

## Integration of Artificial Intelligence at the National Earth Science Museum of Namibia: Enhancing Interactive Exhibits

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**Abstract** :- The integration of Artificial Intelligence (AI) and Machine Learning (ML) in earth science museums is revolutionising the way visitors engage with geological exhibits. By employing AI-driven interactive exhibits and ML-based geological reconstructions, museums can offer immersive and personalised learning experiences going much farther than traditional static displays. This paper explores the transformative impact of AI, its highlighting its relevance in enhancing visitor engagement, improving scientific accuracy, and generally in fostering public interest in the earth sciences. Examples from leading institutions that have successfully implemented AI technologies, on-site observations, digital architectures, benefits and challenges are discussed.

**Keywords** :- Interactive displays, Artificial intelligence, National Earth Science Museum

### Introduction

Museums play a vital role in education, preservation, and public engagement, by providing visitors with insights into history, science, and culture (Kung and Lin, 2024). The National Earth Science Museum of Namibia, like most traditional museums, primarily features static exhibits of fossils, minerals (including the use of various minerals in daily life), models and information on the rich mining history of the country. While these exhibits and showcases effectively present geological and palaeontological knowledge, they lack interactivity, thus limiting visitor engagement and experiential learning, especially with respect to the younger generation.

Although museums have habitually been places of static exhibits and passive learning, science museums, in order to fulfil their role in science communication and education, need to revise and modernise their approach to continue engaging visitor interest. Recent advancements in artificial intelligence (AI) and machine learning (ML) offer innovative solutions to transform static displays into interactive and immersive experiences with reputedly greater learning effect. While AI is the ability of machines to perform tasks that normally require human intelligence, such as learning, reasoning, problem-solving, and understanding language, ML is a branch of AI that enables computers to learn from data provided and improve their performance accordingly over time without reprogramming. In

particular, augmented reality (AR), virtual reality (VR), and natural language processing (NLP) are some of the AI-driven technologies employed by museums to enhance visitor engagement, enrich exhibit interpretations, facilitate personalised learning, and provide real-time insights into earth science phenomena (Tseng and Lin, 2024).

In the era of digital transformation, museums worldwide are increasingly utilising information technology to expand their reach and engage broader audiences, as digital initiatives extend their educational influence far beyond their physical boundaries. The digitisation of collections and other material enhances accessibility and fosters public engagement, while promoting life-long learning. Among various digital transformation trends, AI has emerged as a pivotal tool in reshaping museum operations, particularly in enhancing educational practices and visitor interaction (Tseng and Lin, 2024).

VR and AR technologies can be effectively integrated into the context of museum exhibitions to support both storytelling and interaction. While AR overlays digital information on to the real world (for instance by using AR glasses to view dinosaurs moving), VR goes further still to create a fully immersive, computer-generated environment. Viewing content instead of reading or listening to protracted explanations demonstrably enhances the learning experience, as well as increases

the probability of retaining information. By means of AR applications, visitors are able to enjoy interactive experiences in which additional content, such as the history and meaning of objects, is digitally added to real artefacts (Spadoni *et al.*, 2022). Modern museums have successfully integrated AI with AR and VR to create immersive experiences that reconstruct, for example, historical events, ancient and recent ecosystems and celestial phenomena. At 'Dynamic Earth' (Edinburgh, Scotland), immersive exhibits (Fig. 1) include a virtual meeting with 18<sup>th</sup> century geologist James Hutton - also known as the 'Father of Modern Geology' - in his study, where he extols his revolutionary theories to captivated audiences.

But AI-powered interactive displays have not only the potential to transform museum experiences by facilitating dynamic reconstructions of past environments or real-time simulations of geological processes; they can also of create responsive virtual guides

with the ability of engaging with visitors. ML algorithms can analyse visitor interactions to optimise content delivery, ensuring an adaptive and personalised educational experience. In addition, AI-driven image recognition allows visitors to explore detailed information, for instance about minerals and fossils through interactive kiosks.

This study explores the potential for integrating the various branches of AI at the National Earth Science Museum of Namibia to enhance visitor engagement, interactivity, and learning outcomes. It examines how AI-driven exhibits can provide deeper insights into geological events, simulate ancient ecosystems, and create a bridge between science and public education. By leveraging these technological advancements, the National Earth Science Museum can move beyond static displays, fostering a more immersive and rewarding visitor experience, while advancing scientific literacy in the field of the earth sciences.



**Figure 1.** Some of the immersive galleries featured at 'Dynamic Earth' dealing with the evolution of our planet (<https://dynamicearth.org.uk/>)

### Interactive and digital exhibitions

Interactive exhibitions are growing in popularity and effectiveness, involving people through different senses and calling them to action. In the development of earth science

museums, the application of AI technology has become a significant trend. With its rapid advancement, AI not only enhances the interactivity and personalisation of exhibition con-

tent, but also profoundly changes the visitor experience. As museums are crucial institutions for public education, the effective application of new technologies to increase visitor satisfaction has become a focal point both for researchers and practitioners. The application of AI technologies such as computer vision, natural language processing, and machine learning has been pivotal in transforming traditional museum displays into modern interactive galleries. Research conducted by Kung and Lin (2024) identifies essential elements of visitor engagement, including interactivity, educational value, entertainment, and personal satisfaction that are crucial in assessing the effectiveness of AI-driven interactive displays. However, the impact of AI on visitor perception has not yet been methodically studied (Kung and Lin, 2024).

Overlaying digital information on to physical artifacts through AI technologies, enriches the storytelling aspect of exhibits, and notably creates more demonstrative experiences not only for young visitors. Studies have shown that such interactive designs encourage more animated visitor participation, placing the individual at the centre of the learning process (Spadoni *et al.*, 2022). Interactive technology also allows people to view objects that could not otherwise be displayed. With the use of AR and VR, buildings, destroyed artifacts or extinct creatures become part of a 'life-size' exhibition. The interactivity of these methods is enhanced by 3D-technology, so that the exhibits can be studied from all angles.

With the rise of AI, museums are increasingly incorporating intelligent systems to present complex scientific information dynamically, and enhance and personalise visitor experiences. The *MusAB* AR application was developed as part of the *MARSS* Project, a research initiative focused on improving science museum experiences through augmented reality. *MusAB* uses machine learning to allow the virtual reconstruction of ancient instruments and artifacts, offering visitors a realistic impression of their original appearance and functionality, while Natural Language Processing (NLP) enables 'chatbots' and virtual assistants to provide real-time explanations, answering visitor queries and adapting responses on the basis of varying knowledge

levels. Also, physical panels augmented with additional digital layers, such as animations or 3D models, provide a deeper insight into exhibits (Spadoni *et al.*, 2022), as do AI text generators, which produce immersive exhibit descriptions.

Studies on AI-generated content show a growing trend in museum application, with the aim of improving both visitor satisfaction and education. An AI image generation system was developed for an exhibition at the Berlin City Museum, which produces speculative visualisations of potential urban transformation in years to come (Maas, 2024). Conversely, the 'Awakening Earth's Majestic Creatures with AI' project of the Shanghai Natural History Museum (<https://www.snhm.org.cn/eg/>) uses AI-generated 3D - models and spatial computing to digitally resurrect three extinct iconic species, i. e. the Yangtze River Baiji dolphin, the fin whale, and the mammoth. This initiative combines cutting-edge technology with cultural preservation to create immersive educational experiences (Isaacson, 2024).

AI is also being increasingly applied in mineral identification to enhance efficiency and accuracy. Traditional methods, such as X-ray diffraction (XRD) and Raman spectroscopy, rely heavily on expert knowledge and manual analysis, entailing time-consuming processes and susceptibility to human error. The development of intelligent systems have simplified the process of mineral identification by ML adopting characteristic patterns of mineral samples. AI-driven approaches have been utilised to automate classification, significantly improving speed and precision. AI models have efficiently identified minerals by analysing patterns in data from techniques like Raman spectroscopy (Long *et al.*, 2022), refining results and reducing the need for specialised equipment. In addition, AI can process large datasets much more quickly, thus supporting researchers and prospectors in assessing mineral compositions and properties, as well as the geological context of mineral deposits more efficiently. Machine learning methods with applications in interactive museum exhibits contain several mainstream AI models, which are listed and briefly described in Table 1.

Model	Applications	Advantages	Shortcomings
Multilayer Perceptron (MLP)	mineral classification; feature extraction; simple pattern recognition	more effective with smaller data sets (compared to deeper models)	not suitable for complex patterns or large data sets; requires careful regularisation to avoid overfitting; less robust to variations in input data compared to deeper models
Convolutional Neural Network (CNN)	image classification; object detection; mineral identification from images	excellent for image-based classification tasks; robust to transformations like rotation and scaling; automatically extracts relevant features from images; achieves high accuracy in image classification	requires significant computational resources for training; needs large, diverse data sets for effective training; training can be time-consuming
ResNet-18/ResNet-50	deep learning-based image classification with robust feature extraction ability	achieves high accuracy in classification tasks due to robust feature extraction; generalises well across different data sets and tasks	requires significant computational resources for training; needs large data sets for effective training; complex to fine-tune for specific tasks

**Table 1.** AI Models used in interactive displays (Ahari, 2024)

### Approach

To explore the application of AI in the National Earth Science Museum, a qualitative approach, combining case studies, personal observation and interviews with visitors was employed. Case studies of museums that have already integrated AI into their exhibitions provide insights into implementation strategies, AI architectures, benefits, and challenges. These include ‘Dynamic Earth’, the ‘Awakening Earth’s Majestic Creatures with AI’ project, and AI-powered virtual guides, such as the ‘Pepper’ robots of the Smithsonian (Washington, USA; <https://www.si.edu/newsdesk/releases/smithsonian-launches-pilot-program-pepper-robots>), which employ NLP and sentiment analysis to respond to visitor questions. The same institution uses AR to bring its ‘Bone Hall’ to life by superimposing digital layers over skeletons to reproduce the live animal and their movements (Ahari, 2024), while the Franklin Institute (Philadelphia,

USA) employs VR technology that allows visitors, among other exciting options, to explore exotic environments such as the depths of the ocean or outer space (<https://fi.edu/en/exhibits-experiences>).

Interviews were conducted with visitors of the National Earth Science Museum during guided tours to gather first-hand information on personal experiences and perceptions, as well opinions and feedback regarding the integration of AI in museums, with the aim to of getting a better understanding of the role this technology can play in enhancing the museum experience. Visitor interaction with the various interactive displays were monitored and analysed for an objective assessment of overall user experience. This included tracking how visitors interact with simulations, the duration of their engagement with the respective exhibits, their responses to demonstrations, and their understanding of key concepts.

### Findings and discussion

#### Visitor engagement

The Namibian National Earth Science Museum at present only has three interactive exhibits, i. e. the earthquake display, the fluo-

rescent minerals display and the ‘Dino Dig’, especially beloved of young visitors. Although Namibia is not prone to severe seismic disturbances, the demonstration of their causes by

means of a model of the earth’s crust and a seismometer, registering strength of movement along a fault line (Fig. 2), has proved of considerable interest not only to school learners. Similarly, in a darkened cubicle, common minerals such as calcite, fluorite and opal are made to glow in brilliant shades of red, green and blue, depending on their composition, by

immersing them in ultraviolet light to visualise the concept of fluorescence (Fig. 3), while at the very popular ‘Dino Dig’ kids can practise fossil hunting, using trowel and brush to uncover their ‘finds’ (Fig. 4). The engagement and dwell time at each of these three exhibits clearly indicates their attraction and interest to the museum’s visitors (Table 2).



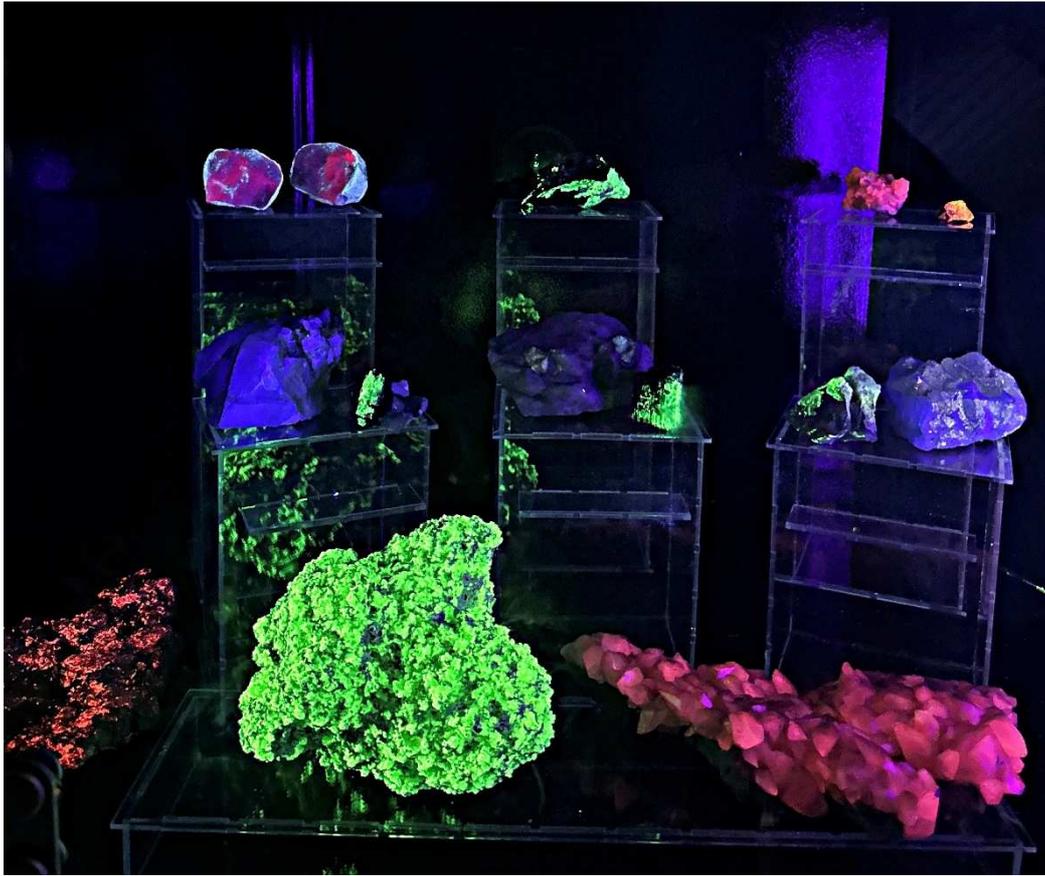
**Figure 2.** Earthquake interactive exhibit consisting of a simplified model of the earth’s crust and a seismometer

The dwell time on interactive displays is about 3 to 7.5 times higher than that of customary, static displays. Moreover, some 90% of visitors in a group engage in conversations on interactive displays, while only 15% of visitors were moved to discuss static displays. This aligns with findings of a University of Twente (Netherlands) study, where interactive exhibits achieved 92% positive engagement ratings versus 67% for static exhibits (Voorde,

2023). These statistics highlight the need for a greater number of attractive, interactive exhibits. However, the study also revealed that reaction to interactive displays is age-related: while over 90% of the younger visitors (e. g. school children) expressed more interest in interactive exhibits, older visitors frequently prefer the more “sober”, static displays, as dictated by tradition and authenticity.

Display	Earthquake	Fluorescent minerals	‘Dinosaur dig’	Static exhibits
Dwell time [minutes]	5 - 10	5	10 - 15	1.5 - 2
Group conversation [%]	60	75	90	15

**Table 2.** Time spent on interactive versus static displays at the National Earth Science Museum



**Figure 3.** Fluorescent minerals display



**Figure 4.** 'Dinosaur dig' and model of *Massospondylus* at the National Earth Science Museum

### **Interactive display for Animatronics**

While specific examples of animatronics in earth science museums are less common, they have been successfully adopted and are used to create interactive storytelling experiences. This technology can bring historical figures or extinct species to life (Fig. 5), or realistically reproduce natural processes, such as volcanic eruptions, thus improving the narrative and educational value of exhibits (e. g. Lava Dome – Deutsches Vulkanmuseum, Mendig, Germany, <https://www.lavadome.de/en/lava-dome/>; Natural History Museum, Lon-

don, UK, with its T. Rex display, <https://www.nhm.ac.uk/events/t-rex-show-with-teach-rex.html>; Dynamic Earth; Gondwana Praehistorium). Integrating animatronics with AR or VR further enhances the immersive experience, as it allows visitors to view and interact with life-like models of ancient creatures or experience geological processes. ‘Multi-Layered Interaction Engines’ combines considered, autonomous, and reactive AI systems to simulate natural behaviours in animatronics.

### **Interactive displays in mineral identification**

Interactive displays can be designed to allow visitors to scan minerals and receive real-time information about their chemical and physical properties. This includes AR overlays that highlight specific features or provide educational content about a mineral. AI-powered

apps analyse images of adequate resolution or data of specimens and, by comparing them with a set of training data, return more or less detailed information and identifications. The architecture of AI-based mineral identification is shown in Figure 6.

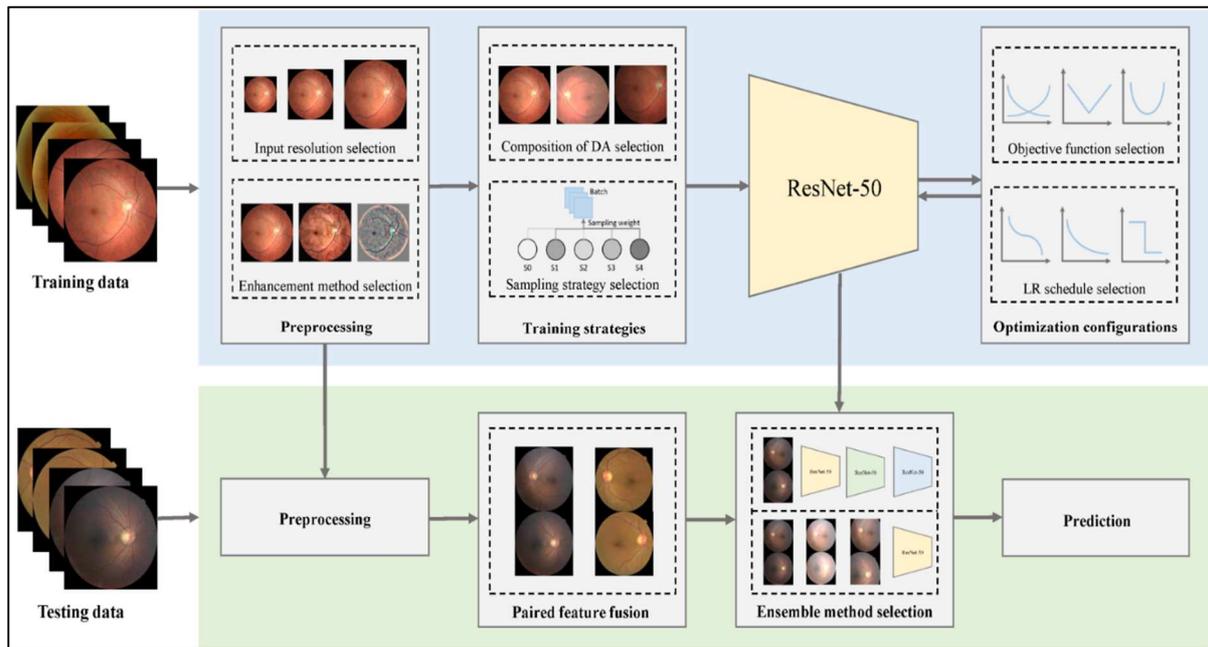


**Figure 5.** *Tyrannosaurus rex* in his natural environment at the ‘Gondwana Praehistorium’ natural history museum (Schiffweiler, Germany; <https://gondwana-das-praehistorium.de/en/home-en>)

### **Model architectures used in interactive museum display**

ResNet50 is a deep convolutional neural network (CNN) architecture that serves as a powerful base network for feature extraction. The model requires a minimum of 10 000 images for accurate training. The learning rate (LR) determines how well a model can make predictions on a new sample, based on the data it has previously been exposed to. This system

of AI-powered image recognition tools has been used in mineral and fossil exhibits to allow for more immersive and informative exploration, increasing visitor curiosity and participation (Cha, 2024). Once the model is trained and tested, museum visitors, small-scale miners and other users can apply it to identify unknown minerals.

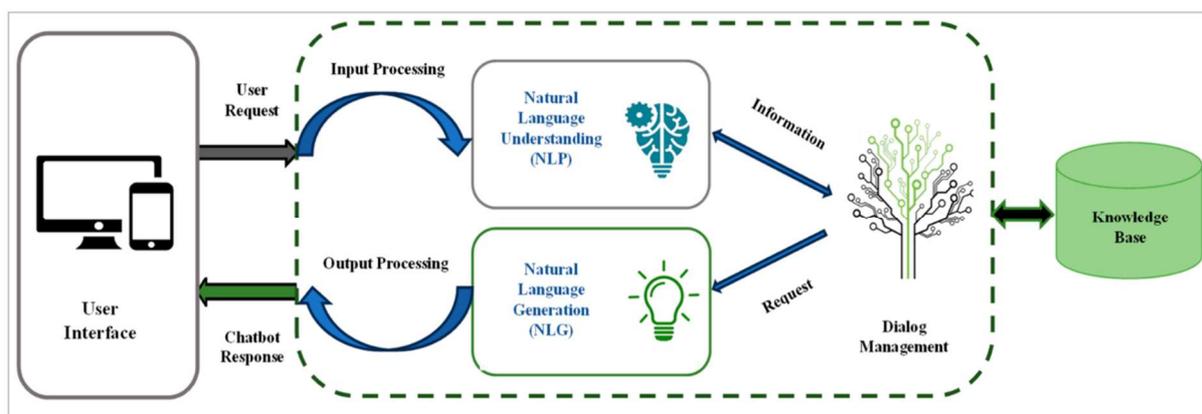


**Figure 6.** Architecture of AI-based mineral identification (ResNet-50; Huang *et al.*, 2023)

In addition, transformer-based ‘chatbots’ have been adopted by several museums including the Field Museum in Chicago (USA), the Centre Pompidou in Paris (France), and the Milan House Museums (Case Museo di Milano, Italy) to support visitor engagement. Their systems use NLP and deep learning (DL) to answer visitor questions, provide guided tours, and enable interactive storytelling experiences.

Figure 7 illustrates the architecture of an AI-based chatbot. The User Interface (UI)

serves as the front end of this architecture. ‘Input Processing’ is the initial gatekeeper, organising user inputs and preparing them for analysis. The chatbot employs NLP components to interpret user intention. The processed information is subsequently fed into the Dialogue Management System, the chatbot’s decision-making hub. Responses are generated based on the conversation context, accumulated knowledge, and past interactions, ensuring relevant and meaningful interaction.



**Figure 7.** Transformer-based chatbots using NLP (Izadi and Forouzanfar, 2024)

## Conclusions

AI-driven interactive museum displays represent significant improvements in visitor

engagement and educational outcomes. Museums which have implemented AR and VR

technologies report increased knowledge retention and deeper understanding of scientific concepts. Applications, such as ChatGPT offer a variety of ways to modernise and improve performance and visitor satisfaction (e. g. curatorial assistance, personalised exhibition guides, real-time translation services and interactive storytelling; Charr, 2024). While the technology obviously still has limitations, for instance accuracy, bias and copyright issues

(Charr, 2024), not to mention implementation and maintenance cost, the above-mentioned benefits clearly outweigh initial challenges.

The adoption of advanced AI technologies at the Namibian National Earth Science Museum are believed to significantly enhance its educational and engagement capabilities, increase visitor numbers and interest, and in general make earth sciences more understandable to a diverse audience.

## References

- Ahari, H. D. 2024. A review of AI for mineral identification. *ISERDAR*, **2(2)**, 8–20. <https://doi.org/10.5281/zenodo.13631172>
- Cha, V. 2024. *Demystifying Artificial intelligence for mineral exploration*. <https://wearevuka.com/insights/smart-city/demystifying-artificial-intelligence-for-mineral-exploration/>
- Charr, M. 2024. *How Museums Can Use ChatGPT to Transform Their Operations in 2025*. <https://www.museumnext.com/article/how-museums-can-use-chatgpt-to-transform-their-operations-in-2025/>
- Huang, Y., Lin, L., Cheng, P., Lyu, J., Tam, R. and Tang, X. 2023. Identifying key components in ResNet-50 for diabetic retinopathy grading from fundus images: Asystematic investigation. *Diagnostics*, **13(10)**, <https://doi.org/10.3390/diagnostics13101664>
- Isaacson, A. 2024. *Lenovo and Shanghai Natural History Museum resurrecting Earth's majestic creatures with VR and AI*. <https://thevrcollective.com/lenovo-and-shanghai-natural-history-museum-resurrecting-earths-majestic-creatures-with-vr-and-ai/>
- Izadi, S. and Forouzanfar, M. 2024. Error correction and adaptation in conversational AI: A review of techniques and applications in chatbots. *AI*, **5(2)**, 803-841, <https://doi.org/10.3390/ai5020041>
- Kung, C.-H. and Lin, P.-S., 2024. A study on the application of artificial intelligence in interactive museum displays and visitors perception. *International Journal of Organisational Innovation*, **17(2)**, 155-167.
- Long, T., Zhou, Z., Hancke, G., Bai, Y. and Gao, Q. 2022. A review of artificial intelligence technologies in mineral identification classification and visualization. *Journal of Sensor and Actuator Networks*, **11(3)**, <https://doi.org/10.3390/jsan11030050>
- Maas, C. 2024. *Using AI Image Generation for Museum Exhibitions*. <https://www.aureka.ai/aureka-blog/using-ai-image-generation-for-museum-exhibitions>
- Spadoni, E., Porro, S., Bordegoni, M., Arosio, H., Barbalini, L. and Carulli, M. 2022. Augmented reality to engage visitors of science museums through interactive experiences. *Heritage*, **5(3)**, 1370-1394.
- Tseng, J.-L. and Lin, C.-C. 2024. Leveraging Artificial intelligence in Museum Education: Innovations and challenges for promoting sustainable development goals. *Taiwan Education Review Monthly*, **13(11)**, 19-32.
- Voorde, B. T. 2023. *Exploring engagement in Science Museums: A comparative study of static and interactive exhibitions*. BA thesis, University of Twente, Enschede, Netherlands, 30 pp.