From Curiosity to Understanding: Immersive Technologies and Interactive Exhibits in Informal STEM Learning – A Case Study of MOTIO

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Abstract. Informal STEM learning environments provide opportunities to engage with science and technology through exploration, interaction, and direct experience beyond formal education. This paper presents the MOTIO Science Centre at the University of Žilina as a case study of integrating virtual and augmented reality (VR/AR), hands-on exhibits, and guided interpretation in informal STEM education. The study uses a descriptive case-study approach based on internal visitor records, programme data, and visitor feedback. Visitor participation, visitor groups, and technology-oriented activities were analysed to describe the development and reach of the centre and the opportunities it provides for informal STEM engagement. Between January–May 2025 and January–May 2026, visitor attendance increased from 1,733 to 2,449, representing an increase of approximately 41%. From January to August 2026, MOTIO and ROBOLab recorded 4,665 visits across school, public, university, Erasmus, summer camp, and other organised and international groups. Visitor feedback from 200 respondents showed that 178 (89%) selected guided visits with spoken explanations, while 17 (8.5%) selected both guided and independent exploration, and 5 (2.5%) did not provide a response. The findings highlight the potential of combining immersive technologies with hands-on exploration and human guidance rather than treating VR/AR as standalone tools. The study demonstrates how a university-based science centre can integrate emerging technologies into accessible informal STEM experiences, while recognising that attendance and participation data do not directly measure learning outcomes or cognitive engagement.

Keywords: informal STEM education; science centres; VR; AR; guided interpretation; hands-on learning; science communication

1 Introduction

Science, technology, engineering, and mathematics (STEM) play an important role in contemporary society, yet engagement with STEM extends beyond formal classroom education. Informal learning environments such as science centres and museums pro-

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vide opportunities to encounter science through exploration, experimentation, and direct experience [1]. Interactive science centres complement formal education by offering hands-on experiences connected to visitors' curiosity and interests [2], [3].
However, interaction alone does not guarantee meaningful learning. The educational value of science-centre experiences depends on exhibit design, opportunities for exploration, and interaction between visitors, educators, and the learning environment [4–7]. University-based science centres can further connect informal learning with formal education and scientific institutions through cooperation with schools, public programmes, and access to contemporary technologies.
The MOTIO Science Centre at the University of Žilina represents such an approach. MOTIO combines interactive science exhibits and hands-on activities with technology-oriented programmes. Its activities are complemented by ROBOLab, which focuses on robotics, virtual and augmented reality (VR/AR), digital fabrication, and other emerging technologies.
This paper examines MOTIO as a case study of a university-based interactive science centre and explores how VR/AR, guided interpretation, and hands-on activities are combined to support informal STEM engagement. The study addresses two research questions:
RQ1: How does the MOTIO Science Centre provide opportunities for informal STEM learning and engagement through interactive and experiential activities?
RQ2: How has visitor participation at the MOTIO Science Centre developed during the analysed period?

For the purposes of this study, a visitor is defined as any person participating in or attending an activity at the MOTIO Science Centre. This includes participants in organised school and university visits, public programmes, summer camps, and other organised activities, as well as individual members of the public. The attendance records represent recorded visits rather than unique individuals; therefore, the same person may be represented more than once if they visited the centre on multiple occasions.

2 Related work

Previous research on science-centre visits shows that visitor learning and engagement are influenced by several interacting factors rather than by the presence of interactive exhibits alone. Falk and Storksdieck [4] identified prior knowledge, visitor motivation, interest, choice and control, social interaction, and the physical environment as important components of the learning experience. Their findings suggest that learning outcomes emerge from the interaction between visitors and their environment rather than from a single exhibition feature.

Exhibit design can nevertheless influence how visitors engage with scientific content. Shaby et al. [5] analysed the behaviour of 1,800 students interacting with science museum exhibits and identified different levels of engagement, ranging from basic interaction to behaviours involving exploration, discussion, and the development of explanations. Their findings indicate that well-designed exhibits can encourage visitors

to move beyond simply operating an exhibit towards more sustained investigation. Barriault and Pearson [6] similarly proposed an engagement framework distinguishing different stages of visitor interaction, from initial participation to deeper engagement with the scientific concepts presented by an exhibit.

Recent research on VR/AR-supported STEM learning highlights the potential of immersive technologies to support active engagement, inquiry-based learning, and the visualisation of scientific concepts that can be difficult to experience directly [3]. At the same time, the review highlights challenges associated with VR/AR use, including technical and operational issues, potential distraction, and the need for appropriate learning design and teacher or facilitator support [3]. This is particularly relevant to informal STEM environments, where immersive technologies can complement rather than replace physical interaction and human guidance.

The social context of a visit can also influence engagement. Science-centre experiences frequently involve interaction between peers, family members, teachers, and other visitors. These interactions can encourage visitors to discuss observations, compare ideas, and develop explanations together. Social interaction is therefore considered an important contextual component of learning in informal science environments [4].

Another important factor is the role of facilitators. Facilitators can support visitors by encouraging questions, drawing attention to relevant features of an exhibit, demonstrating possible approaches, and connecting observations with scientific concepts. Machado Corral et al. [7], analysing 47 exhibits and 4,835 visitors, found that the presence of facilitators was associated with a higher proportion of visitors reaching the highest level of engagement within their assessment framework. This suggests that human guidance can complement the physical and technological design of interactive exhibits, as illustrated in Fig. 1.

Visitor characteristics also influence the nature of engagement. Visitors arrive with different levels of prior knowledge, interests, motivations, and expectations, which can affect how they respond to the same exhibition [4,8]. Science-centre experiences therefore need to accommodate different forms and levels of participation rather than assume a uniform learning process.

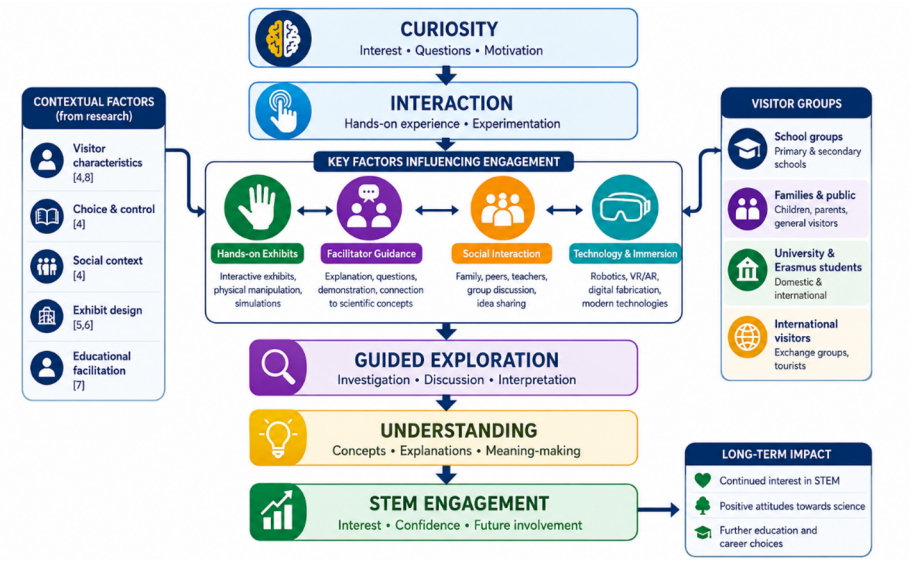


Fig. 1 *Proposed conceptual pathway illustrating how hands-on exhibits, guided interpretation, social interaction, and immersive technologies may contribute to STEM engagement in informal learning environments. Source: Authors, based on [4–8].*

Figure 1 represents a proposed conceptual pathway derived from the literature. It is intended as a framework for interpreting the potential relationships between the different elements of informal STEM learning at MOTIO and is not presented as an empirically validated model based on the data collected in this study.

Overall, research indicates that meaningful engagement in science centers results from the interaction of exhibit design, visitor characteristics, social context, educational facilitation, and appropriate use of technology [3–8]. These findings provide a basis for examining how VR/AR, interactive exhibits, and guided interpretation can be combined to support STEM engagement in informal learning environments.

2.1 MOTIO Science Centre as a Case Study

The MOTIO Science Centre is a university-based science popularisation center at the University of Žilina (UNIZA), Slovakia. It was established through cooperation between UNIZA and the Kia Foundation and opened in April 2024. The center was created to make science and technology accessible through experiential activities, interactive exhibits, and direct engagement with scientific and technological principles [9].

MOTIO combines physical interactive exhibits with digital and immersive technologies. Its original exhibition included 38 interactive exhibits, supported by digital applications, an interactive classroom, and virtual reality activities [9]. This combination

enables visitors to encounter scientific principles through physical manipulation as well as digitally mediated environments.

Virtual and augmented reality form an important part of the centre's technology-oriented educational activities. VR enables visitors to experience simulated environments that cannot easily be reproduced through conventional physical exhibits, while AR can connect digital content with the physical environment. These technologies provide opportunities for visualisation, exploration, and active interaction with STEM concepts. Their educational potential is particularly relevant when immersive experiences are combined with appropriate explanation and guidance.

A distinctive element of the MOTIO model is the combination of interactive technology with guided interpretation. Visitors do not simply interact with the exhibits independently. Each hands-on exhibit is accompanied by a commented explanation provided by centre staff, who introduce the underlying scientific principle and encourage visitors to test, observe, and interpret what they experience. This approach combines independent exploration with direct educational support and places the facilitator within the learning process.

In 2026, MOTIO expanded its technological offer through the establishment of ROBOLab, a dedicated laboratory focused on contemporary technologies and practical STEM learning. ROBOLab includes LEGO Education robotics, 3D printing, virtual and augmented reality, and industrial robotics. The laboratory extends the centre's activities towards programming, digital fabrication, robotics, and immersive technologies and also provides opportunities for teacher training and activities involving university and doctoral students [10].

The combination of MOTIO and ROBOLab creates several forms of experiential STEM engagement, ranging from physical interaction with scientific phenomena to programming, robotic construction, digital fabrication, and immersive experiences. The centre therefore serves audiences with different levels of prior knowledge and different motivations for engaging with science and technology.

MOTIO serves diverse audiences, including organised school groups, families and the public, university students, Erasmus participants, and visitors from different countries and organisations. This extends the centre's reach beyond the traditional school excursion model and creates opportunities for STEM engagement across different age groups and cultural backgrounds. With the support of the Kia Foundation, MOTIO also provides its activities free of charge, reducing the financial barrier to participation in interactive STEM experiences.

The combination of interactive exhibits, VR and AR, robotics, digital fabrication, and guided educational interaction makes MOTIO a relevant case for examining how contemporary technologies can be integrated into informal STEM learning. The following section describes the methodology used to analyse visitor engagement and the development of the centre's activities.

3 Methodology

This study uses a descriptive case-study approach to examine visitor engagement and informal STEM activities at the MOTIO Science Centre. The analysis focuses on the centre's development and activities during 2026.

Visitor participation refers to attendance and involvement in activities offered by the centre, while visitor engagement is used to describe the opportunities provided for visitors to interact with exhibits, technologies, facilitators, and other participants. These concepts should not be interpreted as direct measures of cognitive learning or educational achievement, as such outcomes were not systematically assessed in the present study.

The quantitative analysis is based on MOTIO's internal visitor records and visitor feedback data, including monthly attendance, organised and public visits, and visitor preferences regarding guided interpretation. Additional programme records were used to identify the different visitor groups and types of educational activities provided by MOTIO and ROBOLab.

The attendance records were compiled from MOTIO's internal booking and visitor records and include both organised group visits and individual/public participation. The reported figures represent recorded visits rather than unique individuals, and repeat visits by the same person may therefore be included. Attendance was analysed in aggregated form without identifying individual visitors.

Visitor data were analysed using descriptive statistics to identify attendance patterns and changes over the analysed period. The analysis considers overall visitor numbers, monthly attendance, and the composition of visitor groups. Visitor feedback was used to describe preferences regarding guided interpretation, while programme records complement the quantitative data by illustrating the range of audiences and STEM activities provided by the centre.

The study focuses on visitor participation and engagement opportunities rather than measured learning outcomes, as the available records do not include standardised pre- and post-visit assessments. Visitor feedback was collected during August 2026 among participants in different MOTIO activities, including summer camps, Erasmus groups, university students, families with children, and other organised groups. At the beginning of the visit, participants were informed about a short anonymous questionnaire containing three questions. The questionnaire was introduced as part of the initial MOTIO presentation, and participants were invited to complete it voluntarily after the visit. Staff did not monitor individual responses. The questionnaire was available in English and Spanish, with Slovak translations provided alongside the questions. A total of 200 questionnaires were included in the analysis. Because participation was voluntary and anonymous, some questions were left unanswered. As the questionnaire was anonymous, voluntary, and did not collect any personally identifiable or demographic information, no personal data were processed as part of the survey.

For the first question, respondents were presented with three response options: guided visits with spoken explanations, no preference between guided and independent visits, and independent exploration of the exhibits. Responses were recorded using checkboxes, allowing participants to indicate more than one option. In the analysis,

respondents who selected both guided and independent exploration were interpreted as having no exclusive preference for one mode of interaction.

4 Results

4.1 Visitor Engagement and Attendance

Visitor records show a total of 4,665 visitors between January and August 2026. Monthly attendance varied considerably, with the highest numbers recorded in May (797 visitors), July (795 visitors), June (784 visitors), and March (778 visitors). Despite MOTIO being closed for one full week in August due to operational reasons, the centre recorded 684 visitors during the month. The monthly distribution is shown in Fig. 2.

Visitor attendance also increased substantially compared with the previous year. During January–May 2025, MOTIO recorded 1,733 visitors, compared with 2,449 visitors during the same period in 2026, representing an increase of approximately 41%.

Visitor feedback indicates a preference for guided visits among the surveyed participants. Of the 200 respondents, 178 (89%) selected guided visits with spoken explanations, while 17 respondents (8.5%) selected both guided and independent exploration, indicating that they were comfortable with both forms of interaction. Five respondents (2.5%) did not provide a response.

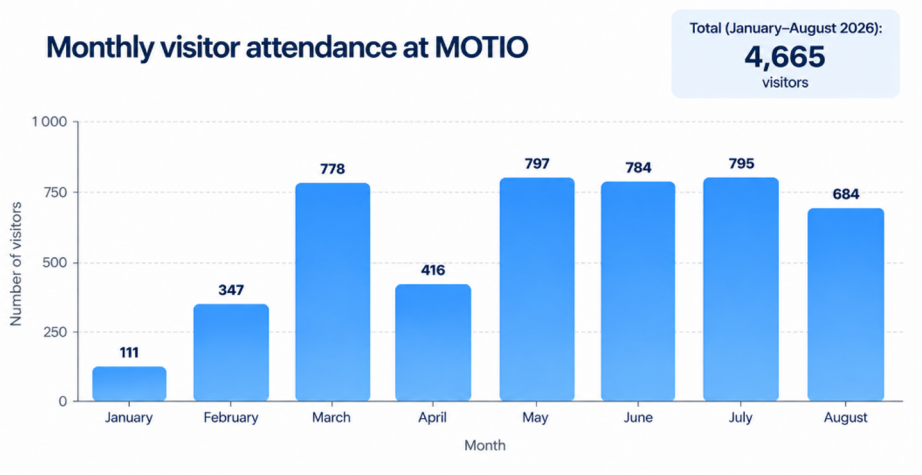


Fig. 2. Monthly visitor attendance at MOTIO and ROBOLab, January–August 2026.

These findings suggest that guided interpretation was preferred by the majority of respondents. This result is relevant to the MOTIO model, in which center staff provide explanations alongside hands-on exhibits and encourage visitors to actively explore them.

Diversity of Visitor Groups

The August visits also demonstrate the diversity of MOTIO's visitor base. During the analysed period, the centre hosted primary and secondary school groups, families and individual visitors, university students, Erasmus participants, summer camps, and other organised groups. The records also include visits connected with organisations and institutions outside formal education. International participation represents an additional dimension of the centre's outreach. Erasmus groups and international visitors contribute to the diversity of audiences engaging with the centre's STEM activities. This supports the role of MOTIO as a university-based informal learning environment accessible to visitors with different educational and cultural backgrounds.

4.2 Technology-Oriented Engagement

Technology-oriented activities form an important part of MOTIO's visitor experience. In addition to interactive physical exhibits, visitors can engage with virtual and augmented reality, robotics, 3D printing, and other digital technologies through MOTIO and ROBOLab.

During guided visits, centre staff informally observed that some young visitors reported having access to a VR headset at home. This observation suggests that some visitors may already have experience with immersive technologies before visiting MOTIO. For MOTIO, this familiarity creates an opportunity to use VR and AR not only as engaging technologies but also as tools for scientific exploration, explanation, and interpretation.

The integration of physical exhibits with immersive and technology-based activities provides visitors with multiple ways to engage with STEM concepts, ranging from hands-on experimentation to digitally mediated and immersive experiences.

5 Discussion

The findings suggest that the educational value of MOTIO lies in the combination of immersive technologies, hands-on interaction, and guided interpretation. Rather than using VR and AR as standalone attractions, MOTIO integrates them into a broader informal learning environment in which visitors can explore phenomena, receive explanations from facilitators, and connect their experiences with scientific concepts.

Visitor feedback provides further support for the relevance of guided interpretation within this model. Among 200 respondents, 178 (89%) preferred guided visits with spoken explanations, while 17 respondents (8.5%) selected both guided and independent exploration. Five respondents (2.5%) did not provide a response. The results therefore indicate a clear preference for guided visits among the surveyed respondents and are consistent with previous research highlighting the role of facilitators in visitor engagement [7]. However, the feedback does not establish that guided visits caused the observed increase in attendance.

MOTIO and ROBOLab also provide opportunities to engage with VR, AR, robotics, 3D printing, and other digital technologies. Visitors can move between physical experimentation and immersive or technology-based experiences, creating multiple pathways for STEM exploration.

Attendance growth provides supporting evidence of the centre's expanding reach. Visitor numbers increased by approximately 41% between January–May 2025 and January–May 2026, from 1,733 to 2,449 recorded visits. This observed increase indicates greater visitor participation during the comparable period; however, the available data do not establish that VR/AR, guided interpretation, or any individual programme caused this increase. Attendance may also have been influenced by the continued development of the centre following its opening in April 2024, the expansion of the programme portfolio, the introduction of ROBOLab, outreach and promotional activities, and increasing familiarity of local schools and the public with the centre.

5.1 Repeated engagement and familiarity with the university environment

An important long-term objective of MOTIO is not limited to attracting visitors for a single educational experience, but also to encourage repeated and positive encounters with science and the university environment. The intention is to make the university setting familiar, accessible, and associated with enjoyable and meaningful experiences from an early age. This perspective is consistent with psychological research on the mere-exposure effect, which indicates that repeated exposure can increase familiarity and, under appropriate conditions, positive evaluation of a stimulus [11]. Research on place attachment further suggests that positively experienced places during childhood can contribute to the development of longer-term affective bonds with those places [12]. In this context, repeated visits to MOTIO may represent one potential pathway through which young people gradually become familiar with science and the university environment and develop positive associations with these settings.

This interpretation represents a long-term conceptual objective rather than an outcome demonstrated by the present dataset. The current study does not track individual visitors longitudinally and therefore cannot determine whether repeated visits to MOTIO influence later educational aspirations, university choice, or enrolment. Future research could examine this possibility by following participants over time and relating their experiences at MOTIO to changes in STEM interests, educational aspirations, and subsequent study choices.

5.2 Limitations

Several limitations should be considered when interpreting the findings. First, the study represents a single-site descriptive case study of one university-based informal STEM learning centre, which limits the generalisability of the findings to other institutions and contexts. Second, the analysis relies primarily on internal attendance and programme records and on visitor feedback collected in the context of MOTIO activities. These data provide useful information about participation, visitor preferences, and the

development of the centre, but they do not directly measure cognitive learning, STEM knowledge, or the quality of engagement. The study does not include standardised pre- and post-visit measures, a comparison group, or longitudinal follow-up. Consequently, changes in attendance and visitor preferences cannot be interpreted as evidence of causal effects on learning, STEM interest, or future educational choices. In addition, the attendance records represent recorded visits rather than necessarily unique individuals, meaning that repeated visits may be included in the reported totals. Future research should combine attendance data with systematic measures of learning and engagement and, where appropriate, longitudinal data examining whether repeated experiences with informal STEM environments influence educational aspirations or subsequent study choices.

6 Conclusion

This study examined MOTIO as a university-based informal STEM learning environment and explored how VR/AR, hands-on exhibits, and guided interpretation are combined within its educational activities. The findings indicate that MOTIO provides multiple opportunities for STEM engagement by connecting physical experimentation and immersive technologies with direct guidance from facilitators. The fact that 89% of surveyed respondents selected guided visits, while a further 8.5% indicated comfort with both guided and independent exploration, highlights the relevance of human interpretation alongside opportunities for autonomous interaction with exhibits.

Visitor participation also increased during the analysed period, with 2,449 recorded visits during January–May 2026 compared with 1,733 during the same period in 2025, representing an increase of approximately 41%. From January to August 2026, MOTIO and ROBOLab recorded 4,665 visits. These figures indicate the development and reach of the centre, but they should not be interpreted as direct evidence of learning outcomes or causal effects of particular technologies or programmes.

More broadly, MOTIO is designed not only as a place for individual STEM experiences but also as an accessible university environment to which young people can return repeatedly. Repeated positive encounters may contribute to familiarity with science and the university setting, although this potential long-term effect was not examined in the present study. Future research should therefore investigate learning outcomes, visitor engagement, repeated participation, and the possible relationship between sustained experiences in university-based informal STEM environments and later educational aspirations or study choices.

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