Journal of Moeslim Research Technik, 1(3) - April 2024 155-168

The Role of Mechanical Engineering in the Development of Environmentally Friendly Electric Vehicles

Zhang Wei [1], Snyder Bradford [2], Xie Guilin [3]
[1] *University of Missouri, Columbia*
[2] *International University of Monaco, Monaco*
[3] *University of Science and Technology of Hanoi, Vietnam*

Corresponding Author: Zhang Wei, E-mail; zhangwei@gmail.com

Received: April 19, 2024	Revised: April 22, 2024	Accepted: April 25, 2024	Online: April 27, 2024

ABSTRACT
In an effort to address environmental issues caused by greenhouse gas emissions and air pollution from fossil fuel vehicles, the development of electric vehicles is a promising solution. Electric vehicles offer a more environmentally friendly alternative and have the potential to reduce dependence on fossil fuels. The role of mechanical engineering in the innovation and development of electric vehicle technology is crucial to achieve higher efficiency and minimal environmental impact. This research aims to analyze the contribution of mechanical engineering in the development of environmentally friendly electric vehicles, including the identification of technologies and methods used to improve the performance and efficiency of electric vehicles. This research uses a qualitative method with a literature study approach and comparative analysis. Data were collected from various scientific and technical sources, including relevant journals, books, and industry publications. Technical innovations in the design of electric motors, energy storage systems, and materials used in electric vehicles were analyzed. The results show that mechanical engineering has an important role in various aspects of electric vehicle development. Innovations in electric motor design such as the use of permanent magnet synchronous motors (PMSM) and induction motors have improved efficiency and performance. The development of batteries with high energy density and good thermal management is also key in improving the range and reliability of electric vehicles. In addition, the use of lightweight and strong materials in vehicle construction contributes to reducing energy consumption. Mechanical engineering plays a crucial role in the development of more efficient and environmentally friendly electric vehicles. Through various technical innovations, electric vehicles can be a sustainable solution for future transportation, with great potential to reduce negative impacts on the environment. The implementation of new technologies in motor design, energy storage systems, and vehicle materials are decisive factors in achieving this goal.

Keywords: *Engineering, Environmentally, Vehicles*

Journal Homepage https://journal.ypidathu.or.id/index.php/ijnis

How to cite: Wei, Z., Bradford, S & Guilin, X. (2024). The Role of Mechanical Engineering in the Development of Environmentally Friendly Electric Vehicles. *Journal of Moeslim Research Technik*, 1(3), 155-168. https://doi.org/10.55849/technik.v1i1.172
Published by: Yayasan Pedidikan Islam Daarut Thufulah

INTRODUCTION

In recent decades, environmental problems caused by greenhouse gas emissions and air pollution have become increasingly alarming (Clinch et al., 2021). Fossil fuel vehicles are one of the main contributors to this problem, with CO2 emissions and other harmful pollutants released into the atmosphere (Shahmoradi et al., 2020). This problem has a significant impact on global climate change and human health, given the high concentration of emissions from the transportation sector.

The problem is becoming more urgent as population increase and urbanization lead to an increase in the number of vehicles on the road (Mosco, 2023). Air pollution from vehicles not only affects air quality but also impacts global warming (Bajić et al., 2023). Therefore (Elazhary, 2019), efforts are needed to reduce emissions from the transportation sector to mitigate these negative impacts. One solution being developed is more environmentally friendly electric vehicles (Derakhshan et al., 2024). Electric vehicles offer an alternative that not only reduces greenhouse gas emissions but also improves overall energy efficiency (Gomez et al., 2021). However, the development of electric vehicles faces various technical challenges that need to be solved (Tupouniua, 2023), such as the efficiency of electric motors, energy storage systems, and the materials used.

Discussing the role of mechanical engineering in the development of electric vehicles is important because mechanical engineering plays a central role in technological innovations that can improve the performance and efficiency of electric vehicles (Barz et al., 2024). Understanding the contributions and challenges in this field will help accelerate the adoption of electric vehicle technology and address the environmental issues faced. To address these issues, research and development in mechanical engineering is focused on various aspects (Bahmani Kashkouli et al., 2020), including the design of more efficient electric motors, the development of high-energy density batteries, and the use of lightweight yet strong materials. These innovations are expected to overcome technical obstacles and make electric vehicles a sustainable solution for future transportation. Environmental problems caused by fossil fuel vehicle emissions are increasingly urgent to address. Greenhouse gas emissions and other air pollutants from conventional vehicles have been shown to contribute significantly to global warming and air quality degradation. Therefore, there is an urgent need to develop more environmentally friendly transportation solutions. This research was conducted with the rationale of supporting the transition towards the use of cleaner and more efficient electric vehicles as a measure to reduce negative impacts on the environment.

This research aims to fill the existing gap in the development of electric vehicle technology, especially in the field of mechanical engineering. Currently, key challenges in electric vehicle development include improving the efficiency of electric motors, optimizing energy storage systems, and using lightweight yet strong materials. This research will use innovative approaches in the design and development of key electric vehicle components to address these gaps. Through in-depth analysis and comparative testing, this research will contribute to improving the overall performance and efficiency of electric vehicles.

In the state of the art review, various innovations in mechanical engineering for electric vehicles have been developed, such as permanent magnet synchronous motors (PMSM) and high-energy density batteries. However, there are still challenges in terms of cost, reliability, and energy efficiency. This research proposes new innovations in the design of more efficient electric motors, more effective battery thermal management systems, and the use of lighter yet stronger composite materials. These innovations are expected to provide a more optimized solution in the development of electric vehicles.

The novelty of this article lies in its holistic approach to electric vehicle development, which covers various aspects of mechanical engineering in an integrated manner. In contrast to previous research that often focuses on one particular aspect, this research seeks to combine various technical innovations in one comprehensive framework. As such, it offers a more efficient and integrated solution to address the challenges in electric vehicle development.

Furthermore, this research will be conducted through a series of experiments and simulations to test the effectiveness of the proposed innovations. It is expected that the results of this research can provide practical guidance for the development of electric vehicles in the future. Researchers are expected to continue this effort by focusing on field testing and further development of the identified technologies, so as to accelerate the adoption of more environmentally friendly and efficient electric vehicles.

RESEARCH METHOD

Research design

This research uses a quantitative research design, which is inputted into google form as many as 20 questions (Payal et al., 2024). Which includes what effects will be caused when students use technology-enabled language learning (Favale et al., 2020). This method is used to formulate a new thought that is useful for every level of students (Spernjak, 2021). Then developed into a research that can be accounted for accuracy (Dong & Liu, 2023), which is tailored to each event experienced by students (Selwyn, 2019). This method of collection is useful for testing the feasibility of language-based learning itself in order to improve student learning achievement (Shadiev & Yang, 2020). The quantitative method can also be interpreted as a research stage that begins with making a questionnaire containing 20 items (Gosal et al., 2019), then each answer given by students is processed using the spss application (Pardo et al., 2019). The data obtained can be proven accurate through a google form created by the researcher. And researchers also input the highest gain and also the lowest gain from the questionnaire distributed to each student (Baek et al., 2021). Then conclude these statements.

Research Procedure

The steps taken in this study began by asking permission from the campus and working with English teachers. Then every student filled in (Else, 2023), from the beginning of the questionnaire made by the researcher until it reached the filling acquisition that the researcher considered had fulfilled the expected acquisition by the researcher (Besser et al., 2022). Then the researcher is also very concerned about ethics in

making questionnaires that use good language and are also polite (Kapasia et al., 2020). So that students can fill out this questionnaire in a short period of time (Chow et al., 2023), which makes it easier for researchers to examine various Exploring the Potential of Renewable Energy in Today's Engineering Development.

Research Subjects

The subjects of this research are students of UIN Mahmud Yunus Batusangkar, the role of the researcher is to collect every answer given by students (Dube, 2020). Researchers are also assisted by English lecturers who teach at UIN Mahmud Yunus Batusangkar, especially educators who teach in the field of technology (Dubey, 2021). This study is to measure the ability of students to use questions in the form of tests and then count from the highest series of acquisition numbers to the lowest series of numbers (Hao & Ho, 2019). The researcher then inputs the score obtained through the research subject which becomes a reference to determine the Role of Mechanical Engineering in the Development of Environmentally Friendly Electric Vehicles (Alma Çallı & Ediz, 2023). The type of research conducted is research that strongly considers every answer given by students, which aims to determine the effect of Exploring the Potential of Renewable Energy in Today's Engineering Development.

Research Ethics

Of the approximately 1000 students enrolled at Mahmud Yunus State Islamic University Batusangkar, only 50 students contributed to this study (Dwivedi et al., 2023). Of these. 50 students participated in this study, of which 25 were male and 25 were female with a maximum age of 19 years and 18 years (Maulida et al., 2023). The data collection of these participants came from various villages or jorongs adjacent to UIN Mahmud Yunus Batusangkar. This research has obtained permission from the lecturer who teaches the language course. This research uses several principles of research ethics (Oulaich, 2020). First, there is no coercion in filling out the questionnaire. This research only expects the volunteerism of students and female students who study here. Then every question must be answered completely without leaving any part of the questionnaire. This formular is very supportive and upholds rights and there is no coercion at all. This was done to ensure that the participants understood the essence of this study, out of 50 participants 80% expressed their willingness to fill out this questionnaire.

Data Collection Technique

The technique used by researchers in collecting data is to obtain various information that can be measured, compared, and calculated carefully. Through a google form format made by researchers (Ibrar et al., 2019), which was filled in by 50 students of UIN Mahmud Yunus Batusangkar (Alshater, 2022). Data collection was carried out on first semester students in the 2023/2024 academic year. After obtaining permission to conduct research from the language lecturer (Jansen et al., 2023), and also the IT link the online questionnaire was distributed to students of various majors. The distribution of this questionnaire was carried out on March 1, 2024 to March 30, 2024 (Memon et al., 2021). The process of processing data that has been collected from research field respondents. The questionnaire data is then downloaded into an Excel file and then transferred to SPSS

(Yudiawan et al., 2021). 20 questions to review (Gosal et al., 2019), the final score data is recorded in the SPSS application which can be verified. Then recapitulated as interesting as possible so that readers are interested in reading the articles made by researchers.

Data Collection and Analysis

Then the data that has been collected is inputted and processed using the SPSS application. Distributed in the form of tables and diagrams that can calculate the scores obtained from students (Teimouri et al., 2022). The way the data is analyzed is by comparing each answer given by each student with previous studies (Cohen et al., 2020). Data is presented in the form of average scores and percentages (Castañeda-Babarro et al., 2020). Then the data were tested using the oneway anova test (Kang et al., 2022). Which compares the acquisition scores of each group who filled out each statement related to the questionnaire made by the researcher (Loewen et al., 2019). Researchers also take into account the scores obtained by each student who fills out the questionnaire previously made by the researcher (Betlem et al., 2019). And will never leave any answers given by students from the beginning of filling out the questionnaire until the last student fills out this questionnaire (Shadiev & Yang, 2020). Furthermore, researchers will also summarize in an accurate conclusion.

Table 1. 1

Category of Mechanical Engineering Role in the Development of Environmentally Friendly Electric Vehicles

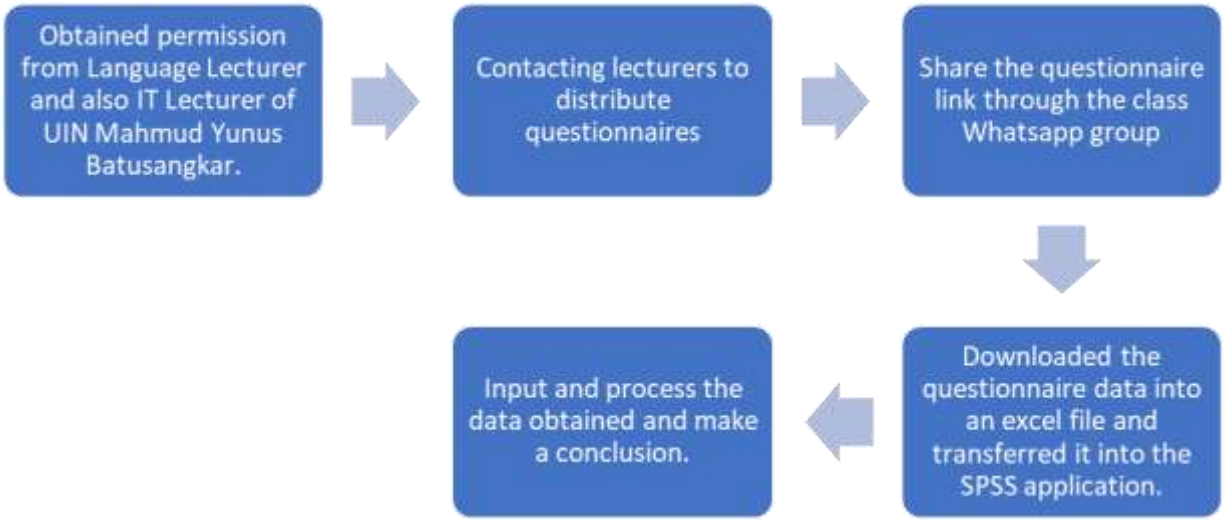
No.	Gain category	**Value interval**
1	Strongly agree	>90%
2	Agree	70-80%
3	Disagree less	50-60%
4	Do not agree at all	0-40%
Total		100%

Table 1. 2

Research Sample Details

No	**Student Batch**	**Gender**		**Total**
		Male	**Female**	
1	T.A 2022	10	10	20
2	T.A 2023	15	15	20
	Total	**25**	**25**	**50**

Flowchart of quantitative research



Results

Table 1.3

The Role of Mechanical Engineering in the Development of Environmentally Friendly Electric Vehicles

No	Statement	**SS**	**S**	**KS**	**SKS**
1	Mechanical engineering plays a role in designing more efficient and lightweight components for electric vehicles, such as frames and bodies, thereby reducing energy consumption and increasing vehicle range.	60%	40%	0%	0%
2	Mechanical engineers develop more efficient and powerful electric motors, which are key components in electric vehicle performance.	50%	50%	0%	0%
3	Mechanical engineers play a role in designing effective cooling systems to maintain the optimum temperature of batteries and electric motors, increasing component life and performance.	70%	30%	0%	0%
4	Mechanical engineers work on the aerodynamic design of electric vehicles	65%	30%	5%	0%

	to reduce air resistance, which directly improves the energy efficiency and range of the vehicle.				
5	Mechanical engineers are involved in the development and integration of improved battery technologies, including battery management systems (BMS) that optimize performance and safety.	60%	40%	0%	0%
6	6. Mechanical engineers develop efficient transmission systems for electric vehicles, which enable better power distribution from the electric motor to the wheels.	80%	20%	0%	0%
7	Mechanical engineering contributes to the research and use of advanced materials, such as composites and lightweight alloys, which reduce vehicle weight without compromising strength and safety.	60%	40%	0%	0%
8	Mechanical engineering plays a critical role in the prototyping and testing process of electric vehicles, ensuring that all components function properly and safely before mass production.	75%	20%	5%	0%
9	Mechanical engineers integrate various electric vehicle systems, including the drivetrain, battery, and electronics, to ensure optimal performance and high reliability.	65%	30%	5%	0%
10	10. Mechanical engineering is also involved in the development of supporting infrastructure such as faster and more efficient charging stations, which support the overall electric vehicle ecosystem.	70%	30%	0%	0%

Table 1.4

The Role of Mechanical Engineering in the Development of Environmentally Friendly Electric Vehicles Tested for Feasibility with the One Way Anova Test

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.

X.01	T. A 2022	2,400	4	,500	.	.
	T. A 2022	,000	5	,000		
	Total	2,400	9			
X.02	T. A 2022	1,100	4	,275	2,750	,148
	T. A 2022	,500	5	,100		
	Total	1,600	9			
X.03	T. A 2022	2,100	4	,525	.	.
	T. A 2022	,000	5	,000		
	Total	2,100	9			
X.04	T. A 2022	,900	4	,225	.	.
	T. A 2022	,000	5	,000		
	Total	,900	9			
X.05	T. A 2022	1,600	4	,400	4,000	,080
	T. A 2022	,500	5	,100		
	Total	2,100	9			
X.06	T. A 2022	2,100	4	,525	.	.
	T. A 2022	,000	5	,000		
	Total	2,100	9			
X.07	T. A 2022	1,600	4	,400	4,000	,080
	T. A 2022	,400	5	,300		
	Total	2,100	9			
X.08	T. A 2022	2,100	4	,525	.	.
	T. A 2022	,000	5	,000		
	Total	2,100	9			
X.09	T. A 2022	1,600	4	,400	.	.
	T. A 2022	,000	5	,000		
	Total	1,600	9			
X.10	T. A 2022	1,900	4	,475	4,750	,059
	T. A 2022	,500	5	,100		
	Total	2,400	9			

Discussion

The role of mechanical engineering in the development of eco-friendly electric vehicles is significant, covering various aspects from component design to system integration. First of all, mechanical engineering plays an important role in designing more efficient and lightweight components. In an effort to reduce vehicle weight, mechanical engineers use advanced materials such as aluminum, magnesium, and carbon fiber composites. These materials enable weight reduction without compromising strength and safety, which in turn reduces energy consumption and extends the range of electric vehicles. Weight reduction is one of the key factors in improving the vehicle's energy

efficiency, as each decrease in weight reduces the amount of energy required for movement.

Furthermore, the development of more efficient and powerful electric motors is a key area where mechanical engineering makes a major contribution. Electric motors are the heart of electric vehicles, and mechanical engineers focus on improving their performance through better design and the use of advanced magnetic materials. More efficient electric motors not only reduce energy consumption but also improve vehicle performance, enabling faster acceleration and more reliable performance**.** Mechanical engineering has also played a role in the development of brushless motor technology, which offers advantages in terms of efficiency and longevity. Cooling systems are also a critical aspect in electric vehicles, where mechanical engineering plays an important role in designing effective systems. Batteries and electric motors generate heat during operation, and if not managed properly, can lead to performance degradation or even component damage. Mechanical engineers develop cooling systems that use coolant or air to maintain component temperatures at optimal levels. Effective cooling technologies not only increase the lifespan of batteries and electric motors but also ensure consistent performance under various environmental conditions.

Mechanical engineering also contributes to the aerodynamic design of electric vehicles. A good design can reduce air resistance, which directly improves energy efficiency. Mechanical engineers use simulation and wind tunnel testing to optimize the shape of the vehicle so that it is more streamlined and has a lower drag coefficient. Aerodynamic design not only helps in increasing the range of the vehicle but also contributes to overall performance and stability at high speeds.

Battery technology development is another area where mechanical engineering makes an important contribution. Mechanical engineers work on various aspects of batteries, including electrode materials, cell design, and battery management systems (BMS). The BMS is a critical component that regulates battery charge and discharge, monitors temperature, and ensures safe operation. Through the development of better battery technology, mechanical engineers are helping to increase energy density, extend lifespan, and speed up charging time, all of which are important factors for making electric vehicles more practical and attractive to consumers.

Transmission systems in electric vehicles also receive special attention from mechanical engineers. Although electric vehicles often use simpler transmission systems compared to conventional vehicles, there is a need to optimize power distribution from the electric motor to the wheels. Mechanical engineering plays a role in designing efficient and durable transmission systems, which can reduce energy loss and improve performance. Some electric vehicles also use direct drive systems, which eliminate the need for conventional transmissions and offer higher efficiency and reduced weight. Advanced materials are one of the main focuses in mechanical engineering for the development of electric vehicles. Mechanical engineers are researching new materials that can be used for various vehicle components, from the frame structure to the suspension system. The use of lighter and stronger materials such as carbon composites not only helps

reduce vehicle weight but also improves safety and performance. In addition, materials that are more resistant to corrosion and wear can reduce maintenance costs and extend the life of the vehicle.

The prototyping and testing process is an important step in the development of electric vehicles, where mechanical engineering plays an important role. Before an electric vehicle can be mass-produced, every component and system must go through an extensive prototyping and testing phase to ensure its reliability. Mechanical engineers use tools such as computer simulations, laboratory testing, and road tests to evaluate vehicle performance and safety. This process helps identify and fix potential problems before the vehicle is launched into the market, thus improving the quality and reliability of the final product. Integration systems engineering is another aspect where mechanical engineering plays an important role in the development of electric vehicles. Electric vehicles consist of various systems that must work in harmony, including the drivetrain, battery, electric motor, and electronics. Mechanical engineers are responsible for ensuring that all these systems are well integrated and function efficiently. This involves developing complex control algorithms, designing optimal component layouts, and testing the system as a whole. Good integration not only improves efficiency and performance but also ensures driver safety and comfort. Besides the technical aspects, mechanical engineering also plays a role in the development of supporting infrastructure for electric vehicles. One of the key challenges in the adoption of electric vehicles is the availability of fast and efficient charging stations. Mechanical engineers work closely with experts in other fields to design and develop charging stations capable of charging batteries quickly without damaging the cells. This includes research into fast charging technology, thermal management during charging, and integration with the power grid. Good infrastructure is key to supporting the growth of the electric vehicle market and making it more attractive to consumers. On the other hand, mechanical engineering also plays a role in the end-of-life management of electric vehicles, including battery recycling. Electric vehicle batteries contain valuable materials that can be recycled and reused. Mechanical engineers develop technologies and processes to efficiently recycle batteries, reduce environmental impact, and reduce dependence on new raw materials. Effective recycling not only supports sustainability but also helps reduce the cost of producing new batteries.

Overall, the role of mechanical engineering in the development of green electric vehicles is broad and deep. From efficient and lightweight component design, electric motor development, cooling systems, to battery and transmission technologies, mechanical engineering touches almost every aspect of electric vehicles. With a focus on innovation and efficiency, mechanical engineers help create vehicles that are more environmentally friendly, safe and attractive to consumers. In addition, through the development of supporting infrastructure and recycling technologies, mechanical engineering contributes to the creation of an ecosystem that supports the growth and sustainability of electric vehicles. Wider adoption of electric vehicles will play an important role in reducing greenhouse gas emissions and dependence on fossil fuels, thereby contributing to global efforts to address climate change.

REFERENCES

Alma Çallı, B., & Ediz, Ç. (2023). Top concerns of user experiences in Metaverse games: A text-mining based approach. *Entertainment Computing*, *46*, 100576. https://doi.org/10.1016/j.entcom.2023.100576

Alshater, M. (2022). Exploring the Role of Artificial Intelligence in Enhancing Academic Performance: A Case Study of ChatGPT. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4312358

Baek, S., Kim, S., & Rhee, T. (2021). [Editors' Remarks] Special Theme 1: Globalization in the Era of COVID-19. *Journal of Economic Integration*, *36*(1), 1–2. https://doi.org/10.11130/jei.2021.36.1.1

Bahmani Kashkouli, M., Karimi, N., Sianati, H., & Khademi, B. (2020). Techniques of Eyebrow Lifting: A Narrative Review. *Journal of Ophthalmic and Vision Research*. https://doi.org/10.18502/jovr.v15i2.6740

Bajić, I. V., Saeedi-Bajić, T., & Saeedi-Bajić, K. (2023). Metaverse: A Young Gamer's Perspective. *2023 IEEE 25th International Workshop on Multimedia Signal Processing (MMSP)*, 1–6. https://doi.org/10.1109/MMSP59012.2023.10337702

Barz, N., Benick, M., Dörrenbächer-Ulrich, L., & Perels, F. (2024). The Effect of Digital Game-Based Learning Interventions on Cognitive, Metacognitive, and Affective-Motivational Learning Outcomes in School: A Meta-Analysis. *Review of Educational Research*, *94*(2), 193–227. https://doi.org/10.3102/00346543231167795

Besser, A., Flett, G. L., & Zeigler-Hill, V. (2022). Adaptability to a sudden transition to online learning during the COVID-19 pandemic: Understanding the challenges for students. *Scholarship of Teaching and Learning in Psychology*, *8*(2), 85–105. https://doi.org/10.1037/stl0000198

Betlem, K., Kaur, A., Hudson, A. D., Crapnell, R. D., Hurst, G., Singla, P., Zubko, M., Tedesco, S., Banks, C. E., Whitehead, K., & Peeters, M. (2019). Heat-Transfer Method: A Thermal Analysis Technique for the Real-Time Monitoring of *Staphylococcus aureus* Growth in Buffered Solutions and Digestate Samples. *ACS Applied Bio Materials*, *2*(9), 3790–3798. https://doi.org/10.1021/acsabm.9b00409

Castañeda-Babarro, A., Arbillaga-Etxarri, A., Gutiérrez-Santamaría, B., & Coca, A. (2020). Physical Activity Change during COVID-19 Confinement. *International Journal of Environmental Research and Public Health*, *17*(18), 6878. https://doi.org/10.3390/ijerph17186878

Chow, J. C. L., Sanders, L., & Li, K. (2023). Impact of ChatGPT on medical chatbots as a disruptive technology. *Frontiers in Artificial Intelligence*, *6*, 1166014. https://doi.org/10.3389/frai.2023.1166014

Clinch, D., Damaskos, D., Di Marzo, F., & Di Saverio, S. (2021). Duodenal ulcer perforation: A systematic literature review and narrative description of surgical techniques used to treat large duodenal defects. *Journal of Trauma and Acute Care Surgery*, *91*(4), 748–758. https://doi.org/10.1097/TA.0000000000003357

Cohen, L., Malloy, C., & Nguyen, Q. (2020). Lazy Prices. *The Journal of Finance*, *75*(3), 1371–1415. https://doi.org/10.1111/jofi.12885

Derakhshan, A., Teo, T., & Khazaie, S. (2024). Is game-based language learning general or specific-oriented? Exploring the applicability of mobile virtual realities to medical English education in the middle east. *Computers & Education*, *213*, 105013. https://doi.org/10.1016/j.compedu.2024.105013

Dong, H., & Liu, Y. (2023). Metaverse Meets Consumer Electronics. *IEEE Consumer Electronics Magazine*, *12*(3), 17–19. https://doi.org/10.1109/MCE.2022.3229180

Dube, B. (2020). Rural online learning in the context of COVID 19 in South Africa: Evoking an inclusive education approach. *Multidisciplinary Journal of Educational Research*, *10*(2), 135. https://doi.org/10.17583/remie.2020.5607

Dubey, J. P. (2021). *Toxoplasmosis of Animals and Humans* (3rd ed.). CRC Press. https://doi.org/10.1201/9781003199373

Dwivedi, Y. K., Kshetri, N., Hughes, L., Slade, E. L., Jeyaraj, A., Kar, A. K., Baabdullah, A. M., Koohang, A., Raghavan, V., Ahuja, M., Albanna, H., Albashrawi, M. A., Al-Busaidi, A. S., Balakrishnan, J., Barlette, Y., Basu, S., Bose, I., Brooks, L., Buhalis, D., … Wright, R. (2023). Opinion Paper: "So what if ChatGPT wrote it?" Multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy. *International Journal of Information Management*, *71*, 102642. https://doi.org/10.1016/j.ijinfomgt.2023.102642

Elazhary, H. (2019). Internet of Things (IoT), mobile cloud, cloudlet, mobile IoT, IoT cloud, fog, mobile edge, and edge emerging computing paradigms: Disambiguation and research directions. *Journal of Network and Computer Applications*, *128*, 105–140. https://doi.org/10.1016/j.jnca.2018.10.021

Else, H. (2023). Abstracts written by ChatGPT fool scientists. *Nature*, *613*(7944), 423–423. https://doi.org/10.1038/d41586-023-00056-7

Favale, T., Soro, F., Trevisan, M., Drago, I., & Mellia, M. (2020). Campus traffic and e-Learning during COVID-19 pandemic. *Computer Networks*, *176*, 107290. https://doi.org/10.1016/j.comnet.2020.107290

Gomez, A., Sainbhi, A. S., Froese, L., Batson, C., Alizadeh, A., Mendelson, A. A., & Zeiler, F. A. (2021). Near Infrared Spectroscopy for High-Temporal Resolution Cerebral Physiome Characterization in TBI: A Narrative Review of Techniques, Applications, and Future Directions. *Frontiers in Pharmacology*, *12*, 719501. https://doi.org/10.3389/fphar.2021.719501

Gosal, A. S., Geijzendorffer, I. R., Václavík, T., Poulin, B., & Ziv, G. (2019). Using social media, machine learning and natural language processing to map multiple recreational beneficiaries. *Ecosystem Services*, *38*, 100958. https://doi.org/10.1016/j.ecoser.2019.100958

Hao, J., & Ho, T. K. (2019). Machine Learning Made Easy: A Review of *Scikit-learn* Package in Python Programming Language. *Journal of Educational and Behavioral Statistics*, *44*(3), 348–361. https://doi.org/10.3102/1076998619832248

Ibrar, I., Naji, O., Sharif, A., Malekizadeh, A., Alhawari, A., Alanezi, A. A., & Altaee, A. (2019). A Review of Fouling Mechanisms, Control Strategies and Real-Time Fouling Monitoring Techniques in Forward Osmosis. *Water*, *11*(4), 695. https://doi.org/10.3390/w11040695

Jansen, M., Donkervliet, J., Trivedi, A., & Iosup, A. (2023). Can My WiFi Handle the Metaverse? A Performance Evaluation Of Meta's Flagship Virtual Reality Hardware. *Companion of the 2023 ACM/SPEC International Conference on Performance Engineering*, 297–303. https://doi.org/10.1145/3578245.3585022

Kang, D., Choi, H., & Nam, S. (2022). Learning Cultural Spaces: A Collaborative Creation of a Virtual Art Museum Using Roblox. *International Journal of Emerging Technologies in Learning (iJET)*, *17*(22), 232–245. https://doi.org/10.3991/ijet.v17i22.33023

Kapasia, N., Paul, P., Roy, A., Saha, J., Zaveri, A., Mallick, R., Barman, B., Das, P., & Chouhan, P. (2020). Impact of lockdown on learning status of undergraduate and postgraduate students during COVID-19 pandemic in West Bengal, India. *Children and Youth Services Review*, *116*, 105194. https://doi.org/10.1016/j.childyouth.2020.105194

Loewen, S., Crowther, D., Isbell, D. R., Kim, K. M., Maloney, J., Miller, Z. F., & Rawal, H. (2019). Mobile-assisted language learning: A Duolingo case study. *ReCALL*, *31*(3), 293–311. https://doi.org/10.1017/S0958344019000065

Maulida, A., Hanif, H., Kamal, M., & Suryani Oktari, R. (2023). Roblox-based tsunami survival game: A tool to stimulate early childhood disaster preparedness skills. *E3S Web of Conferences*, *447*, 02003. https://doi.org/10.1051/e3sconf/202344702003

Memon, N. A., Chown, D., & Alkouatli, C. (2021). Descriptions and enactments of Islamic pedagogy: Reflections of alumni from an Islamic Teacher Education Programme. *Pedagogy, Culture & Society*, *29*(4), 631–649. https://doi.org/10.1080/14681366.2020.1775687

Mosco, V. (2023). Into the Metaverse: Technical Challenges, Social Problems, Utopian Visions, and Policy Principles. *Javnost - The Public*, *30*(2), 161–173. https://doi.org/10.1080/13183222.2023.2200688

Oulaich, S. (2020). Pedagogy in the Digital Age: Making Learning Effective and Engaging for Students. In M. Ben Ahmed, A. A. Boudhir, D. Santos, M. El Aroussi, & İ. R. Karas (Eds.), *Innovations in Smart Cities Applications Edition 3* (pp. 168–182). Springer International Publishing. https://doi.org/10.1007/978-3-030-37629-1_14

Pardo, A., Jovanovic, J., Dawson, S., Gašević, D., & Mirriahi, N. (2019). Using learning analytics to scale the provision of personalised feedback. *British Journal of Educational Technology*, *50*(1), 128–138. https://doi.org/10.1111/bjet.12592

Payal, R., Sharma, N., & Dwivedi, Y. K. (2024). Unlocking the impact of brand engagement in the metaverse on Real-World purchase intentions: Analyzing Pre-Adoption behavior in a futuristic technology platform. *Electronic Commerce Research and Applications*, *65*, 101381. https://doi.org/10.1016/j.elerap.2024.101381

Selwyn, N. (2019). What's the Problem with Learning Analytics? *Journal of Learning Analytics*, *6*(3). https://doi.org/10.18608/jla.2019.63.3

Shadiev, R., & Yang, M. (2020). Review of Studies on Technology-Enhanced Language Learning and Teaching. *Sustainability*, *12*(2), 524. https://doi.org/10.3390/su12020524

Shahmoradi, J., Talebi, E., Roghanchi, P., & Hassanalian, M. (2020). A Comprehensive Review of Applications of Drone Technology in the Mining Industry. *Drones*, *4*(3), 34. https://doi.org/10.3390/drones4030034

Spernjak, A. (2021). Using ICT to Teach Effectively at COVID-19. *2021 44th International Convention on Information, Communication and Electronic Technology (MIPRO)*, 617–620. https://doi.org/10.23919/MIPRO52101.2021.9596878

Teimouri, Y., Plonsky, L., & Tabandeh, F. (2022). L2 grit: Passion and perseverance for second-language learning. *Language Teaching Research*, *26*(5), 893–918. https://doi.org/10.1177/1362168820921895

Tupouniua, J. G. (2023). Toward culturally sustaining supervision practices in mathematics education: What do Pasifika research students value most about their supervisors? *AlterNative: An International Journal of Indigenous Peoples*, *19*(3), 691–700. https://doi.org/10.1177/11771801231193591

Yudiawan, A., Sunarso, B., Suharmoko, S., Sari, F., & Ahmadi, A. (2021). Successful online learning factors in COVID-19 era: Study of Islamic higher education in West Papua, Indonesia. *International Journal of Evaluation and Research in Education (IJERE)*, *10*(1), 193. https://doi.org/10.11591/ijere.v10i1.21036