

INTEGRATION OF QR CODE TECHNOLOGY IN THE EXHIBITIONS OF THE GEOLOGICAL MUSEUMS AT THE UNIVERSITY OF MINING AND GEOLOGY “ST. IVAN RILSKI” – SOFIA, BULGARIA

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ABSTRACT. This article presents the results of the implementation of QR code digitisation in the exhibitions of the Museum of Unique Crystals, the Museum of Geology and Paleontology, and the Museum of Mineralogy, Petrography, and Mineral Resources at the University of Mining and Geology “St. Ivan Rilski”. The initiative is aimed at improving the accessibility, interactivity, and educational value of the three museums. Through QR technology, visitors can access information, high-quality images, and bilingual descriptions via their smartphones, which brings museums in line with modern digital practices. The indexed exhibitions enrich visitors' knowledge and support Earth science education for both university students and amateur audiences. Building on previous digital initiatives, such as virtual tours and information guides, this innovation contributes to increased visitor engagement. Among the key achievements are the creation of the first specialised exhibition of fluorescent minerals and the first 3D models of fossils at the university, integrated with QR technology in support of modern STEM-oriented education. The implementation of technology significantly improves the museum's educational impact, digital accessibility, and its alignment with modern STEM-oriented practices.

Key words: QR code digitisation, STEM education, museum exhibitions, 3D models, fluorescent minerals.

ИНТЕГРИРАНЕ НА QR КОД ТЕХНОЛОГИЯ В ЕКСПОЗИЦИИТЕ НА ГЕОЛОЖКИТЕ МУЗЕИ В МИННО-ГЕОЛОЖКИ УНИВЕРСИТЕТ „СВ. ИВАН РИЛСКИ“ – СОФИЯ, БЪЛГАРИЯ

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РЕЗЮМЕ. Настоящата статия представя резултатите от внедряването на QR код дигитализация в експозициите в Музея на уникалните кристали, Музея по геология и палеонтология и Музея по минералогия, петрография и полезни изкопаеми в Минно-геоложки университет „Св. Иван Рилски“. Инициативата е насочена към подобряване на достъпността, интерактивността и образователната стойност на трите музеи. Благодарение на QR технологията посетителите могат да получат достъп до информация, висококачествени изображения и двуезични описания чрез своите смартфони, което привлича музеите в съответствие със съвременните дигитални практики. Индексираните експозиции обогатяват знанията на посетителите и подпомагат обучението по науки за Земята както за студенти, така и за любителска аудитория. Надграждатки върху предишни дигитални инициативи, като виртуални разходки и информационни гидове, тази иновация допринася за повишена ангажираност на посетителите. Сред ключовите постижения са създаването на първата специализирана изложба на флуоресцентни минерали и първите 3D модели на фосили в университета, интегрирани с QR технологията в подкрепа на съвременното STEM-ориентирано образование. Внедряването на технологията значително подобрява образователното въздействие на музея, дигиталната достъпност и съответствието му със съвременните STEM-ориентирани практики.

Ключови думи: QR код дигитализация, STEM образование, музейни експозиции, 3D модели, флуоресцентни минерали.

Introduction

Modern museums strive to combine traditional exhibitions with innovative digital technologies to provide a more accessible, interactive, and educational experience for their visitors. In the digital age, the expectations for the museum spaces are evolving with visitors seeking not only a visual observation of the exhibits, but also access to additional information that broadens their understanding of the objects and processes presented. In this context, QR (Quick Response) codes are establishing themselves as an effective tool for digitising museum collections. The technology is a two-dimensional matrix code created in 1994 by Masahiro Hara for the Japanese company Denso Wave with an initial commercial and logistical purpose (Koleva, 2013).

Developed to optimise inventory tracking and manufacturing component management processes, QR codes have established themselves as one of the most common modern communication and distribution tools, thanks to the functionality and capabilities of mobile devices. They are easily accessible through smartphone cameras and are effectively used in various fields, including education (Tofan, 2017). Their main advantage is in providing synthesised, structured, and reliable information directly to the visitor's personal mobile device. They offer fast, convenient, and consistent access to rich information content

via mobile devices, while allowing the integration of text, images, scientific notes, video, and audio content (Williams and Howarth, 2012).

This study examines the application of QR codes in the geological museums at the University of Mining and Geology “St. Ivan Rilski”. The main goal is to analyse the benefits of digital indexing of exhibitions in terms of increasing accessibility and interactivity, as well as increasing the educational and scientific value of museum collections.

Material and methods

In museum practice, QR codes are widely used as a means of digital indexing and expanding information about the exhibitions. They represent an effective tool for modernising the museum environment (Caballero and Aguilera, 2019).

In exhibition halls, they are located directly on the display cases, providing access to additional content related to the variety of rocks, minerals, and fossils displayed. Unlike traditional one-dimensional (1D) linear barcodes, QR codes have a significantly greater information capacity – over 4000 characters compared to approximately 20 for conventional ones. A great advantage is their exceptional reliability and durability, as they can be scanned at different angles thanks to the three

position markers in their corners and can still be read even if partially damaged.

Around 2008 – 2009, as a development of the standard static QR code, the dynamic QR code appeared. Compared to static QR codes, which contain permanent and unchangeable information, the dynamic QR codes use a short URL (Uniform Resource Locator) or unique identifier pointing to an online resource. After scanning, a user's device first opens an intermediate link, which subsequently redirects to the corresponding content. Thanks to this redirection mechanism, the content or final destination can be changed at the server level without the need to replace or reprint the QR code itself (Dix and Jones, 2024).

The methodology for developing and implementing QR codes in the geological museums at the University of Mining and Geology “St. Ivan Rilski” is based on the use of static QR codes. In the future we will most likely switch to using dynamic QR codes because of their greater flexibility.

The study includes a total of 23 display cases distributed in three exhibition spaces – 10 display cases in the Museum of Unique Crystals, 12 display cases in the Museum of Geology and Paleontology, and 1 display case in the Museum of Mineralogy, Petrography, and Mineral Resources. The methodology was developed in five stages (Fig. 1).

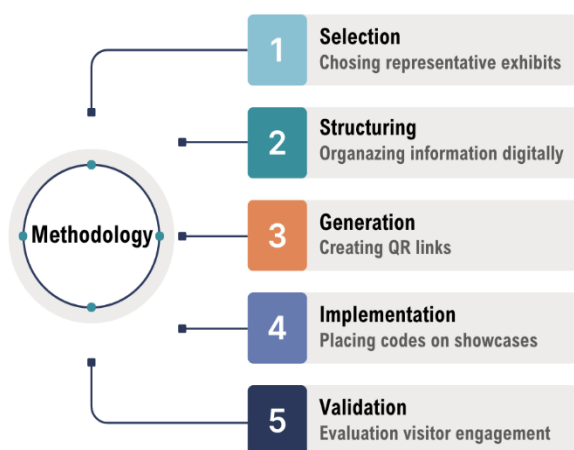


Fig. 1. Methodology for QR-based museum exhibition digitalisation

First stage

During the first stage, the exhibition units were **selected**. Criteria included the scientific significance of the exhibits, visitor interest, and potential for enriching the digital content. The selected showcases contain representative mineral, rock and fossil specimens, which allow supplementing the information through multimedia resources.

Second stage

In the second stage, the information content is **collected** and **structured**. The methodology for digitising the exhibition includes the creation of individual QR code for each showcase, linked to an online digital catalogue. The catalogue contains structured information about the exhibits, high-resolution images, and scientific notes. The content is adapted for accessibility, clarity, and bilingual presentation.

Third stage

The third stage involves **generating** QR codes with an individual code created for each showcase leading to the corresponding digital content. Static QR codes were used, generated through the Canva built-in QR code generator. Each code was tested for functionality, speed of access, and compatibility with various mobile devices.

Fourth stage

In the fourth stage, the **positioning** and **design** of the codes was carried out. The QR codes were placed directly on the display cases, allowing visitors to gain immediate access to the information on site via smartphone. At the same time, the possibility of remote access for continuing education was also provided. They were **integrated** on the display cases through printed labels, which were consistent with the aesthetics of the exhibition. Various factors were taken into account when placing them – height, lighting, and easy recognition by visitors.

Fifth stage

The fifth stage involves pilot **testing** in a real museum environment, where visitors' interaction with the QR codes is monitored. Various indicators are evaluated – frequency of use, time to access content, level of engagement.

Results and discussion

So far, the technology has been applied in the Museum of Unique Crystals, where 10 display cases are indexed, each of which is accompanied by detailed scientific information about the minerals with high-quality photos (Fig 2a, b). For the convenience of the visitors, a digital catalogue of the museum display cases has been created, accessible by scanning on site. Visitors have access to this information even after leaving the museum.



Fig. 2. Indexing with QR codes at the Museum of Unique Crystals
a) View of a museum display case with a QR code (red arrow); b) on-site scanning.

The display cases from the Paleontology collection at the Museum of Geology and Paleontology include a variety of fossils, presented and arranged by fossil genera, with the exhibits accompanied by detailed scientific descriptions presenting information about the origin, age, and characteristic features of the organisms under consideration. Along with

scientific information, the display cases are also accompanied by three-dimensional models of selected fossils (Fig 3a).

The 3D fossil models were created by scanning selected specimens using a Revopoint MINI 2 3D scanner. The resulting data was processed using Revo Scan 5 and uploaded to the online 3D model sharing and viewing platform Sketchfab. The platform allows adding textures, animation, and explanatory notes to the models, making them extremely informative and suitable for presentation purposes in the museums (Fig. 3b, c).



Fig. 3. Indexing with QR codes in the Museum of Geology and Paleontology: a) Paleontology exhibition; b) QR codes embedded with scientific information and 3D models of fossil exhibits; c) scanning of a fossil specimen.

In connection with the preparation of the scientific justification for the exhibition dedicated to fluorescent minerals, analyses of their mineral composition and fluorescence activators were performed. For this purpose, X-ray diffraction and spectroscopic methods were applied. The analyses were conducted at the X-ray powder diffraction laboratory of the University of Mining and Geology "St. Ivan Rilski" and at the Institute of Optical Materials and Technologies "Acad. Yordan Malinovski" at the Bulgarian Academy of Sciences. The results are included in the text, accompanying the QR code, combined with photographs under LED and UV (365 nm) light (Fig. 4).



Fig. 4. a) Exhibition of fluorescent minerals at the Museum of Mineralogy, Petrography, and Minerals, indexed with a QR code; b) Brochures for the geological museums at the University of Mining and Geology "St. Ivan Rilski".

Rotational models (Dollhouse) were created during the digitisation process, and 3D virtual tours of the museum exhibits were generated and integrated into the "Virtual Bulgaria" portal. In this way, visitors are provided with interactive access to the exhibits, which can also be viewed remotely.

Indexing the museum's fluorescence exhibit using QR codes provides visitors not only with visual information, but also with detailed scientific data on fluorescence activators (Fig. 4a). Analyses were conducted to determine the mineral composition and fluorescence activators. The results of these studies allow for the provision of accurate and scientifically based information on mineral phases and fluorescence activators. In this way, the exhibit becomes a valuable resource for visitors interested in mineralogy and physics, and for students and scientists, facilitating educational and research processes through direct access to reliable scientific data.

The spread of QR codes extends beyond the museum space to include websites, social media platforms, and printed materials such as brochures, flyers, and posters, released in 2024 and 2025 (Fig. 4b). In this way, museums reach a wider audience, including prospective students and external visitors. It provides quick and convenient access to information about museum collections, educational opportunities at the university, and various areas of Earth sciences.

One of the significant innovations in recent years, which complements the implementation of QR codes, is the use of virtual tours in the museums of the University of Mining and Geology "St. Ivan Rilski" (Marinova et al., 2022). In a previous project, the exhibits were scanned and presented through 3D rotational models (Dollhouse), allowing observers to freely navigate the museum space and view individual parts of the exhibits with interactive tags in Bulgarian and English. The virtual tours were integrated into the "Virtual Bulgaria" Internet portal. Through the generated QR codes, visitors gain direct access to selected showcases, halls or exhibits during the virtual visit. Feedback shows that this approach significantly increases interest in museums and overall attendance.

Indexing museum exhibits through QR codes allows the integration of physical visits with digital technologies both on site and remotely. This improves the quality of the museum experience, stimulates interest in Earth sciences, and encourages attendance. This approach represents a modern, technologically advanced, and easily accessible tool for promoting and interpreting museum collections (Miladinov, 2024). It is aimed at a diverse audience and seeks to generate sustained interest, personal engagement, and active participation. In addition to its communication function, the QR code system plays an essential educational role, providing quality scientific content, applicable in both face-to-face and distance or online learning.

The applicability of QR codes in a museum environment can be defined as a multidimensional category that includes educational, communication, technological, and management aspects of museum activities. In the context of the increasing digital transformation of cultural institutions, QR codes are a mediator between the physical exhibit and the expanded digital content. In terms of information, QR codes provide access to extended descriptions and multimedia resources that go beyond the limitations of traditional exhibition labels. Extended content can include video materials, audio guides, interactive visualisation, 3D models, etc., which increase the degree of personalisation of the experience. By providing interactive educational materials, the museum strengthens its pedagogical

function and stimulates the active participation of visitors in the learning process (Fig 5).



Fig. 5. Enchanting visitor experience with digital access

From an accessibility perspective, QR codes significantly expand museum communications. Through bilingual and potentially multilingual versions of content, they contribute to greater social engagement and equal access to exhibits. In this way, the technology performs not only an informational, but also a social function within museums.

Implementing QR codes in a museum environment can reduce costs for printed materials and maintenance of physical audio guide devices. It provides flexibility in updating content, which increases organisational efficiency and sustainability of the museum institution.

In the context of modern museum practices, the implementation of QR codes is being established as an effective method for digitisation and enrichment of content. Their application in the field of providing information about exhibits allows guidance to expanded text and multimedia resources,

which contributes to a deeper perception by visitors. Resources are optimised by reducing the need for printed materials, which has both an economic and environmental effect. The level of impact in this area can be defined as high (Table 1).

QR technologies also play a significant role in ensuring bilingual accessibility. By redirecting to translated versions of the content, prerequisites are created for expanding the international audience of museums. In turn, this contributes to increasing cultural exchange, and the impact is defined as high (Table 1).

The integration of interactive content, such as augmented reality (AR), including virtual tours and 3D models, is one of the most significant innovations related to the use of QR codes. These technologies transform passive observation into active participation, stimulating engagement and interest in the exhibits (Pérez-Sanagustín et al., 2016). For this reason, this area is characterised by a very high level of impact (Table 1).

The presence of QR codes facilitates the collection of feedback by providing direct access to surveys and evaluation forms. This allows the systematic accumulation of empirical data on the user experience. The data obtained could be used for subsequent analysis and optimisation of museum practices (Balhaf et al., 2025). Given the activity of visitors, the impact in this aspect can be defined as medium (Table 1).

In educational terms, QR codes contribute to expanding learning opportunities by providing additional resources aimed at students. This supports the integration of museums into the educational process, while the level of impact remains high. In the context of STEAM education (Science, Technology, Engineering, Arts, Mathematics), QR codes are a kind of bridge between traditional content and interactive digital tools (Table 1). Through them, students gain access to multimedia materials, virtual demonstrations, 3D models, and interdisciplinary connections that stimulate participatory learning, promote critical thinking, creativity, and practical skills (Dressler and Kan, 2018).

Table 1. Applications and impact of QR codes in a museum environment

Application area	Additional functionality	Advantage for visitors	Advantage for museums	Level of impact
Information for the exhibits	Link to extended description, video	Deeper understanding	Reduce the need for printed materials	High
Bilingual support	Redirection to translated text	Accessibility for foreigners	Audience growth	High
Interactive content	AR/3D models, video	Engaging experience	Increasing interest in the exhibition	Very high
Feedback	Link to survey	Easy sharing of opinions	Data collection and analysis	Intermediate
Educational resources	Additional materials for students	Educational support	Strengthening the educational role	High
Social impact	Sharing on the Internet and social networks	Remote access	Increased publicity	High

The social dimension of QR codes is manifested through the possibilities for easy sharing of content in a digital environment, including social networks. In addition, the use of QR codes provides remote access to digital information and museum

content. It also increases the visibility and public recognition of museum institution, events, and cultural sites, creating a broader connection with the audience. In this context, the level of impact is also assessed as high (Table 1).

Conclusions and recommendations

The implementation of QR codes in the geological museums at University of Mining and Geology "St. Ivan Rilski" demonstrates significant benefits in terms of accessibility, interactivity, and educational impact. QR codes allow visitors to access detailed scientific information, high-quality images and bilingual descriptions directly through their mobile devices, on-site and remotely.

Their integration into the digital catalogue and virtual tours further enhances visitor experience by enabling interactive exploration and encouraging self-directed learning. The results of the analyses of the mineral composition and fluorescence activators of museum exhibits provide scientifically validated content, making the exhibits a valuable resource for students, researchers, and the general public. The use of QR codes in university and museum contexts, combined with virtual tours and digital catalogs, represents a modern, technologically advanced, and effective approach to improving museum accessibility, educational outcomes, and visitor engagement.

The possibility of active interaction with digital content transforms the traditional model of passive observation into a more dynamic and interactive one. Longer time spent in front of exhibits and the frequency of use of digital resources are interpreted as indicators of increased motivation and interest. From the point of view of accessibility, QR codes significantly expand communications in the museum. Through bilingual versions of the content, they contribute to greater social engagement and equal access to the exhibits. In this way, technology performs not only an informational, but also a social function within museums.

In future, we intend to transition to the use from static QR codes to dynamic ones due to their greater flexibility and the possibility of easily updating content without the need to regenerate the codes. This flexibility in updating content management will improve the efficiency and sustainability of the museum institution.

The applicability of QR codes in a museum environment is not limited to their technological function as a means of quick access to information. They are a complex tool for educational media, social engagement, institutional efficiency, and digital communication, transforming the traditional museum experience into a more interactive form that is adaptable to the modern requirements of visitors.

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References

- Balhaf, K., Hassan, Y., Saleh, K., AlSufyani, A., Bakhuraisah, S. Bindahman, S. (2025). Improving Museum Visitor Experience Using QR Code Technology: Creation of a Mobile Application for Al Ghaydah Museum. *Engineering and Technology Journal* e-ISSN: 2456–3358, 10, 7, 5821–5826. <https://doi.org/10.47191/etj/v10i07.29>, I.F. – 8.482
- Caballero, P., Aguilera, F. (2019). Evaluation for QR codes in environmental museums. *Global Journal of Information Technology: Emerging Technologies*, 9(2) 29–32. <https://doi.org/10.18844/gjit.v9i2.4268>
- Dix, A., Jones, E. (2024). A flexible QR-code infrastructure for heritage. In *2024 Workshop on Advanced Visual Interfaces and Interactions in Cultural Heritage, AVICH 2024. vol. 3798, CEUR Workshop Proceedings*, 2024 Workshop on Advanced Visual Interfaces and Interactions in Cultural Heritage, AVICH 2024, Genoa, Italy, 4/06/24.
- Dressler V., Kan, K. (2018). Mediating Museum Display and Technology: A Case Study of an International Exhibition Incorporating QR Codes. *Journal of Museum Education*, 43, 159–170. <https://doi.org/10.1080/10598650.2018.1459081>
- Koleva, Z. (2013). The "QR code" tool and its marketing applications - First Scientific Seminar of doctoral students, postdoctoral students, and young scientists of the University of Technology "St. St. Cyril and Methodius", 17.01.2013, "Faber" Publishing House, Veliko Tarnovo. (In Bulgarian)
- Marinova, K., Sachanski, V., Stoykov, St., Pazderov, R., Banushev, B., Vatskicheva, M., Zareva, E., Dimitrov, M., Chaush, B., Kostadinov, S. (2022). Digitalisation and creation of a 3D 360-degree HDR 4K virtual tour with interactive tags of the *Ilija Deleff* Museum of Unique Crystals, the Museum of Geology and Paleontology, the Museum of Mineralogy, Petrology, and Mineral Resources and the Museum of Physics at the University of Mining and Geology "St. Ivan Rilski". *Rev. of Bulg. Geol. Soc.*, 83(3) 349–350.
- Miladinov, P. (2024). *Effects of the introduction of new technologies in museums*. University Publishing House "St. Kliment Ohridski", 135 pp. (In Bulgarian)
- Pérez-Sanagustín, M., Parra, D., Verdugo, R., García-Galleguillos, G., Nussbaum, M. (2016). Using QR codes to increase user engagement in museum-like spaces. *Computers in Human Behavior*, 60, 73–85.
- Tofan, Florin-Cătălin. (2017). QR Codes Implementation in Museum Exhibitions. *Studii si Comunicări*, 25, 142
- Williams, P., Howarth, A. (2012). Using QR codes to aid accessibility in a museum. *Journal of Assistive Technology*. 6(4). <https://doi.org/10.1108/17549451211285771>.