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**DIGITISED CULTURAL HERITAGE AS DATA: EMERGING  
TRENDS IN ITS USE IN SCHOOL-LEVEL COMPUTER  
SCIENCE EDUCATION**

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Decades of active digitisation of cultural heritage in galleries, libraries, archives and museums (GLAM institutions) have led to the accumulation of vast amounts of openly accessible digital content. Research and education are the two fields in which this content is most frequently used. The strongest connections have been developed with the teaching of history, literature, art, and music, where digitised materials provide primary sources and rich illustrative resources. However, the contemporary trend of approaching digital collections as data makes this type of open content particularly suitable for incorporating authentic tasks related to data collection, cleaning, analysis, and visualisation. Such tasks are highly appropriate for projects that integrate diverse skills from computer science education and can be offered both as individual and group assignments.

The paper presents real-life examples from international practice of integrating cultural heritage into school-level computer science education, within the broader context of strengthening STEM competencies and project-based learning. These examples demonstrate that cultural heritage can successfully serve as a meaningful context for developing algorithmic thinking, data literacy, digital skills, and AI literacy in schools.

**Keywords:** Digital Cultural Heritage, collections as data

**ДИГИТАЛИЗИРАНОТО КУЛТУРНО НАСЛЕДСТВО  
КАТО ДАННИ: НОВИ ТЕНДЕНЦИИ ЗА ИЗПОЛЗВАНЕТО  
МУ В УЧИЛИЩНОТО ОБУЧЕНИЕ ПО ИНФОРМАТИКА**

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Десетилетията активна дигитализация на културно наследство в библиотеките, музеите, архивите и галериите доведоха до натрупване на огромно количество свободно достъпно дигитално съдържание. Научните изследвания и образованието са двете области, където това съдържание се използва най-често. Най-силно развити като възможност за предоставяне на първични източници и богат илюстративен материал са връзките с обучението по история, литература, изкуство, музика. Но съвременната тенденция да се разглеждат дигиталните сбирки като данни (collections as data) прави този тип отворено съдържание много подходящо за включване на реални задачи по събиране, почистване, анализ и визуализация на данни. Този тип задачи са много подходящи за проекти, които интегрират различни умения от обучението по информатика и могат да се предлагат както като лични, така и като групови задачи.

Докладът ще представи реални примери от международната практика за интегриране на културното наследство в училищното обучение по информатика в контекста на засилването на компетенциите в STEM и проектно-базираното обучение, които демонстрират, че културното наследство може успешно да служи като контекст за развитие на алгоритмично мислене, работа с данни, дигитални умения и грамотност в областта на изкуствения интелект в училище.

**Ключови думи:** дигитално културно наследство, сбирките като данни

## 1. Introduction

Digitisation has reshaped access to cultural heritage by making primary sources accessible 24/7 from any point in the world. In many educational contexts, digitised heritage entered classrooms as a visibility and access intervention: teachers could project artworks and manuscript pages, use museum objects as discussion prompts, or ask students to interpret historical photographs. This content-oriented use is valuable, but it typically retains a “view-and-interpret” model in which learners are consumers of content preselected (or curated) by teachers.

Over the last decade, a complementary model has gained momentum: digitised heritage is increasingly approached as data. In the collections-as-data paradigm, the central educational object is not only the digital surrogate (for example, an image of a print or a scanned letter) but the dataset that represents the collection at scale – metadata exports, full-text corpora, linked data graphs, annotation layers, or derivative datasets made available for computational reuse. This shift aligns with broader changes in education: the rise of computational thinking in school curricula, growing attention to data literacy, and a pedagogical emphasis on inquiry, authentic problems, and project-based learning.

The question this paper addresses is therefore not whether digitised cultural heritage is useful in education – it clearly is – but how educational approaches have evolved, and how the collections-as-data perspective contributes to that evolution by enabling new kinds of learning activity. Rather than treating cultural heritage as an optional illustration, collections-as-data approaches position it as means for developing competencies in computation, data analysis, and even artificial intelligence (AI) literacy.

To examine this domain systematically, the paper is structured as follows. Section 2 formulates the research questions that guide the study. Section 3 outlines the methodological framework adopted to address these questions. Section 4 reviews the principal

pedagogical approaches situated at the intersection of ICT education and cultural heritage. Section 5 analyses in greater depth the potential of the *collections as data* paradigm for supporting computational thinking and data literacy. Section 6 presents illustrative examples demonstrating how major cultural heritage institutions actively contribute to bridging heritage and formal education. Section 7 discusses the implications of these developments for curriculum design and ICT competency frameworks. The paper concludes by synthesising key findings and identifying research gaps and directions for future work.

## 2. Research Questions and Methodology

This paper explores four questions.

RQ1. How have educational approaches for using digitised cultural heritage evolved from content-focused models toward data-oriented learning activities?

RQ2. What learning outcomes are most plausibly supported by collections-as-data work with cultural heritage in school and early higher education?

RQ3. What forms of pedagogy and curriculum design best support meaningful integration of cultural heritage datasets within computational thinking and data literacy objectives?

RQ4. Which contemporary initiatives demonstrate workable models for integrating cultural heritage datasets into educational practice, and what can be learned from them?

## 3. Methodology

The paper is exploratory rather than offering a systematic review of the literature. We explored literature and policy reports across four intersecting areas: (1) digitisation and access initiatives in the cultural heritage sector; (2) collections-as-data and computational use of digitised collections; (3) education research on inquiry, project-based learning, computational thinking, and data literacy; and (4) documentation from major cultural heritage platforms that explicitly support educational reuse.

The goal is integrative rather than exhaustive: to suggest current trends and a practical framework for educational integration, supported by real-life examples. While the present paper is not an empirical classroom study, it specifies what would be required for rigorous evaluation of collections-as-data learning interventions, including learning artefacts, process documentation, and assessment of transferable competencies.

## 4. Evolution of Educational Approaches to Digitised Cultural Heritage

The question how to best use digitised cultural heritage in education is as old as digitisation itself – from the very onset of digitisation activities, education was considered a major domain of using digital content alongside research and leisure [6]. Back in 2015, we argued that there is a paradox within the educational use of cultural heritage collections: despite the rapid expansion of digitised collections and the availability of millions of digital objects through large-scale infrastructures, their integration into formal education remained limited even within the most likely adopters, Humanities and Arts disciplines [6]. The article highlighted a persistent disconnect between digital library development and actual educational practice, noting that most initiatives are supply-driven rather than grounded in empirically studied teacher and learner needs. Evidence of sustained

classroom use was scarce, and terminology, interfaces, and workflows were often poorly aligned with mainstream e-learning environments. Overall, the paper concluded that the challenge is not the lack of digitised content, but the absence of coherent pedagogical frameworks, interoperable tools, and evidence-based models that would make digital libraries meaningfully reusable within educational systems. How much progress we can report ten years later? Let us explore the most popular trends for educational use today.

#### **4.1 Transmission and resource supplementation**

In transmission-oriented models, digitised cultural heritage primarily supplements teaching by providing illustrative materials or authoritative sources. The learner's role is to absorb and reproduce knowledge, supported by digital images, document excerpts, or curated presentations. Digitised heritage in this mode operates similarly to a textbook illustration, although with greater quality and in some cases with the option to manipulate the object (e.g. zoom into it, or rotate it). This approach is very popular in subjects such as history, art, music as explored in the academic literature [2, 4, 10]. A modification of this approach is the use of virtual reality and games as presented by Xu and al. [14] with the idea to offer an engaging environment supporting learning about the past.

#### **4.2 Constructivism and inquiry with primary sources**

Constructivist approaches reconsider learners as active meaning-makers. Inquiry-based learning encourages students to examine sources, ask questions, and justify interpretations. Digitised cultural heritage became particularly valuable here because it provides access to primary sources that support evidence-based argumentation. Teacher-facing programmes that curate sets of primary sources and propose inquiry questions reflect this shift, making it feasible to integrate authentic materials without requiring specialist archival training. This type of use of digital heritage is again strongest in the Humanities and arts and is particularly relevant to the efforts to improve critical thinking and counteract misinformation.

#### **4.3 Project-based learning and authentic tasks**

Project-based learning extends inquiry by organising learning around extended tasks with tangible outputs. In heritage contexts, projects may involve curating a digital exhibit, producing interpretive narratives, or comparing sources across time and place. Digitised collections enable project work by reducing access barriers and allowing learners to assemble evidence sets that would be impractical to gather physically. Project-based learning is the space where cultural heritage can offer objects or datasets which help to improve ICT skills. For example, traditional hats from a local festival had been used to improve computer-aided design skills [13].

#### **4.4 Computational thinking and data literacy**

The contemporary emphasis on computational thinking and data literacy changes the traditional pedagogical space. Learners are increasingly expected to understand how data is structured, processed, analysed, and communicated. In this environment, digitised heritage becomes not only a source of meaning but also a source of data. Collections-as-data approaches provide authentic datasets for teaching data practices: learners can define questions, extract subsets, clean records, visualise patterns, and critically interpret

results. Such examples are already tried in higher education [7] – currently combining tasks of identifying datasets, cleaning them and analysing and visualising the data using Jupyter notebooks and Python.

## 4.5 From digital humanities practice to educational method

Collections-as-data ideas emerged in close relation to digital humanities practice, where researchers sought to use computational methods on corpora, catalogues, and large-scale digitised collections. Educational adoption increasingly follows the same trajectory: methods developed for research are translated into classroom-appropriate forms. This translation is not a simple simplification. It involves deciding which elements of research workflows should be made visible to learners, which should be scaffolded, and which should be deferred. For example, learners may not need to build a full production pipeline, but they benefit from experiencing the logic of a pipeline: selecting evidence, documenting transformations, and validating interpretations.

The educational value lies in method literacy. When students work with heritage-as-data, they are learning how modern knowledge is produced: not only by reading sources, but by structuring evidence, testing patterns, and communicating uncertainty. This resonates with broader aims in contemporary education to develop evidence-based reasoning, to demystify digital tools, and to prepare learners for environments in which data-informed claims are common. With a growing amount of accumulated open software on platforms such as Hugging Face, Github, or DARIAH campus, we are currently living in times of accumulating openly available software and the challenges of discovery of tools which may be suitable to use as illustrations in education [8]. At the same time, the number of openly available datasets based on digital collections is growing; this created the need to describe datasets using datasheets [1]; however, these datasheets are not particularly focused on the potential for educational reuse. We could expect that in the future such descriptions could be extended with reuse guidance.

## 4.6 Shifts in what counts as ‘authentic’ learning

Digitised cultural heritage changes what authenticity can mean in classrooms. In earlier models, authenticity was achieved by viewing an original source (even if mediated digitally) and treating it as evidence for interpretation. In collections-as-data learning, authenticity extends to the practices of contemporary analysis: working with imperfect records, understanding constraints of datasets, and justifying methodological choices. Students encounter the reality that cultural heritage data is heterogeneous and historically shaped, and they learn that responsible analysis requires both technical skill and contextual awareness.

These shifts align with the wider evolution from knowledge-as-content toward knowledge-as-practice. This is an essential component of critical thinking, a skill much discussed but never sufficiently supported to form such a level of skills which would stop the spread of disinformation.

These shifts also open a pathway for stronger integration between humanities and computing/information technology education. Rather than using cultural heritage merely to ‘decorate’ computational lessons, collections-as-data approaches can make heritage a central domain where computation is learned as a way of asking and answering questions.

## 5. What ‘Collections as Data’ Could Add to the Educational System?

Collections as data had been introduced relatively recently introduced [3, 5, 11] and represent the trend of treating digital collections, such as texts, images, audio, and videos, as datasets allowing for computational analysis. There are several noteworthy characteristics of collections as data that can help enrich educational practice.

### 5.1 From item-level interpretation to collection-scale questions

Collections-as-data approaches expand the unit of analysis. Instead of focusing solely on interpreting a single document or object, learners can ask collection-scale questions: how topics change over time, how places and historical personalities are connected, or how descriptive terms cluster. This supports a feedback loop between a narrow interpretation of one source/document and aggregate analysis: computational outputs suggest hypotheses, while source analysis validates and refines them. This may seem a strange advantage, but a general tendency of the Bulgarian educational system is to reduce the number of primary sources used. To what extent replacing the human reading and analysis of multiple sources with a skill to query larger digital collections without knowing the sources in detail raises many questions – here we are merely noting a shift rather than offering an opinion on what this shift will cause in the long term in terms of skills.

### 5.2 Data practices as part of disciplinary understanding

Treating cultural heritage as data makes data practices pedagogically visible. Students learn that data cleaning, normalisation, and linking are not neutral pre-processing steps; they shape what can be asked and answered. This helps learners understand that evidence in digital environments is constructed through a chain of choices. Choices are possibly easiest illustrated in visualisation tasks where the students have to make a choice which aspects of a dataset are worth illustrating visually.

### 5.3 Alignment with contemporary curriculum goals

Collections-as-data pedagogy aligns with major curriculum goals in computing and cross-curricular STEM. It supports computational thinking (decomposition, abstraction, pattern recognition, algorithmic reasoning), data literacy (data quality, analysis, interpretation, communication), and transferable skills (teamwork, documentation, reproducibility, critical reflection). Because cultural heritage materials are meaning-rich, they also support motivation and interdisciplinary relevance: students can see how computational methods apply to questions that matter culturally and socially.

There is also an additional motivation for working on these skills. A recent European Commission report [9] argued that STEM skills are in short supply in the creative industries. Including more activities involving the transformation of datasets from the cultural heritage domain within STEM education in schools could support cultivating more interest in a career in the creative industries. For the time being there is no systematic evidence gathered around this but it is worth exploring.

## **6. Initiatives and Examples of Cultural Heritage Datasets in Education**

This section highlights initiatives that explicitly support educational reuse of digitised cultural heritage and, in several cases, provide dataset-oriented access that enables collections-as-data learning.

### **6.1 Europeana: Europe-wide cultural heritage for teaching and learning**

The European data space for cultural heritage, Europeana, has developed a sustained education ecosystem that supports educators in integrating Europe’s digital cultural heritage into learning activities. Europeana Classroom provides a curated entry point for educators, offering learning resources that draw on Europeana’s aggregated collections and are designed for classroom use. Complementing this, the ‘Teaching with Europeana’ initiative and associated educator community activities support the creation and sharing of learning scenarios that use Europeana data and digital objects in formal and non-formal education.

Europeana has also collaborated with European Schoolnet over multiple years to embed digital cultural heritage into educational practice, including teacher engagement activities and the development of classroom learning scenarios). From a collections-as-data perspective, Europeana’s emphasis on reusable, openly accessible digital culture provides a pathway from item-level learning resources toward more data-oriented uses, especially when educators and students engage with metadata, thematic sets, and aggregation mechanisms across institutions.

### **6.2 Digital Public Library of America: Primary Source Sets and API-enabled learning**

The Digital Public Library of America (DPLA) provides educational materials that package digitised heritage into teachable units. Its Primary Source Sets are designed to support critical thinking and content learning by combining sets of primary sources with teaching guides and contextual information. These sets help educators operationalise inquiry-based learning with cultural heritage at scale.

For more data-oriented learning, DPLA also supports programmatic engagement through its API and openly downloadable metadata. Tutorial and training materials have been developed to introduce learners to retrieving DPLA metadata via the API and manipulating it with data tools such as OpenRefine, demonstrating a bridge from curated educational sets to dataset-based workflows.

### **6.3 Library of Congress: Teaching with primary sources, newspapers, and datasets**

The Library of Congress offers extensive teacher-facing materials and professional development designed to help educators integrate primary sources from its digital collections. Its classroom materials are created to be ready-to-use in instruction.

For dataset-oriented engagement, the Library’s digital newspaper collection *Chronicling America* provides access to digitised historic newspapers through 196 and is frequently recommended as a starting point for classroom exploration of newspaper archives.

## 6.4 Smithsonian: Open access collections, datasets, and educator tooling

The Smithsonian's Open Access initiative has released millions of digital assets under CC0 licence, including collections metadata. This expands educational possibilities from viewing and remixing assets to computational reuse of structured records. The Smithsonian also provides a public data repository for open access metadata and supports discovery and reuse through channels such as GitHub.

For educators, the Smithsonian Learning Lab provides an educational environment that explicitly connects open access content with teaching and learning. The combination of open release and educator-facing tools offers a model for connecting collections-as-data infrastructures to classroom practice.

## 6.5 What these initiatives have in common: design patterns for educational reuse

All these examples come from big GLAM institutions or accumulated resources. One worth-noting aspect is that the initiative to connect digital heritage materials comes from the providers, and is not equally strong in the educational institutions. Although the initiatives above differ in scale and geography, they reveal recurring patterns that are useful for educators and institutions planning collections-as-data learning. First, they provide an on-ramp that is pedagogically familiar: curated classroom materials, learning scenarios, or themed sets that translate collections into teachable units. Second, several of them expose pathways to scale, such as APIs, bulk metadata downloads, or dataset repositories, enabling learners to move from item-level exploration to dataset-based inquiry. This is currently more suitable for higher education students, but may also be beneficial for advanced secondary school learners. Third, they invest in educator capacity through teacher-focused documentation and teachers' networks, recognising that sustainable educational reuse depends on the educators' confidence and time.

In this section we explored how several big GLAM institutions and projects are creating educational materials. In the next section we will explore how these developments influence the curriculum and teachers.

## 7. Implications for Curriculum and Teachers

### 7.1 Curriculum design

Integrating cultural heritage datasets effectively requires curriculum design that treats heritage not as an add-on but as a domain through which core competencies are developed. Educators can sequence tasks from simple to complex: starting with curated sets and basic descriptive analysis, moving toward student-defined questions, subset extraction, data cleaning, and visualisation. Interdisciplinary framing can make objectives transparent: computational techniques are used to answer questions anchored in cultural and historical meaning. Cultural heritage can fit nicely into project-based learning and is suitable for group work projects. Such projects can be developed within the blocks where teachers have the freedom of choice of the most suitable topic(s) and activities.

## 7.2 Teacher professional development

Teacher preparation is a central constraint and opportunity for integrating more cultural heritage materials in the classroom. The digital competences of teachers have been discussed for a considerable time, and with the quick shifts in technologies, it is one of the topics with constantly shifting priorities [12].

Collections-as-data pedagogy requires confidence with data workflows as well as familiarity with working responsibly with cultural materials. This for sure is not common knowledge among all teachers, but partnerships with GLAM professionals can strengthen teachers' domain knowledge and provide access to contextual documentation and support.

## 8. Conclusion

Despite growing practice, most often receiving a push from GLAM institutions, the evidence base for learning outcomes in collections-as-data education remains uneven. Future research can explore several aspects:

- (a) which competencies are most reliably developed through heritage datasets;
- (b) what scaffolding is needed for different age groups;
- (c) how interdisciplinary collaboration affects learning; and
- (d) how tools designed to support educators influence learning outcomes.

Methodologically, mixed approaches are likely to be most informative, combining analysis of learner artefacts (datasets, visualisations) with observation and reflection, skills much needed for the current generation, which is prone to many technological distractors.

The educational role of digitised cultural heritage has evolved from resource supplementation toward inquiry-based learning and, increasingly, toward computationally enabled analysis. This shift is visible in higher education. The collections-as-data paradigm supports this trend by enabling learners to treat cultural heritage as a domain for data experimentation, aligned with modern curriculum priorities such as computational thinking, data and AI literacy.

Initiatives such as Europeana's education ecosystem, DPLA's primary source and API resources, the Library of Congress's teacher programmes and dataset guidance, and the Smithsonian's open access releases demonstrate that educational reuse can be supported at scale when open collections are complemented by educator-facing materials and infrastructure. To realise the full potential of collections as data, educators and cultural heritage institutions should co-design learning pathways that connect meaning-rich heritage contexts to data-centred methods.

Integrating collections as data into education also raises a practical question: how should learning be evaluated when outputs combine technical work, interpretive reasoning, and communication? Conventional assessment in computing often gives advantage to functional correctness of code, while humanities assessment often recognises argumentation and use of sources. Collections-as-data learning requires assessment approaches that combine both.

## **Implications for GLAM-Education Partnerships and Green Considerations**

Collections-as-data, for the time being, heavily depends on the initiative of GLAMs. While educators can use openly published resources independently, deeper learning designs often require clarity about the licensing of data, documentation of fields, and robust access mechanisms. Multiple downloads of identical datasets from the same educational institutions is an aspect which may have a negative green impact – the educational planning is essential, also as it should avoid unnecessary loads and repeated downloads.

### **Lowering the adoption threshold**

Europeana’s educator-facing resources and classroom scenarios exemplify how curated materials can lower adoption barriers for teachers. Similarly, the Library of Congress positions its classroom materials as ready-to-use, created by teachers for teachers. These approaches recognise that classroom time and teacher capacity are limited, and that high-quality documentation is a requirement for educational reuse.

### **Usefulness of cultural heritage materials in introducing FAIR principles**

The educational use of cultural heritage datasets is also offering an opportunity to explore what FAIR (findable, accessible, interoperable and reusable) datasets mean in real-life practice. Datasets can also introduce the importance of personal data and GDPR basics in a more natural manner than pure theoretical one.

### **Future work**

This paper outlined some new trends and opportunities to use cultural heritage datasets in ICT education. For the time being, there is a strong push from larger GLAM institutions to offer pathways into education. As we explored, the use of cultural heritage datasets in education can support diverse skills, from technical ones in cleaning, analysing and visualising data as a precursor to data science, to greater skills for a transition from single source analysis to complex reasoning involving multiple objects.

Future research must move beyond exploratory pilots and focus on systematic empirical evaluation. In particular, there is a need for longitudinal classroom studies that measure the impact of heritage datasets on computational thinking, data literacy, and algorithmic reasoning using validated assessment frameworks. Comparative studies examining heritage datasets versus generic educational datasets would clarify whether cultural context adds measurable cognitive or motivational benefits.

Further work is also required on pedagogical design. This includes creating age-appropriate dataset packages, metadata simplification strategies, and reusable task templates aligned with national ICT curricula.

Another possible direction concerns the integration of cultural heritage datasets into emerging AI literacy initiatives. Heritage collections offer complex, heterogeneous, and often biased datasets that can support critical reflection on data provenance, representation, and algorithmic injustice. Finally, sustainable implementation depends on professional development ecosystems. Partnerships between GLAM institutions, teacher training programmes, and ICT curriculum designers are essential to ensure that learning is useful and enjoyable.

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