a strong foundation for identifying unresolved challenges and opportunities for innovation. The findings derived from this methodology support the development of MARITAS (Maritime Training and Adaptive Skills System), a proposed intelligent adaptive learning framework designed to enhance competency development, personalized learning, and predictive educational analytics within maritime education and training environments.

5. Literature Review and Analysis

5.1 Adaptive Learning Systems

Adaptive learning systems have emerged as one of the most significant advancements in modern educational technology. Unlike traditional learning environments that provide identical instructional content to all learners, adaptive learning systems personalize educational experiences according to individual learner characteristics, knowledge levels, learning pace, and performance patterns. These systems continuously collect learner data, analyze behavioral and academic indicators, and dynamically modify content delivery, assessment difficulty, and learning pathways. The integration of learning analytics, recommendation engines, and intelligent tutoring mechanisms has further enhanced the effectiveness of adaptive learning environments. Numerous studies have reported improvements in learner engagement, knowledge retention, academic achievement, and self-directed learning through adaptive educational frameworks. Despite these advancements, the majority of adaptive learning systems have been developed for general educational contexts such as higher education, online learning platforms, and professional training programs, with limited focus on domain-specific applications such as maritime education.

5.2 Artificial Intelligence in Education

Artificial Intelligence has significantly transformed educational systems by enabling intelligent decision-making, personalized instruction, automated assessment, and predictive analytics. AI-driven educational applications utilize techniques such as machine learning, natural language processing, expert systems, and educational data mining to support learners and educators. Intelligent Tutoring Systems (ITS) represent one of the earliest applications of AI in education, providing individualized feedback and adaptive instructional support. Recent developments have expanded the role of AI in predicting student performance, identifying at-risk learners, recommending learning resources, and optimizing educational interventions. Learning Analytics and Educational Data Mining have become

important components of AI-based educational systems by extracting meaningful patterns from large educational datasets. Although AI technologies have demonstrated considerable success across multiple educational domains, their implementation within maritime education remains relatively limited, particularly in the areas of competency forecasting and adaptive learning support.

5.3 Deep Learning for Student Performance Prediction

Deep Learning has gained substantial attention in educational research due to its ability to identify complex patterns and relationships within large datasets. Various deep learning architectures, including Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Long Short-Term Memory (LSTM), and Gated Recurrent Units (GRU), have been applied to predict student performance and learning outcomes. These models can process multiple educational variables such as attendance records, assessment scores, assignment performance, learning behavior, and historical academic data. Among these techniques, LSTM and GRU models have demonstrated superior capabilities in analyzing temporal educational data due to their ability to capture long-term sequential dependencies. Similarly, CNN-based architectures have shown effectiveness in extracting meaningful features from multidimensional educational datasets. While deep learning approaches have achieved promising prediction accuracy in educational settings, their application to maritime competency prediction and adaptive learning remains an underexplored research area.

5.4 Ensemble Learning Techniques

Ensemble learning techniques have become increasingly popular in predictive analytics because they combine multiple models to improve overall prediction performance, stability, and robustness. Common ensemble approaches include Bagging, Boosting, Random Forest, AdaBoost, Gradient Boosting, XGBoost, Voting, and Stacking. These methods reduce model variance and bias by aggregating the strengths of individual learning algorithms. In educational research, ensemble models have been widely employed for student performance prediction, dropout prediction, and academic risk assessment. Studies have reported that ensemble-based models often outperform standalone machine learning and deep learning models in terms of accuracy, precision, recall, and generalization capability. Despite these advantages, limited research has investigated the integration of ensemble intelligence with adaptive learning systems and competency-based educational frameworks. Furthermore, maritime education has witnessed only minimal adoption of ensemble learning techniques for learner assessment and competency development.

5.5 Maritime Education and Competency-Based Training

Maritime education is fundamentally competency-oriented and is governed by international standards established by the International Maritime Organization through the Standards of Training, Certification and Watchkeeping (STCW) Convention. Maritime institutions employ a combination of classroom instruction, simulator training, practical exercises, computer-based learning, and competency assessments to prepare cadets for professional maritime operations. Competency-based training focuses on developing the knowledge, skills, and attitudes required for safe and efficient shipboard performance. Modern maritime training increasingly incorporates simulation technologies, virtual learning environments, and e-learning platforms to enhance educational effectiveness. However, most existing maritime learning systems remain largely static and provide limited support for personalized learning, competency forecasting, and intelligent educational interventions. Current assessment practices primarily evaluate academic achievement rather than continuously monitoring competency progression and learner development. Consequently, there exists a significant opportunity to integrate adaptive learning, predictive analytics, and AI-driven decision support into maritime education systems.

5.6 Comparative Analysis of Existing Studies

A review of existing literature indicates that significant progress has been achieved in adaptive learning systems, artificial intelligence applications, deep learning-based educational analytics, and ensemble learning methodologies. Most studies have concentrated on improving student performance prediction, enhancing learner engagement, and supporting personalized educational experiences within general academic environments. Deep learning models such as CNN, LSTM, and GRU have demonstrated strong predictive capabilities, while ensemble techniques have improved model reliability and accuracy. However, a critical examination of the literature reveals several limitations. First, the majority of studies are conducted within general educational settings rather than specialized professional domains. Second, very few studies address the unique competency requirements of maritime education. Third, existing systems predominantly focus on academic performance indicators rather than competency development and professional readiness. Finally, there is limited evidence regarding the integration of hybrid deep learning architectures, ensemble intelligence techniques, and adaptive learning frameworks specifically designed for maritime cadets. These findings highlight a substantial research gap and establish the need for the development of MARITAS (Maritime Training and Adaptive Skills System), an intelligent adaptive learning framework capable of supporting competency-driven maritime education through predictive analytics and personalized learning pathways.

6. Research Gap Analysis

The comprehensive review of literature on adaptive learning systems, Artificial Intelligence (AI), Deep Learning (DL), Ensemble Learning, Learning Analytics, and maritime education reveals several significant research gaps that

warrant further investigation. Although adaptive learning technologies have demonstrated substantial success in improving learning outcomes across various educational domains, their implementation within maritime education remains limited. Most existing adaptive learning systems are designed for general educational environments and primarily focus on academic performance improvement rather than competency development, which is a fundamental requirement in maritime training and certification.

The literature further indicates that current maritime education systems predominantly rely on conventional Learning Management Systems (LMS), Computer-Based Training (CBT), simulator-based exercises, and periodic assessments. While these approaches effectively support knowledge delivery and practical training, they provide limited capability for personalized learning, learner behavior analysis, competency forecasting, and adaptive educational interventions. Consequently, maritime institutions often identify learning deficiencies only after assessment outcomes are available, reducing opportunities for timely academic support and competency enhancement.

Another significant research gap relates to the application of Artificial Intelligence and Deep Learning techniques in maritime education. Existing studies have successfully employed Machine Learning, Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), and Gated Recurrent Units (GRU) for student performance prediction in general education. However, very few studies have investigated the application of these advanced techniques within maritime learning environments. Furthermore, most prediction models focus solely on academic achievement indicators such as examination scores and grades, while neglecting competency development, professional readiness, and practical skill acquisition.

The review also reveals limited integration of ensemble learning methodologies within adaptive educational systems. Although ensemble techniques such as Random Forest, XGBoost, AdaBoost, Voting, and Stacking have demonstrated superior predictive performance in educational data mining applications, their utilization for competency-driven adaptive learning remains largely unexplored. The combination of hybrid deep learning architectures and ensemble intelligence for maritime competency assessment has received minimal research attention despite its potential to improve prediction accuracy, model stability, and educational decision-making.

Moreover, existing maritime learning systems generally lack intelligent recommendation mechanisms capable of generating personalized learning pathways based on individual learner performance, competency levels, and learning behavior. Most available systems provide static learning content and standardized assessments regardless of learner characteristics. This limitation reduces the effectiveness of educational interventions and fails to address the diverse learning requirements of maritime cadets.

Based on these observations, it can be concluded that there is a substantial research gap in the development of intelligent, competency-driven adaptive learning systems specifically designed for maritime education. The

literature highlights the absence of frameworks that integrate adaptive learning, hybrid deep learning models, ensemble intelligence techniques, competency-based assessment, and personalized learning recommendations within a unified maritime educational environment. Addressing these limitations provides a significant research opportunity and establishes the foundation for the proposed MARITAS (Maritime Training and Adaptive Skills System). MARITAS aims to bridge the identified gaps by providing an intelligent adaptive learning framework capable of predicting competency deficiencies, personalizing learning experiences, and enhancing competency development through advanced AI-driven educational analytics.

7. Future Research Directions and Proposed MARITAS Framework

The findings of this systematic review indicate that although significant advancements have been achieved in adaptive learning systems, Artificial Intelligence (AI), Deep Learning (DL), Learning Analytics, and Educational Data Mining, their application within maritime education remains at an early stage. Existing maritime learning platforms primarily focus on content delivery, simulator-based training, and conventional assessment methods, with limited support for personalized learning, competency prediction, and intelligent educational interventions. Consequently, there is a growing need for innovative frameworks capable of addressing the unique learning requirements of maritime cadets while supporting competency-based education and training objectives.

Future research should focus on developing intelligent educational systems that integrate adaptive learning methodologies with advanced predictive analytics and competency assessment mechanisms. The incorporation of hybrid deep learning architectures such as Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), and Gated Recurrent Units (GRU) can facilitate accurate prediction of learner performance and competency progression. Furthermore, ensemble learning techniques including Random Forest, XGBoost, Voting, and Stacking can be employed to improve prediction reliability and model robustness. These technologies have the potential to transform traditional maritime education into a more personalized, data-driven, and competency-oriented learning environment.

Based on the research gaps identified in this review, a conceptual framework named MARITAS (Maritime Training and Adaptive Skills System) is proposed. MARITAS is envisioned as an intelligent adaptive learning framework specifically designed for maritime education and training. The framework aims to integrate learner data, academic performance indicators, competency assessment results, learning behavior analytics, and predictive intelligence into a unified educational platform. The proposed system will continuously monitor learner progress and dynamically generate personalized learning pathways tailored to the individual needs of each cadet.

The MARITAS framework consists of several interconnected components. The first component focuses on data acquisition, where information such as attendance records, continuous internal assessment scores, assignment

performance, quiz results, semester examination marks, and competency assessment outcomes are collected and stored. The second component involves data preprocessing and feature engineering to ensure data quality and prepare the information for predictive modeling. The third component incorporates hybrid deep learning models capable of analyzing learning patterns, performance trends, and competency progression. The fourth component utilizes ensemble intelligence techniques to enhance prediction accuracy and support educational decision-making processes.

Another important component of MARITAS is the adaptive learning engine, which dynamically recommends learning materials, revision plans, assessment activities, and competency enhancement strategies based on learner profiles and predicted performance outcomes. The framework also includes a competency mapping module that aligns learning activities and assessments with maritime competency requirements and STCW standards. This capability enables continuous monitoring of competency development and assists educators in identifying potential deficiencies before they impact overall performance.

The expected benefits of MARITAS include improved learner engagement, early identification of at-risk cadets, enhanced competency development, personalized learning experiences, and data-driven educational decision-making. The framework is also expected to support educators and training institutions in monitoring learner progress more effectively while facilitating timely academic interventions. By combining adaptive learning principles, hybrid deep learning models, ensemble intelligence, and competency-based educational strategies, MARITAS has the potential to significantly improve the effectiveness and efficiency of maritime education and training.

Therefore, future research should focus on the design, implementation, validation, and evaluation of the MARITAS framework using real-world maritime educational datasets. The successful development of such a system would contribute to the advancement of intelligent maritime education and provide a foundation for next-generation competency-driven training environments capable of meeting the evolving demands of the global maritime industry.

8. Conclusion

This study presented a systematic review of the existing literature related to adaptive learning systems, Artificial Intelligence (AI), Deep Learning (DL), Ensemble Learning, Learning Analytics, and competency-based training approaches with particular emphasis on their applicability to maritime education. The review examined recent advancements in intelligent educational technologies and analyzed their contributions toward personalized learning, student performance prediction, educational decision-making, and competency development. Through an extensive evaluation of published research, it was observed that adaptive learning systems have significantly improved educational outcomes across various academic domains by providing individualized learning experiences and data-driven instructional support.

The review further revealed that Artificial Intelligence, Machine Learning, and Deep Learning techniques have become increasingly effective in analyzing educational data and predicting learner performance. Advanced models such as Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), and Gated Recurrent Units (GRU) have demonstrated promising results in identifying learning patterns and forecasting academic outcomes. Similarly, ensemble learning techniques have contributed to improving prediction accuracy and model reliability by combining the strengths of multiple predictive models. Despite these technological advancements, the application of such intelligent approaches within maritime education remains relatively limited compared to other educational domains.

The analysis identified several significant research gaps. Existing maritime learning systems primarily focus on content delivery, simulator-based training, and traditional assessment mechanisms, with limited support for adaptive learning, competency forecasting, and personalized educational interventions. Furthermore, most educational prediction models emphasize academic performance indicators rather than competency development, which is a critical requirement in maritime education governed by international competency standards. The review also highlighted the limited integration of hybrid deep learning architectures, ensemble intelligence techniques, and competency-based learning frameworks within maritime training environments.

Based on these findings, this study established the need for developing intelligent maritime-specific adaptive learning systems capable of supporting competency-driven education and personalized learning experiences. To address the identified gaps, the concept of MARITAS (Maritime Training and Adaptive Skills System) was proposed as a future research direction. MARITAS aims to integrate adaptive learning principles, hybrid deep learning models, ensemble intelligence techniques, learning analytics, and competency assessment mechanisms into a unified framework for maritime education. The proposed framework has the potential to enhance learner engagement, improve competency development, support early identification of learning deficiencies, and facilitate data-driven educational decision-making.

In conclusion, the future of maritime education lies in the adoption of intelligent and adaptive educational technologies capable of addressing the diverse learning needs of maritime cadets while ensuring compliance with competency-based training requirements. The findings of this review provide a strong foundation for future research and development in this area and establish the theoretical basis for the design, implementation, and evaluation of MARITAS. The successful realization of such intelligent learning frameworks can contribute significantly to the advancement of maritime education, ultimately supporting the development of highly competent maritime professionals for the global shipping industry.

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Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this paper. The research was conducted independently for academic and research purposes, and no financial, commercial, or personal relationships influenced the outcomes or conclusions presented in this study.

References

- Adefemi, K. O., Mutanga, M. B., & Jugoo, V. (2025). Hybrid deep learning models for predicting student academic performance: CNN + BiGRU approach. *Mathematical and Computational Applications*, 30(3), 59.
- Angeioplastis, A., Aliprantis, J., Konstantakis, M., & Tsimpiris, A. (2025). Predicting student performance and enhancing learning outcomes: A data-driven educational data mining approach. *Computers*, 14(3), 83.
- Villegas-Espinoza, A. E., & Necochea-Chamorro, J. I. (2024). Using deep learning in student performance prediction: A systematic review. *TEM Journal*, 14(3), 51–63.
- Karimi, E., Smith, J., Billard, R., & Veitch, B. (2024). AI-based adaptive instructional systems for maritime safety training: A systematic literature review. *Discover Artificial Intelligence*, 4(51), 1–23.
- Gligorea, I., Cioca, M., Oancea, R., Gorski, A. T., Gorski, H., & Tudorache, P. (2023). Adaptive learning using artificial intelligence in e-learning: A literature review. *Education Sciences*, 13(12), 1216.

- Mallam, S. C., Nazir, S., & Renganayagalu, S. K. (2019). Rethinking maritime education, training, and operations in the digital era: Applications for emerging immersive technologies. *Journal of Marine Science and Engineering*, 7(12), 428.
- Siemens, G., & Long, P. (2011). Penetrating the fog: Analytics in learning and education. *EDUCAUSE Review*, 46(5), 30–40.
- Baker, R. S., & Inventado, P. S. (2014). Educational data mining and learning analytics. In *Learning Analytics* (pp. 61–75). Springer.
- Romero, C., & Ventura, S. (2020). Educational data mining and learning analytics: An updated survey. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, 10(3), e1355.
- Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. MIT Press.
- LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, 521(7553), 436–444.
- Hochreiter, S., & Schmidhuber, J. (1997). Long short-term memory. *Neural Computation*, 9(8), 1735–1780.
- Cho, K., Van Merriënboer, B., Gulcehre, C., et al. (2014). Learning phrase representations using RNN encoder-decoder for statistical machine translation. *EMNLP*.
- Breiman, L. (2001). Random forests. *Machine Learning*, 45(1), 5–32.
- Chen, T., & Guestrin, C. (2016). XGBoost: A scalable tree boosting system. *KDD Conference Proceedings*.
- Freund, Y., & Schapire, R. E. (1997). A decision-theoretic generalization of online learning and an application to boosting. *Journal of Computer and System Sciences*, 55(1), 119–139.
- Dietterich, T. G. (2000). Ensemble methods in machine learning. *Multiple Classifier Systems*, 1–15.
- Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of artificial intelligence applications in higher education. *International Journal of Educational Technology in Higher Education*, 16(39), 1–27.
- Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence unleashed: An argument for AI in education*. Pearson Education.
- Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education*. Center for Curriculum Redesign.

- Shute, V. J., & Zapata-Rivera, D. (2012). Adaptive educational systems. *Adaptive Technologies for Training and Education*.
- Brusilovsky, P. (2001). Adaptive hypermedia. *User Modeling and User-Adapted Interaction*, 11(1–2), 87–110.
- Brusilovsky, P., & Millán, E. (2007). User models for adaptive hypermedia and adaptive educational systems. *The Adaptive Web*.
- Ally, M. (2019). *Competency-based learning and personalized education*. Commonwealth of Learning.
- IMO. (2024). *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)*. International Maritime Organization.
- WMU. (2023). *Maritime education and training trends*. World Maritime University Publications.
- UNCTAD. (2024). *Review of Maritime Transport*. United Nations Conference on Trade and Development.
- Kirkpatrick, D., & Kirkpatrick, J. (2016). *Evaluating training programs: The four levels*. Berrett-Koehler Publishers.
- Alpaydin, E. (2021). *Introduction to machine learning (4th ed.)*. MIT Press.
- Aggarwal, C. C. (2018). *Neural networks and deep learning*. Springer.
- Han, J., Pei, J., & Kamber, M. (2022). *Data mining: Concepts and techniques*. Morgan Kaufmann.
- Russell, S., & Norvig, P. (2021). *Artificial intelligence: A modern approach (4th ed.)*. Pearson.
- Sutton, R. S., & Barto, A. G. (2018). *Reinforcement learning: An introduction*. MIT Press.
- Kumar, V., & Sharma, A. (2023). Adaptive learning technologies in higher education: Opportunities and challenges. *Education and Information Technologies*, 28(5), 5671–5694.
- Woolf, B. P. (2021). *Building intelligent interactive tutors*. Morgan Kaufmann.

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