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Makhliyokhon Turdikhujaeva[1]
Tashkent State University of Oriental Studies
Iso Khudaynazarov[1]
Tashkent State University of Oriental Studies
Jurabek Begaliev
Kimyo International University in Tashkent
Nilufar Nazarova
Tashkent State Transport University
Rustam Mamajonov[1]
Tashkent State University of Oriental Studies
Anvar Shosaidov
anvarshosaidov@proton.me
Tashkent State University of Oriental Studies

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Makhliyokhon Turdikhujaeva[1], Iso Khudaynazarov[2], Jurabek Begaliev[3], Nilufar Nazarova[4], Rustam Mamajonov[1], Anvar Shosaidov[1]*

1 Tashkent State University of Oriental Studies, Department of History of the Peoples of Central Asia, Tashkent, Uzbekistan.

2 Tashkent State University of Oriental Studies, Department of the Peoples of Central Asia, Tashkent, Uzbekistan

3 Kimyo International University in Tashkent, Department of Social Sciences and Humanities, Samarkand Branch, Samarkand, Uzbekistan.

4 Tashkent State Transport University, 100167 Tashkent, Uzbekistan.

* Corresponding author: Anvar Shosaidov; anvarshosaidov@proton.me

Author e-mails in author order: turdixujayevamakhliyoe@gmail.com; issakbey83s@gmail.com; j.begaliyevd@kiut.uz; nazarovanilufar79v@gmail.com; tafrun19911@gmail.com; anvarshosaidov@proton.me.

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Abstract

Craft history is difficult to teach from text alone, and the Turkestan Album of 1871 to 1872 offers a large photographic resource that has rarely been examined for craft content in a structured way. This study assembled 900 de-duplicated plates from the open digital copies of the album, coded each plate for 11 craft domains and 6 depiction modes with explicit rules, and converted the results into a source-based framework for teaching the craft history of Uzbekistan. Craft was salient in 384 plates (42.7%). Architectural ceramics and ornament (27.7% of the corpus) and calligraphy and inscription (14.4%) were the leading domains, and 97.1% of the 279 craft-salient plates located in Uzbekistan were attributed to Samarkand. The 48 plates that show a craft process or tool carried no plate-specific commentary, whereas 281 of 281 monumental plates carried it (95% interval 98.7% to 100%). Agreement between text rules and cataloguer headings reached Cohen's κ of 0.74 for ceramics and ornament, 0.81 for inscription and 1.00 for guild customs. A teaching suitability index that combines documentation, domain breadth and place confidence gave a median of 0.70 for archaeological plates and 0.13 for ethnographic and trades plates. A greedy selection of 16 plates covered 21 domain-by-depiction cells, whereas random selection of 16 plates covered 27.1% of them. The framework organises 5 stages (locate, describe, contextualise, trace, transfer) into 6 teaching units and identifies where teachers need to supply context that the catalogue does not provide.

Keywords: Turkestan Album; craft history; source-based learning; heritage education; Uzbekistan; Sustainable Development Goal 4

1. Introduction

1.1 Background and motivation

Quality education, which is Sustainable Development Goal 4, depends on teaching materials that connect learners with the places and practices around them. Quantitative work on the indicators of this goal has applied exploratory analysis and association rule mining and has shown that the indicators are associated with each other (Saini et al. 2023). Heritage has been proposed as a vehicle for such connections. An outdoor orientation task on medieval Madrid, built for future teachers and enriched with gamification, was designed to show them the ways in which their own students can come to value heritage, and its authors tied the task to the goals of quality education and sustainable cities (Gómez-Ruiz et al. 2021). A questionnaire survey of 392 respondents from the Melaka World Heritage site examined attitudes, cultural awareness and participation in living heritage conservation within a community-based education model, and a positive relationship appeared between the perceived importance of living heritage and the level of participation (Abdul Aziz et al. 2023). These studies treat heritage as a resource for quality education, and they rely on questionnaires, observation and interviews to describe the reception of heritage by learners and communities. Craft heritage has attracted particular interest since it combines material, procedural and social dimensions. Case studies of costume culture and traditional embroidery in universities, supported by a questionnaire that produced 26 indicators in 6 dimensions, positioned heritage education as a participatory activity (Yan and Li 2023). A grounded-theory analysis of expert interviews on lacquerware framed craft education through cognitive, affective and skill objectives (Hung et al. 2021). Co-design workshops with 60 students aged 17 to 20 on Madeira Island showed that teenagers associate crafts such as embroidery and wickerwork with identity and belonging, and that their proposals for preserving crafts relied on gamification, social media and storytelling (Cesário 2025). The transmission of crafts from masters to apprentices has been modelled with replicator dynamics, in which the payoffs of both parties shape the probability of successful inheritance (Sun et al. 2021). Action research with 160 student teachers across 3 academic years indicated that intangible heritage can be reconsidered as an educational resource for critical citizenship, although traditional habits of heritage teaching persisted (Pérez-Guilarte and García-Morís 2023).

The craft history of the territory that is now Uzbekistan is long. Micromorphological and proteomic analyses of 3 cocoons from the Sapalli Tepe site identified Bombyx mori and dated the cocoons directly to 1940 to 1765 cal. before the common era, which indicates sericulture in the Oxus region much earlier than previously established (Zhou et al. 2026). Architectural ornament offers a later case: an analysis of the Sayfiddin Boharziy Complex, the Bayonqulixon Mausoleum and the Ulugh Beg Madrasa in Bukhara traced a progression from restrained brick construction to dense glazed decoration, supported by field observation and photographic documentation (Shukurova et al. 2026). Raman analysis of glazed shards from Anatolia, the Caucasus, Iran and Central Asia, dated between the 12th and 19th centuries, distinguished 3 types of glaze by the nanostructure of the silicate network (Colomban and Simsek Franci 2023). Such findings show that the territory offers learners craft histories that extend from early sericulture to Timurid glazing, and that these histories can be examined through materials, techniques and decoration. Visual sources of the 19th century can carry such histories into the classroom. The Turkestan Album was compiled in 1871 to 1872 under General Konstantin von Kaufman, and the catalogue entries of its digital copies describe a multi-volume album that is organised in parts and contains photographs, architectural plans, drawings and maps. A study of the photograph collections of the Museum of Anthropology and Ethnography that feature cotton production in Central Asia identified the Turkestan Album among the earliest sources depicting the pre-treatment steps of cotton processing, including boiling out, batting, scutching and spinning (Prischepova 2024). The album therefore contains images of crafts as well as of monuments and peoples. Classroom use, however, requires a prior decision on which plates show craft, of which kind, and with what documentation. That selection problem motivates the present study.

1.2 Literature review

Source-based teaching has been examined mainly in history classrooms. A quasi-experimental study with 300 students in 3 high schools evaluated the integration of primary sources into online history learning through Likert-scale surveys and focus group discussions, analysed with descriptive statistics, analysis of variance and the Kruskal-Wallis test, and its findings suggested gains in satisfaction, engagement and retention (Fahruddin and Saefudin 2025). A design study in Flemish history education developed a lesson series on decolonisation after 1945 for students in the 12th grade, applied the model of cognitive apprenticeship to historical thinking, and evaluated and revised the series in 2 rounds on the basis of a pilot study, an expert review and an intervention study (Wilke et al. 2023). A school intervention at the Roman Baths of Valduno with 16 students, based on educational ethnography, indicated that an open guided tour produced greater learning than a classroom explanation (I'Anson Gutiérrez et al. 2023). Digitised photograph collections raise a different set of questions. The FORBIN dataset, composed of 62,135 historical photographs with archival metadata, was assembled to support computational analysis of large and poorly curated photographic archives (Chelali et al. 2026). The analytical tools involved group photographs by semantic content or generate textual descriptions of them. A study of crowdsourcing at the Copenhagen City Archives showed that approximately 94% of the work of describing and placing images on a map was done by 7 of 2,433 participants, and that exploratory discussion took place in private forums outside the interface of the archive (Hansson and Dahlgren 2022). A parallel literature addresses the documentation of craft. Zabulis et al. (2022) proposed a method for representing craft processes as digital structures that are compatible with preservation standards and implemented it in an online platform in which craft records are authored collaboratively, shared and preserved in standardised formats. Hauser et al. (2022) attached semantic annotations to digital assets for Jacquard weaving at a former silk factory that is now a museum, allowing tangible and intangible dimensions to be presented through storytelling and mixed-reality exhibitions. An ontology for Phum Riang silk weaving, constructed from ethnographic fieldwork and interviews with craftspeople, comprised 23 classes, 15 object properties and 12 data properties across 5 domains: production processes, raw materials, traditional tools, geographical context and cultural significance (Molee et al.

2026). A mixed-method analysis of a collaborative embroidery project at a Danish museum of modern art, craft and design examined the way in which the project created a sense of community and cultivated creative agency (Sørensen and Eriksson 2022). Museums and digital media extend these approaches. Museums on the Silk Road, examined through interviews and direct observation, give educational issues particular weight since silk production is a local tradition at each site, and the Valencia Silk Museum was examined as a specific case (Huerta 2021). Virtual reality applications for digital cultural heritage have been evaluated with 3 key performance indicators that refer to the Revised Bloom's Taxonomy (Paolanti et al. 2023), and virtual reality content creation by 302 undergraduate students outperformed other traditional learning approaches in learning outcome achievement (Hu and Ng 2026).

1.3 Research gap

Current published work has focused primarily on the classroom use of primary sources in history, on the digitisation and crowdsourced description of photograph collections, and on the documentation of living craft practices through platforms, ontologies and museum programmes. These strands have generated valuable designs and measurements, and each addresses a different part of the task of teaching craft history from historical images. The interaction between them has received comparatively less attention. A photographic survey of the 19th century can serve as a source for craft history only if the plates that show craft can be identified, classified by the kind of craft and by the manner of depiction, and connected to the commentary that a teacher can use. The existing literature addresses the quality of image metadata at the level of collections, though the distribution of craft content within a single historical survey, and the documentation attached to each kind of depiction, warrant further quantitative characterisation. For Uzbekistan, a more detailed quantitative understanding of which crafts the Turkestan Album depicts, in which places, in which album parts and with which documentation would complement the existing body of work on heritage education. Such an understanding allows lesson designers to choose plates deliberately instead of by familiarity, and it offers an avenue for further insight into the planning of source-based sequences around the strengths and limits of a digitised catalogue.

1.4 Objectives and novelty

The novelty of this study lies in treating a digitised photographic survey as a quantified teaching source for craft history. A corpus of 900 de-duplicated plates is coded with explicit rules, the distribution of craft content and of documentation is measured with interval estimates, and the measurements are converted into a teaching suitability index, minimal plate sets and a source-based teaching sequence. The specific original contributions are as follows.

1. A reproducible corpus of 900 plates of the Turkestan Album, built from open catalogue records, with a coding scheme of 11 craft domains and 6 depiction modes that distinguishes craft processes, trade goods, craft objects and incidental presence.
2. A quantitative description of the distribution of craft content across album parts, present-day places and depiction modes, expressed through prevalence with 95% intervals, a representation index and a diversity index for each part.
3. A measurement of the documentation gap between plates of monumental ornament and plates of craft processes, which shows where plate-specific commentary exists and where a teacher needs to supply context.
4. A teaching suitability index and a greedy selection rule that return minimal plate sets covering every combination of craft domain and depiction mode, tested for stability under changes of weights and thresholds.

5. A 5-stage source-based teaching sequence applied to 6 teaching units, each tied to counted plates of the corpus and to the documentation available for them.

2. Methodology

2.1 Source material and corpus assembly

The source material was the open image repository that mirrors the digitised copies of the Turkestan Album held by the Library of Congress and the partners of the World Digital Library (WDL). Metadata were retrieved in October 2026 through the public programming interface of the repository, starting from the category of the album and descending through its 27 categories. The retrieval returned 1,463 file records, each with a title, a free-text description, the repository categories and, for English-titled records, a closing line of cataloguer subject headings. Volunteer uploads to this repository have been analysed at scale for photographs of built heritage (Azizifard et al. 2023), and interviews with contributors identified cultural heritage value among the value dimensions that they express (Yu and McDonald 2023). Descriptive metadata of this kind determine the discoverability and usability of a collection (Kaldeli et al. 2021), and the commentary available for each plate was therefore recorded as a variable. Records were reduced to unique plates in 3 steps. English-titled records carry a catalogue number with the prefix WDL; cropped derivatives and the 2 volume-level files were discarded, which left 848 plates. Records of the Library of Congress digitisation carry a Library of Congress Control Number and a transliterated Russian title. Of 567 such records, 518 belonged to series that correspond to an English-titled series and were excluded as alternative digitisations, and 49 belonged to series without an English counterpart (silk production, Kyrgyz crafts, baking, candle and soap making, wool products, carpentry, irrigation methods and a portrait of a general). A further 3 uploads that show cotton production and iron casting were retained, and the remaining 45 files were derivative, cropped, volume-level or portrait uploads. English glosses of the 49 transliterated titles were supplied by the authors (Online Resource 1). Plate-specific commentary was isolated by removing sentences that recurred in 8 or more descriptions, which stripped the album-level and monument-level passages repeated across plates, and its length was counted in words. The album part was read from the commentary where stated and otherwise assigned from the catalogue number, with numbers up to 3999 belonging to the Archaeological Part. The present-day country was read from the parenthetical country in the commentary and, when the parenthesis was absent, from a place-name dictionary applied to the title. The resulting workflow, and the teaching sequence derived from it, are summarised in Fig. 1.

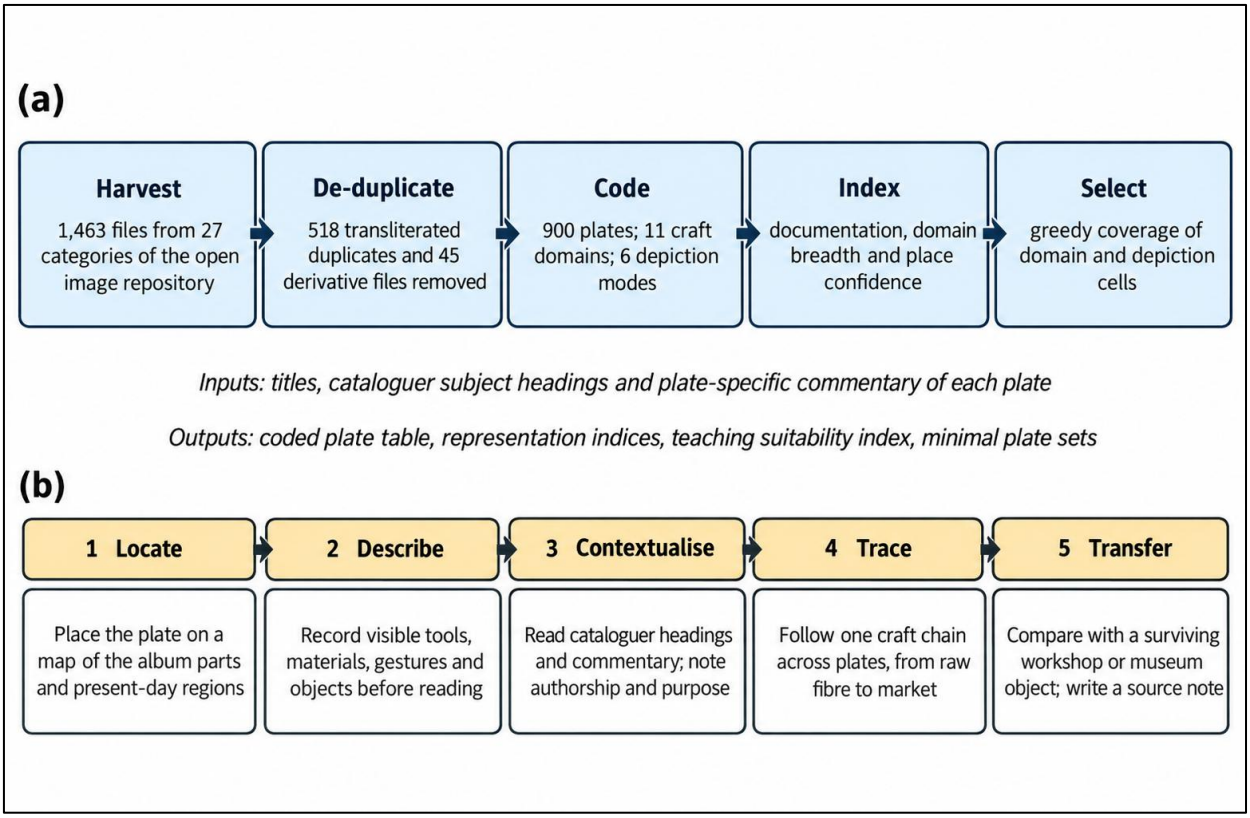


Fig. 1 Assembly and coding workflow for the plate corpus and the source-based teaching sequence derived from it; (a) corpus workflow from harvest to plate selection, (b) 5 stages of the teaching sequence

The workflow in Fig. 1(a) starts from 1,463 file records retrieved from 27 repository categories. Removal of 518 transliterated duplicates and 45 derivative, cropped, volume-level or portrait files leaves 900 plates, which are coded for 11 craft domains and 6 depiction modes. The coded table feeds an index that combines documentation, the number of craft domains shown and place confidence, and a greedy selection returns a minimal set of plates. The 2 italic lines in Fig. 1(a) name the inputs and the outputs. The sequence in Fig. 1(b) organises classroom work around 1 unit of 5 to 8 plates: learners locate the plate, describe visible tools, materials and gestures, read the cataloguer headings and commentary, trace 1 craft chain across consecutive plates, and compare the chain with a surviving workshop or museum object before writing a source note

2.2 Coding scheme and depiction modes

Craft content was coded in 11 domains, chosen to cover the craft categories that appear in the titles and subject headings of the corpus (Table 1). Multimodal content analysis of 148 ensembles of visual images, textual features and design elements in 2 history textbooks has examined the way in which these modes portray their subjects (Carmichael et al. 2026), and the present coding applies explicit rules to titles, headings and commentary in place of human coders for English-titled records.

Table 1 Craft domains, codes and cue terms applied to titles, cataloguer subject headings and plate-specific commentary

Code	Craft domain	Cue terms (stems)a
CER	Architectural ceramics and ornament	tile, ceramic, majolica, glaze, mosaic, ornament, polychrome, stucco, brickwork, decoration
CAL	Calligraphy, inscription and book arts	inscription, calligraphy, bookbinder, Koran stand, handwriting, script

Code	Craft domain	Cue terms (stems)a
MET	Metalwork and cast ware	cast-iron, cauldron, candlestick, bronze, knife, copper, brass, smithy, engraved
TXT	Textile and fibre production and trade	cotton, silk, fabric, carpet, rug, felt, wool, yarn, embroidery, mat, rope, weaving
DRS	Dress, headwear and adornment	clothing, dress, robe, turban, hat, headgear, shirt, jewellery, bead, braids
LEA	Leather, saddlery and footwear	saddle, leather, boot, cobbler, hide, trunk, harness
WOD	Woodwork, mats and containers	wood, wooden, carpentry, palanquin, mat, trunk, cradle
MUS	Musical instruments	instrument, dutar, rubab, nagara, surnay, karnay, kamancha, dayra, lute, drum
PRO	Food and household processing trades	baking, soap, candle, mill, perfumery, incense, dyeing
BLD	Building construction	construction, under construction, caravansarai
GLD	Guild and craft customs	guild, craft customs, apprentice, craftsman, artisan

Each plate was assessed with 3 cue sources, namely the words of the title, the cataloguer subject headings and the plate-specific commentary. A domain was assigned when a cue appeared in the title or in a heading, or when 3 distinct cues appeared in the commentary. The indicator for plate i and domain d is expressed as:

$$f_{id} = \min\left\{1, t_{id} + h_{id} + \left\lfloor \frac{n_{id}}{3} \right\rfloor\right\}$$

where f_{id} is the binary domain indicator, t_{id} and h_{id} are binary indicators of a cue in the title and in the subject headings, n_{id} is the number of distinct cue terms in the commentary, and the brackets denote rounding down to the nearest integer.

Each plate received 1 of 6 depiction modes: process shown, tool shown, goods in trade, craft object or ornament, incidental presence and none. Process and tool modes applied when the title named a maker, workshop, guild or implement; goods in trade applied when a vendor or stall offered a craft product; craft object or ornament applied when an artefact, ornament, inscription or instrument was the principal subject; and incidental presence applied when a domain was flagged without being the subject. The 4 craft modes define a craft-salient plate, with process and tool combined as 1 group in the results. Transliterated plates received domains and modes from the glosses.

2.3 Representation and diversity indices

The prevalence of a domain was the number of craft-salient plates that show the domain divided by the 900 plates of the corpus, with a 95% Wilson score interval. The representation of a domain in an album part was compared with its representation in the craft-salient corpus, and values greater than 1 indicate greater than expected representation. The representation index is defined as:

$$Q_{dp} = \frac{\frac{n_{dp}}{n_p}}{\frac{n_d}{N_s}}$$

where Q_{dp} is the representation index of domain d in album part p, n_{dp} is the number of craft-salient plates of part p that show domain d, n_p is the number of craft-salient plates of part p, n_d is the number of craft-salient plates that show domain d, and N_s is the number of craft-salient plates in the corpus.

Diversity complements the representation index by describing the range of crafts that a part presents. The Shannon index is 0 when a single domain is present and increases as plates spread evenly across domains. It is given by:

$$H_p = -\sum_{d=1}^{D} q_{dp} \ln q_{dp}$$

where Hp is the Shannon index of album part p, D is the number of domains (11), and qdp is the proportion of the domain counts of part p that belong to domain d. Located craft-salient plates were cross-classified by country and by primary domain (ornament, inscription or other crafts), and the association was summarised by the chi-square statistic $\chi 2$ and Cramér's V.

2.4 Reliability and sensitivity

Agreement between the text rules and the cataloguer subject headings was quantified for the 7 domains that have a counterpart heading. The rules were restricted to titles and commentary to keep the 2 sources independent. The statistic corrects the proportion of agreement for agreement expected by chance. It is described by:

$$\kappa = \frac{P_{\mathrm{o}} - P_{\mathrm{e}}}{1 - P_{\mathrm{e}}}$$

where κ is Cohen's coefficient, P_{o} is the measured proportion of plates on which the 2 sources agree, and P_{e} is the proportion of agreement expected by chance, calculated from the marginal proportions of the 2 sources. The Jaccard index of the 2 sets of flagged plates was calculated in addition. Sensitivity of the domain counts was tested by changing the number of distinct commentary cues from 3 to 2, 4 and 5, and rank stability of the teaching index was summarised with the Spearman rank correlation coefficient ρ.

2.5 Teaching suitability index and plate selection

Interpretive richness expresses the amount of plate-specific commentary that a teacher can draw on. Commentary length was scaled by the 95th percentile of the English-titled catalogue to limit the influence of extreme values. The richness of plate *i* takes the form:

$$R_i = \min\left\{1, \frac{w_i}{w_{95}}\right\}$$

where R_i is the richness of plate *i*, w_i is the number of words of plate-specific commentary, and w_{95} is the 95th percentile of commentary length in the English-titled catalogue (206 words).

The teaching suitability index combines documentation, domain breadth and place confidence for each craft-salient plate. Documentation enters through richness, breadth through the number of craft domains shown, and place confidence through a weight assigned from the attribution. The index is written as:

$$T_i = g_i \left[\alpha \frac{c_i}{c_{\max}} + (1 - \alpha) R_i\right]$$

where T_i is the index of plate *i*, g_i is the place weight (1 for plates located in Uzbekistan, 0.5 for plates without a place name and 0 for plates located elsewhere), c_i is the number of craft domains shown by plate *i* excluding dress, $c_{\max}$ is the largest such number in the corpus (2), and α is the weight of domain breadth (0.50 in the base case, with 0.25 and 0.75 tested).

Plates were selected in order that the chosen set covers the largest number of domain-by-depiction cells. A cell is a pair of a craft domain, excluding dress, and a depiction mode that occurs

among craft-salient plates located in Uzbekistan or without a place name. The coverage of a selected set is derived as:

$$K(S) = \frac{|\bigcup_{i \in S} U_i|}{|U|}$$

where $K(S)$ is the coverage of the selected set S, U_i is the set of cells shown by plate i, and U is the set of 21 cells that occur in the eligible plates. At each step the plate that added the largest number of uncovered cells was chosen, with ties resolved in favour of the higher index. Random selection was simulated with 500 permutations of the 366 eligible plates, and computations used Python 3.13. A large language model (Claude, Anthropic) assisted with drafting the text, writing the analysis code and assembling the reference records, and the authors remain accountable for the final content.

3. Results and discussion

3.1 Corpus composition and geographical attribution

The corpus comprised 900 plates (Fig. 2(a)): 362 from the Archaeological Part, 486 from the Ethnographic Part and 52 from the Trades Part, the last assembled from 49 transliterated records and 3 other uploads. A present-day place was available for 538 plates (59.8%). Of these, 453 were located in Uzbekistan, 59 in Kazakhstan and 26 in Tajikistan, while 362 plates carried no place name (Fig. 2(b)). Within Uzbekistan, Samarkand accounted for 372 plates, followed by Tashkent with 31 and the Kokand valley with 19 (Fig. 2(c)). The concentration reflects the focus of the Archaeological Part on the monuments of Samarkand, which supplied 328 of the 453 plates located in Uzbekistan. A teaching resource built from the album therefore inherits a geographical imbalance that has to be addressed in the design of lessons rather than in the choice of individual plates.

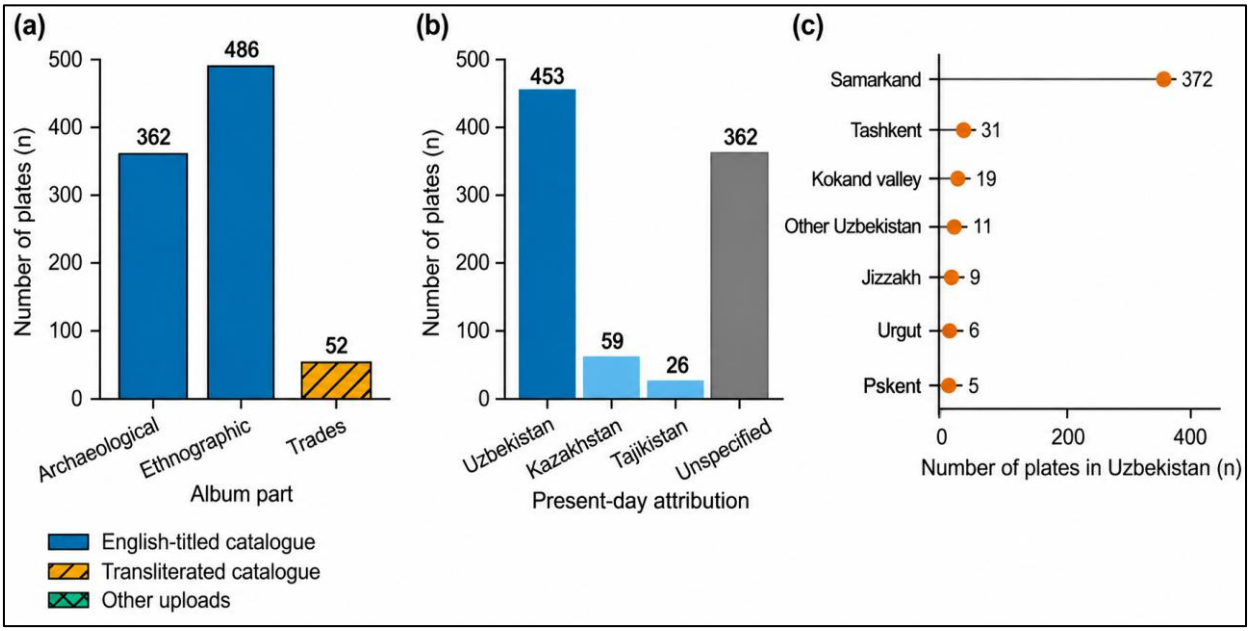


Fig. 2 Composition and geographical attribution of the de-duplicated plate corpus; (a) plates by album part and catalogue stream, (b) plates by present-day attribution, (c) plates by locality within Uzbekistan

The 900 plates are divided in Fig. 2(a) into 362 archaeological and 486 ethnographic plates from the English-titled catalogue and 52 trades plates, of which 49 come from the transliterated catalogue and 3 from other uploads; hatching distinguishes the catalogue streams. Place attribution in Fig. 2(b) covers 59.8% of the corpus, with 453 plates in Uzbekistan, 59 in Kazakhstan and 26 in Tajikistan, and 362 plates without a place. Fig. 2(c) shows the concentration within Uzbekistan, with 372 plates for

Samarkand, 31 for Tashkent, 19 for the Kokand valley, 11 for other localities, 9 for Jizzakh, 6 for Urgut and 5 for Pskent, and each dot gives the plate count of 1 locality. Samarkand holds 82.1% of the plates located in Uzbekistan The composition by album part, with place attribution and documentation, is given in Table 2. The Archaeological Part held 328 plates located in Uzbekistan, 24 in Kazakhstan and 4 in Tajikistan, and its 362 plates carried plate-specific commentary. The Ethnographic Part, with 486 plates, held 125 plates located in Uzbekistan and 304 without a place name, since portraits are attributed to peoples rather than to places, and only 2 of its plates carried commentary. The Trades Part carried no place name and no commentary in any of its 52 plates, and 48 of them were craft-salient.

Table 2 Composition of the corpus by album part, present-day attribution and documentation

Album part	Plates (n)	Uzbekistan (n)	Kazakhstan (n)	Tajikistan (n)	No place (n)	With commentary (n)	Craft-salient (n)	Subject headings (mean n)
Archaeological	362	328	24	4	6	362	281	5.4
Ethnographic	486	125	35	22	304	2	55	7.0
Trades	52	0	0	0	52	0	48	not recorded
Corpus	900	453	59	26	362	364	384	not applicable

3.2 Craft domains and depiction modes

Craft was salient in 384 plates, which is 42.7% of the corpus (95% Wilson interval 39.5% to 45.9%). Architectural ceramics and ornament accounted for 249 plates (27.7%), calligraphy and inscription for 130 (14.4%), textile and fibre production and trade for 33 (3.7%) and musical instruments for 23 (2.6%) (Fig. 3(a)). The depiction mode differed between domains. Textile plates were dominated by process and tool depictions (24 of 33), whereas the ornament domain consisted of craft objects (249 of 249) and the inscription domain consisted of craft objects with 1 exception (129 of 130). Dress and adornment was flagged in 133 plates but was salient in 7, since 126 plates depicted dress only incidentally (Fig. 3(b)). The Shannon index of the 11 domain counts was 1.53, relative to a maximum of 2.40, which shows an uneven distribution produced by the 2 leading domains.

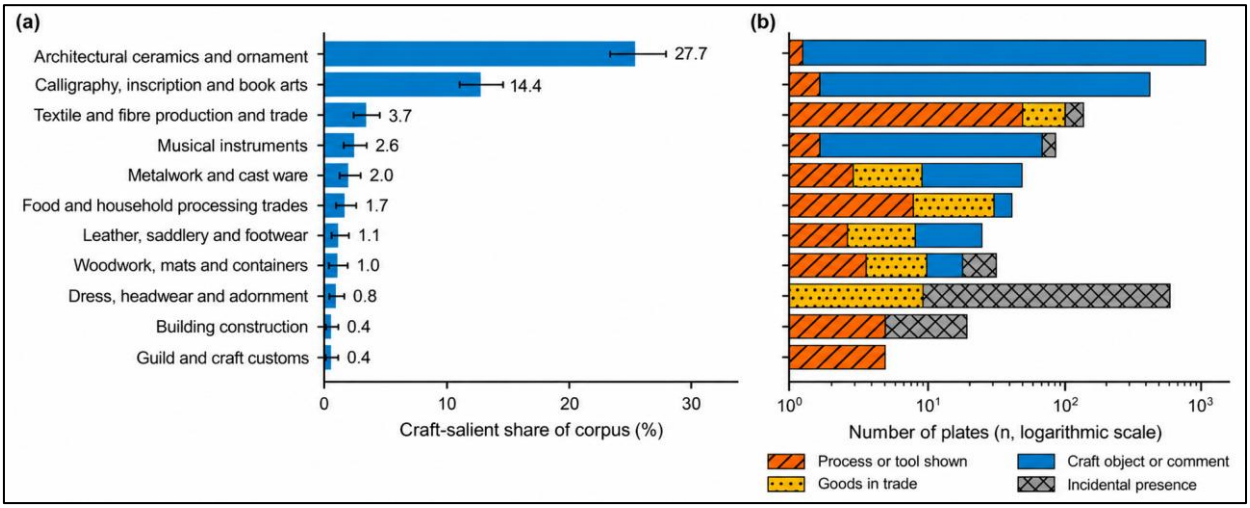


Fig. 3 Craft domains and depiction modes among the 900 plates; (a) craft-salient share of the corpus with 95% Wilson intervals, (b) composition of each domain by depiction mode

The craft-salient share in Fig. 3(a) is 27.7% for architectural ceramics and ornament (interval 24.8% to 30.7%) and 14.4% for calligraphy and inscription (12.3% to 16.9%), followed by textile and fibre production and trade at 3.7%, musical instruments at 2.6%, metalwork at 2.0% and food and household processing trades at 1.7%. The remaining 5 domains each contribute 1.1% or less, and the error bars show 95% Wilson intervals. Fig. 3(b) divides the plates of each domain into 4 depiction categories on a logarithmic count scale, distinguished by hatching. Ornament and inscription consist of craft objects with 1 exception, guild customs consist of 4 process plates, and dress is dominated by 126 plates of incidental presence

The counts and intervals that underlie the domain shares are given in Table 3. Architectural ceramics and ornament reached 249 craft-salient plates with an interval of 24.8% to 30.7%, calligraphy and inscription 130 plates with 12.3% to 16.9%, and textile and fibre production and trade 33 plates with 2.6% to 5.1%. The 24 process or tool plates in the textile domain and the 7 in food and household processing trades form the core of any lesson on production chains.

Table 3 Craft-salient plates by domain with prevalence, 95% Wilson intervals and depiction mode

Code	Craft domain	Craft-salient plates (n)	Share of corpus (%)	Lower limit (%)	Upper limit (%)	Process or tool (n)	Goods in trade (n)	Object or ornament (n)	Incidental (n)[a]
CER	Architectural ceramics and ornament	249	27.7	24.8	30.7	0	0	249	4
CAL	Calligraphy, inscription and book arts	130	14.4	12.3	16.9	1	0	129	2
TXT	Textile and fibre production and trade	33	3.7	2.6	5.1	24	9	0	5
MUS	Musical instruments	23	2.6	1.7	3.8	1	0	22	4
MET	Metalwork and cast ware	18	2.0	1.3	3.1	3	2	13	0
PRO	Food and household processing trades	15	1.7	1.0	2.7	7	8	0	1
LEA	Leather, saddlery and footwear	10	1.1	0.6	2.0	2	4	4	0
WOD	Woodwork, mats and containers	9	1.0	0.5	1.9	4	3	2	2
DRS	Dress, headwear and adornment	7	0.8	0.4	1.6	0	7	0	126
BLD	Building construction	4	0.4	0.2	1.1	4	0	0	5
GLD	Guild and craft customs	4	0.4	0.2	1.1	4	0	0	0

3.3 Distribution of craft across the album parts

The album parts differ sharply in the craft they present. In the Archaeological Part, 249 of the 281 craft-salient plates showed architectural ceramics and ornament and 129 showed calligraphy and inscription (Fig. 4(a)). Representation indices express the same pattern relative to expectation (Fig. 4(b)). Ceramics and ornament reached 1.37 and inscription 1.36 in the Archaeological Part, textile 6.54, food and household processing 6.93 and woodwork 4.44 in the Trades Part, and dress, musical instruments and guild customs 6.98 each and leather 6.28 in the Ethnographic Part. The Shannon index of the domain

counts was 0.79 for the Archaeological Part, 1.89 for the Ethnographic Part and 1.24 for the Trades Part, which shows that the part with the largest number of plates presents the narrowest range of crafts. Among the 297 located craft-salient plates, crafts other than ornament and inscription numbered 16 in Uzbekistan and 14 in Kazakhstan, although Uzbekistan supplied 279 of the 297 plates; the association between country and domain group had a χ^2 of 104.65 with 4 degrees of freedom and a Cramér's V of 0.42. Each album part was compiled for a distinct purpose, namely the survey of monuments, the portrayal of peoples and everyday life, and the description of production, and the purpose of a part determines which crafts enter its plates.

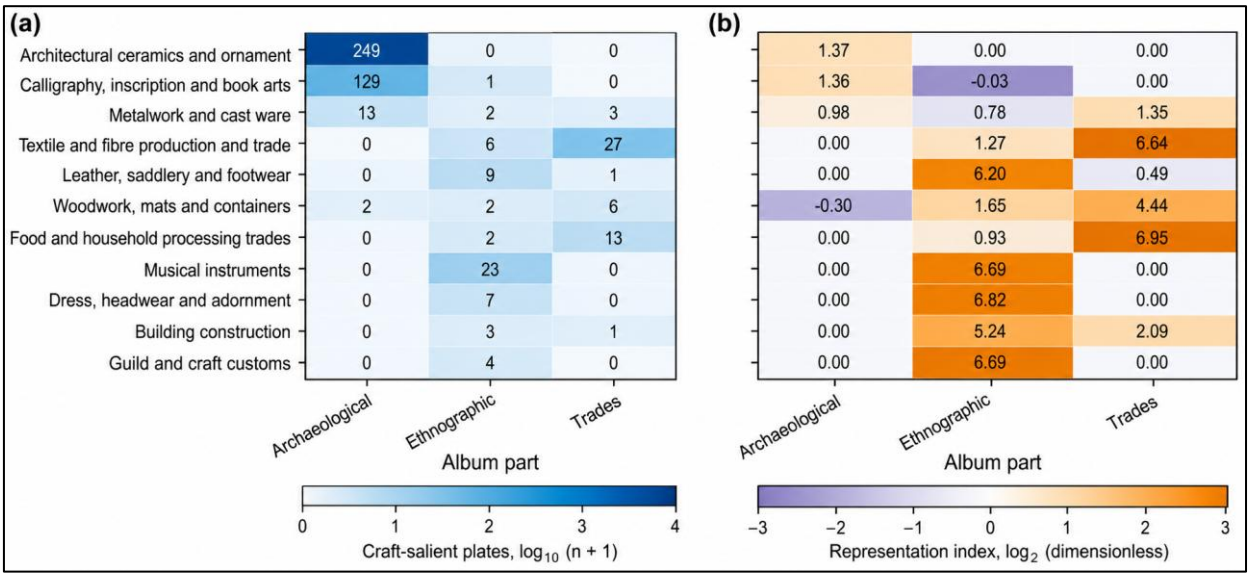


Fig. 4 Distribution and representation of craft domains across the 3 album parts; (a) craft-salient plates, (b) representation index

The craft-salient plates of each domain are counted for each album part in Fig. 4(a) on a logarithmic scale. The Archaeological Part contains 249 plates of architectural ceramics and ornament, 129 of calligraphy and inscription and 13 of metalwork; the Trades Part contains 27 plates of textile and fibre production, 13 of food and household processing and 5 of woodwork; the Ethnographic Part contains 23 plates of musical instruments, 9 of leather and saddlery and 7 of dress and adornment. The representation index in Fig. 4(b) normalises these counts by the size of each part and the prevalence of each domain, with values of 1.37 and 1.36 for ornament and inscription in the Archaeological Part and between 4 and 7 for domains confined to the Ethnographic and Trades Parts. Cells without plates show 0.00

3.4 Documentation of plates

Plate-specific commentary was present for the 362 archaeological plates, with a median of 171 words and an interquartile range of 140 to 194 words, but for only 2 of the 486 ethnographic plates, each with 90 words (Fig. 5(a)). By depiction group, commentary was present for 281 of 281 monumental plates (95% interval 98.7% to 100%), 0 of 48 process or tool plates (0% to 7.4%) and 0 of 29 trade plates (0% to 11.7%) (Fig. 5(b)). Cataloguer subject headings were assigned irrespective of commentary: ethnographic plates carried a mean of 7.0 headings and archaeological plates 5.4, which produced a negative rank correlation of -0.41 between commentary length and heading count (Fig. 5(c)). Sparse image metadata act as a barrier to keyword searching of photograph archives (Late et al. 2024), and the same mechanism applies to the process plates, which can be located only through the words of their titles.

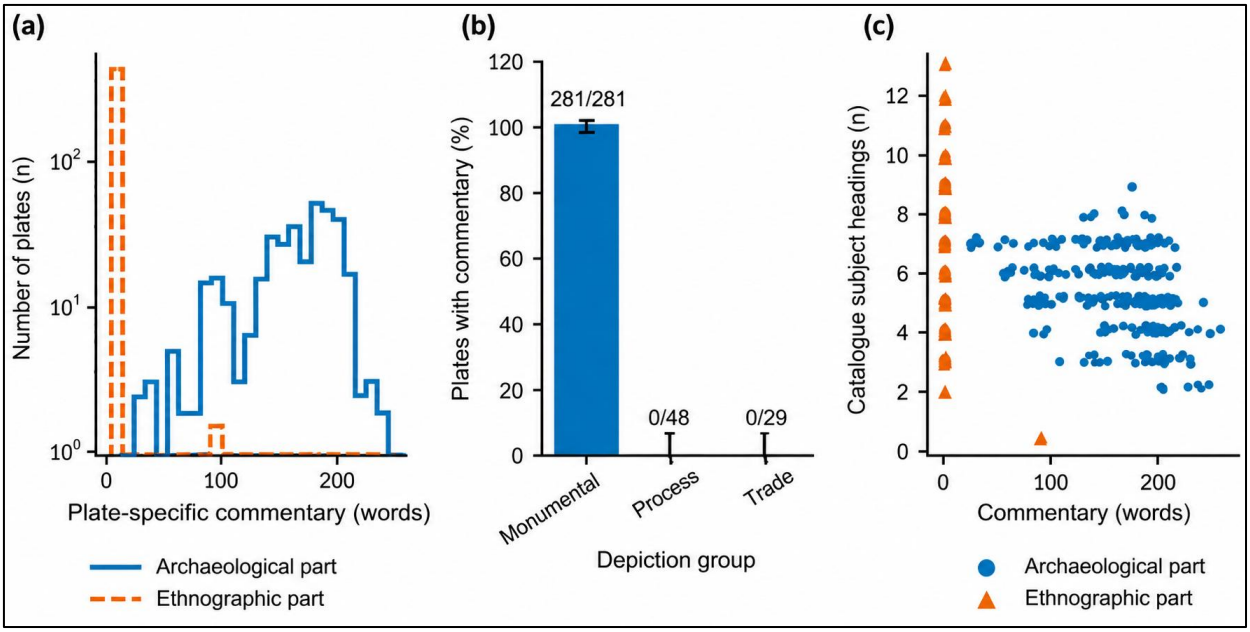


Fig. 5 Plate-specific commentary and cataloguer subject headings as a function of album part and depiction group; (a) distribution of commentary length, (b) share of plates with commentary, (c) relation between commentary length and subject headings

The English-titled plates fall into 2 separate groups in Fig. 5(a), on a logarithmic count scale: archaeological plates have a median of 171 words and a maximum of 261 words, whereas ethnographic plates are concentrated at 0 words, with 2 plates at 90 words. In Fig. 5(b), commentary is present for 100% of monumental plates (interval 98.7% to 100%) and for 0% of the 48 process or tool plates and the 29 trade plates, with upper limits of 7.4% and 11.7%; the error bars show 95% Wilson intervals. Fig. 5(c) relates commentary length to the number of cataloguer subject headings, with archaeological plates (circles) carrying 2 to 9 headings and ethnographic plates (triangles) up to 13 headings and no commentary, which gives a rank correlation of -0.41 The documentation of each depiction group is quantified in Table 4. Monumental ornament and inscription plates numbered 281, each with commentary and a median of 161 words (interquartile range 127 to 186). The 48 process or tool plates and the 29 trade plates had no commentary, and the 143 plates of incidental presence had commentary in 1 case (interval 0.1% to 3.9%). The groups that carry the greatest weight in lessons on craft processes are therefore the least described.

Table 4 Plate-specific commentary by depiction group

Depiction group	Plates (n)	With commentary (n)	With commentary (%)	Lower limit (%)	Upper limit (%)	Median commentary (words)	Interquartile range (words)
Monumental ornament and inscription	281	281	100.0	98.7	100.0	161	127 to 186
Process or tool shown	48	0	0.0	0.0	7.4	0	0 to 0
Goods in trade	29	0	0.0	0.0	11.7	0	0 to 0
Incidental presence	143	1	0.7	0.1	3.9	0	0 to 0
Ethnographic craft objects	26	2	7.7	2.1	24.1	0	0 to 0

3.5 Reliability of the coding rules

Agreement between the text rules and the cataloguer headings was high for 5 of the 7 domains with a counterpart heading (Fig. 6(a)). Cohen's κ was 0.74 for ceramics and ornament, 0.81 for inscription, 0.79 for musical instruments, 0.80 for leather and 1.00 for guild customs. Textile reached

0.53, but on only 7 plates with a heading, and dress reached 0.19. The low value for dress reflects a difference of definition: cataloguers assigned clothing headings to 132 portrait plates, whereas the text rules flagged 17 plates whose titles or commentary named garments. This difference is the reason why dress was treated as incidental unless goods in trade were depicted. Sensitivity of the domain counts was confined to the 2 large domains (Fig. 6(b)). Raising the commentary threshold from 3 to 5 distinct cues reduced ornament from 253 to 211 plates (a change of -16.6%) and inscription from 132 to 130 plates (-1.5%), and lowering it to 2 cues raised them to 273 plates (+7.9%) and 153 plates (+15.9%). Metalwork, leather, woodwork and guild customs were unchanged across the 4 thresholds, since their plates carried the cues in titles or headings.

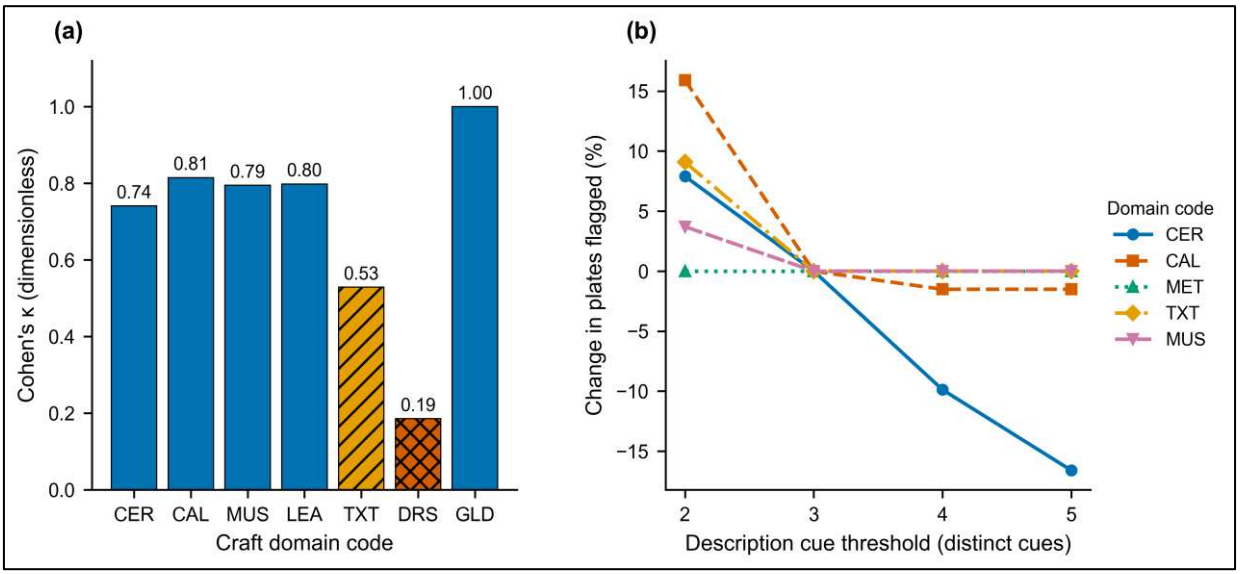


Fig. 6 Agreement between text rules and cataloguer headings and sensitivity of domain counts to the commentary-cue threshold; (a) Cohen's κ, (b) change in plates flagged

Cohen's κ in Fig. 6(a) is 0.74 for architectural ceramics and ornament, 0.81 for calligraphy and inscription, 0.79 for musical instruments, 0.80 for leather and saddlery and 1.00 for guild customs on 4 plates, which is the range of high agreement. Textile reaches 0.53 on a base of 7 plates with a heading, and dress reaches 0.19 since the headings were assigned to 132 portraits while the text rules flagged 17 plates; hatching distinguishes values under 0.60 and under 0.40. Fig. 6(b) shows the change in the number of plates flagged when the number of distinct commentary cues is varied from 2 to 5, relative to the base value of 3: calligraphy and inscription change by +15.9% at 2 cues and by -1.5% at 4 and 5 cues, ornament by +7.9%, -9.9% and -16.6% at 2, 4 and 5 cues, and metalwork is unchanged. Each domain has its own symbol and line style. The agreement counts are given in Table 5. For ceramics and ornament, 203 plates carried a cataloguer heading and 226 were flagged by the text rules, with 173 plates in common and a Jaccard index of 0.68. The text rules flagged more plates than the headings in 4 of the 7 domains, since commentary mentions ornament and inscription in monuments whose headings are assigned at the level of the monument.

Table 5 Agreement between text rules and cataloguer subject headings for the English-titled plates

Code	Craft domain	Plates with heading (n)	Plates flagged by text (n)	Shared plates (n)	Cohen's κ	Jaccard index
CER	Architectural ceramics and ornament	203	226	173	0.74	0.68

Code	Craft domain	Plates with heading (n)	Plates flagged by text (n)	Shared plates (n)	Cohen's κ	Jaccard index
CAL	Calligraphy, inscription and book arts	104	120	94	0.81	0.72
MUS	Musical instruments	25	20	18	0.79	0.67
LEA	Leather, saddlery and footwear	7	8	6	0.80	0.67
TXT	Textile and fibre production and trade	7	8	4	0.53	0.36
DRS	Dress, headwear and adornment	132	17	16	0.19	0.12
GLD	Guild and craft customs	4	4	4	1.00	1.00

3.6 Teaching suitability and minimal plate sets

Across the 384 craft-salient plates, the teaching suitability index had a median of 0.64, and 248 plates reached at least 0.50, each of them located in Uzbekistan (Fig. 7(a)). The median was 0.70 for archaeological plates and 0.13 for ethnographic and trades plates. Values in the upper group follow interpretive richness, and the lower group clusters at 0.13 to 0.25 where commentary is absent (Fig. 7(b)). In total, 24 plates had an index of 0 (17 in Kazakhstan, 4 in Uzbekistan, 2 without a place name and 1 in Tajikistan), owing either to a place weight of 0 or to dress being the only craft domain shown. The ranking was stable under changes of the weights: ρ was 0.92 between α of 0.25 and 0.50, 0.99 between 0.50 and 0.75, and 0.88 between 0.25 and 0.75 (Fig. 7(c)), and a change of the place weight for plates without a place name from 0.5 to 0.25 left the ranking unchanged (ρ of 1.00). The index measures the readiness of a source for classroom use and not the learning that results from it, and its low values for process plates identify the plates for which a teacher needs to prepare context.

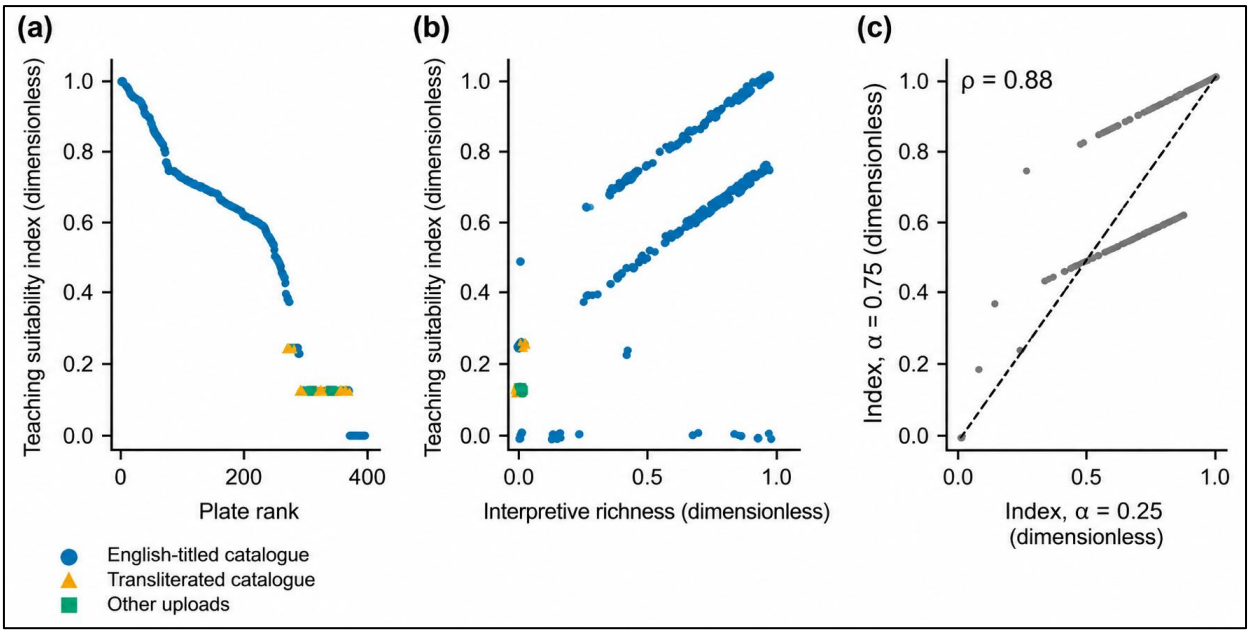


Fig. 7 Teaching suitability index of the 384 craft-salient plates; (a) ranked index, (b) index as a function of interpretive richness, (c) rank stability between 2 weightings

The 384 plates are ranked by the index in Fig. 7(a). A continuous decline from 1.00 to 0.38 covers 265 plates, followed by a step to 0.23 and 0.25 for 16 plates and a plateau at 0.13 for 79 plates, which lack commentary; 24 plates have an index of 0. In Fig. 7(b), plates with a richness of more than 0.30 fall on 2 bands that differ by the breadth term, 1 band for plates with 1 craft domain and the other for plates with 2 domains, and plates with a richness of 0 cluster at 0.13 and 0.25. Fig. 7(c) compares the indices obtained with a breadth weight of 0.25 and of 0.75, with a rank correlation of 0.88, and the

dashed line is the line of equality. Circles, triangles and squares in Fig. 7(a) and Fig. 7(b) denote the English-titled catalogue, the transliterated catalogue and other uploads The greedy selection reached complete coverage of the 21 domain-by-depiction cells with 16 plates (Fig. 8(a)). The initial plate, an inscription at the Gur-Emir mausoleum with an index of 1.00, covered 2 cells, and the 5th plate brought the coverage to 47.6%. The plates added after the 6th were mostly process, tool or trade plates with indices of 0.25 or lower, and 13 of the 16 plates fell in that range. Random selection of 16 plates covered 27.1% of the cells on average. Complete coverage therefore requires the deliberate inclusion of low-index plates, which shows that a ranking by index alone does not produce a balanced unit.

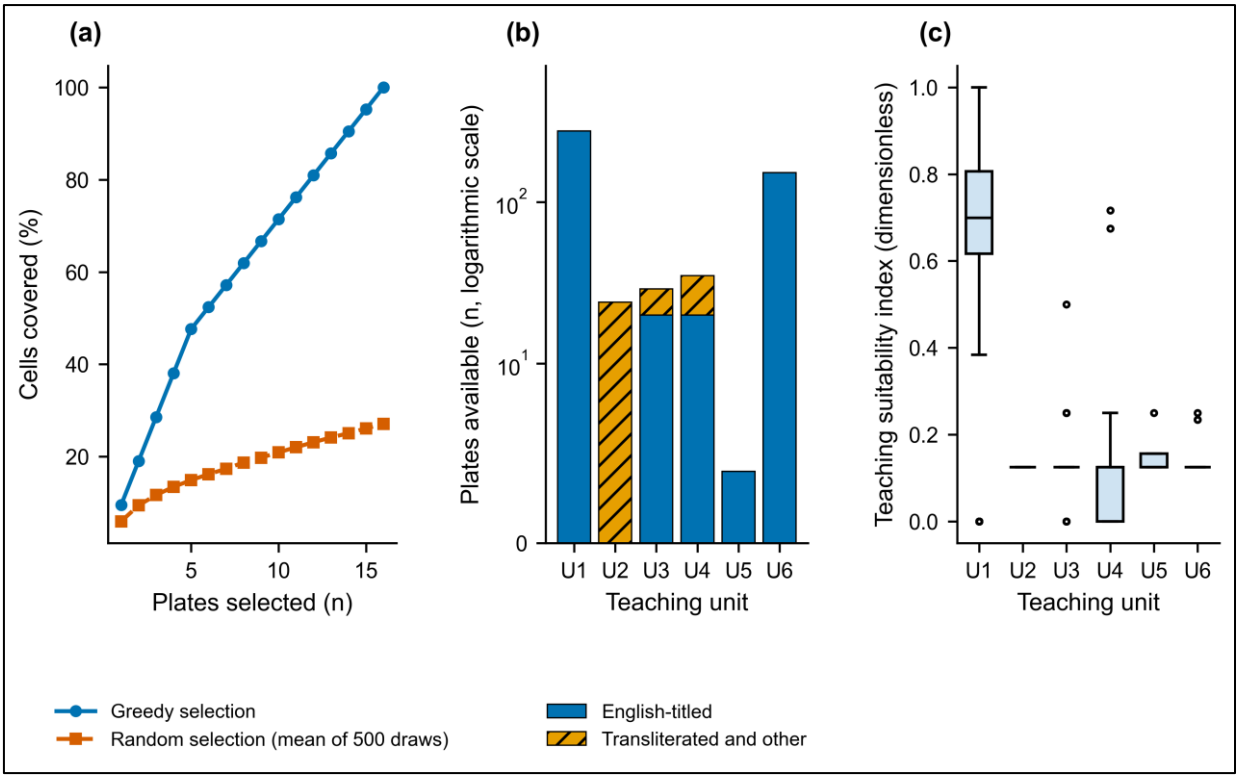


Fig. 8 Minimal plate selection and teaching unit profiles; (a) cell coverage as a function of plates selected, (b) plates available for each teaching unit, (c) index distribution within teaching units

The cumulative coverage of the 21 domain-by-depiction cells is shown in Fig. 8(a) as plates are added: the greedy selection covers 9.5% of the cells with 1 plate, 47.6% with 5 plates, 71.4% with 10 plates and 100% with 16 plates, whereas random selection reaches 27.1% with 16 plates. Fig. 8(b) gives the plates available for 6 teaching units on a logarithmic scale: 276 for ornament, tile and inscription (U1), 24 for the silk, cotton and wool production chain (U2), 29 for marketplace goods (U3), 35 for metal, wood, leather and household trades (U4), 4 for guild ritual (U5) and 152 for instruments, dress and adornment (U6); hatching shows the transliterated and other catalogue. In Fig. 8(c), U1 has a median index of 0.70 and the other units 0.13, and the boxes span the interquartile range

3.7 Teaching units and interpretive scope

The measurements are translated into 6 teaching units in Table 6. Unit 1 on ornament, tile and inscription has 276 plates, 262 of them located in Uzbekistan, with a median commentary of 160.5 words and a median index of 0.70, and it can be taught largely from the catalogue. Unit 2 on the silk, cotton and wool production chain has 24 plates, drawn only from the transliterated catalogue, none located in Uzbekistan by the catalogue and none with commentary, which gives a median index of 0.13. Units 3 to 6 have 29, 35, 4 and 152 plates, with a median commentary of 0 words except for unit 4 (32 words). The framework therefore assigns different roles to the teacher according to the unit: in unit 1 the teacher selects and sequences, and in units 2 to 6 the teacher has to supply the geography, the technical

vocabulary and the context that the catalogue omits. Digital reuse of cultural heritage is often assessed by proxy measures that say little on the interpretation of materials (Mahey et al. 2026), and the unit profiles provide a more specific description of what a lesson needs to add.

Table 6 Teaching units, plates available and documentation

Teaching unit	Plates (n)	Located in Uzbekistan (n)	English-titled (n)	Transliterated or other (n)	Median commentary (words)	Median index[a]
U1 Ornament, tile and inscription	276	262	276	0	160.5	0.70
U2 Silk, cotton and wool production chain	24	0	0	24	0	0.13
U3 Marketplace goods and vendors	29	9	20	9	0	0.13
U4 Metal, wood, leather and household trades	35	3	20	15	32	0.13
U5 Guild ritual and craft organisation	4	0	4	0	0	0.13
U6 Instruments, dress and adornment	152	12	152	0	0	0.13

The 5-stage sequence can be tied to these counts. In unit 2, the stage of locating depends on geography supplied by the teacher, since none of the 24 plates carries a place name; the stage of describing draws on the 8 plates of tools such as reels, heddles and looms; and the stage of tracing follows the 18 silk plates from the rearing of silkworms and the reeling of skeins to winding, warping and weaving on a loom. In unit 1, the same stages rest on the catalogue itself, since the commentary of 281 monumental plates describes monuments, building dates and ornament. The difference in documentation between the 2 units determines the amount of preparation that each requires. The scope of these results is defined by 4 limits. The corpus is the set of plates available in the open repository and not the full album, and its Trades Part is represented by 52 plates. Craft salience was determined from titles, headings and commentary, not from the pixel content of the images, and crafts that are visible but not named are not counted. The glosses of the transliterated titles were produced by the authors, and the place attribution depends on the place names of the catalogue. The suitability index measures the readiness of sources and was not tested in a classroom, which means that no result of this study concerns learning gains.

4. Conclusions

A corpus of 900 de-duplicated plates of the Turkestan Album, coded for 11 craft domains and 6 depiction modes, shows that craft is salient in 384 plates (42.7%), but that the salience is concentrated in 2 domains. Architectural ceramics and ornament account for 27.7% of the corpus and calligraphy and inscription for 14.4%, whereas textile and fibre production and trade account for 3.7% and each of the remaining 8 domains for 2.6% or less. The Shannon index of 1.53 relative to a maximum of 2.40 confirms the uneven distribution. The geographical attribution is equally concentrated. Samarkand supplies 271 of the 279 craft-salient plates located in Uzbekistan (97.1%), and the 52 plates of the Trades Part, which contain the direct depictions of silk, wool, cotton, metal and wood production, carry no place name in the catalogue. Lessons on the craft history of Uzbekistan that draw on the album therefore rest on monuments of Samarkand for place and on unlocated plates for process. Documentation follows the same division. Plate-specific commentary is present for 281 of 281 monumental plates (95% interval 98.7% to 100%) and for 0 of the 48 plates that show a craft process or tool and 0 of the 29 plates that show goods in trade, with upper limits of 7.4% and 11.7%. The plates that carry the greatest information on the practice of crafts are the least explained, and a teacher has to supply the context for them.

The coding rules are reliable where titles and headings share their cues. Cohen’s κ is 0.74 for ceramics and ornament, 0.81 for inscription, 0.79 for musical instruments, 0.80 for leather and 1.00 for

guild customs, while dress, at 0.19, reflects a difference of definition. Changing the commentary threshold from 3 to 5 distinct cues alters the count of ornament plates by -16.6% and of inscription plates by -1.5% and leaves the smaller domains unchanged. The teaching suitability index is stable under changes of weights, with rank correlations of 0.88 to 0.99. Selection by index alone gives a lopsided unit, whereas a greedy rule covers the 21 domain-by-depiction cells with 16 plates, relative to a coverage of 27.1% for 16 randomly chosen plates. The 5-stage sequence of locating, describing, contextualising, tracing and transferring, applied to 6 teaching units, assigns the teacher a selecting role in the unit on ornament and tile and a context-supplying role in the other 5 units. In practical terms, a teacher or curriculum designer can assemble a balanced set of 16 plates with identified gaps from open catalogue records, which reduces the preparation needed for a source-based lesson on the crafts of Uzbekistan.

Statements and Declarations

Funding. This research received no funding.

Competing interests. The authors declare no competing interests.

Ethics approval. Not applicable. The study used publicly available catalogue metadata of historical photographs and involved no human participants or animals.

Consent to participate and consent for publication. Not applicable.

Data availability. The catalogue records analysed are publicly available from the open image repository described in the Methods. The coded plate table, the domain tables and the author-supplied glosses are provided as Online Resource 1, and the data underlying Fig. 1 to Fig. 8 are provided as Online Resource 2.

Code availability. The analysis code is provided as Online Resource 3.

Author contributions. [To be completed by the authors.]

Online Resource 1 Coded metadata for 900 plates of the Turkestan Album, author-supplied English glosses, coding rules, domain prevalence and representation tables, agreement and sensitivity summaries, greedy plate selection, and teaching unit summaries (ESM_1.xlsx)

Nomenclature

Abbreviations

Abbreviation	Definition
BLD	Building construction (domain code)
CAL	Calligraphy, inscription and book arts (domain code)
CER	Architectural ceramics and ornament (domain code)
DRS	Dress, headwear and adornment (domain code)
GLD	Guild and craft customs (domain code)
LEA	Leather, saddlery and footwear (domain code)
MET	Metalwork and cast ware (domain code)
MUS	Musical instruments (domain code)
PRO	Food and household processing trades (domain code)
TXT	Textile and fibre production and trade (domain code)
U1 to U6	Teaching units 1 to 6
WDL	World Digital Library
WOD	Woodwork, mats and containers (domain code)

Symbols

Symbol	Definition	Unit

c_i	Number of craft domains shown by plate *i*, excluding dress	-
c_{max}	Largest number of craft domains shown by a plate in the corpus	-
D	Number of craft domains	-
f_{id}	Binary indicator that plate *i* shows domain *d*	-
g_i	Place weight of plate *i*	-
H_p	Shannon index of album part *p*	-
h_{id}	Binary indicator of a cue for domain *d* in the subject headings of plate *i*	-
$K(S)$	Coverage of the selected set *S*	-
N_s	Number of craft-salient plates in the corpus	-
n	Number of plates or files (count)	-
n_d	Number of craft-salient plates that show domain *d*	-
n_{dp}	Number of craft-salient plates of album part *p* that show domain *d*	-
n_{id}	Number of distinct cue terms for domain *d* in the commentary of plate *i*	-
n_p	Number of craft-salient plates of album part *p*	-
P_e	Proportion of agreement expected by chance	-
P_o	Measured proportion of agreement	-
Q_{dp}	Representation index of domain *d* in album part *p*	-
q_{dp}	Proportion of the domain counts of album part *p* that belongs to domain *d*	-
R_i	Interpretive richness of plate *i*	-
S	Selected set of plates	-
T_i	Teaching suitability index of plate *i*	-
t_{id}	Binary indicator of a cue for domain *d* in the title of plate *i*	-
U	Set of domain-by-depiction cells that occur in the eligible plates	-
U_i	Set of cells shown by plate *i*	-
V	Cramér's coefficient of association	-
w_i	Number of words of plate-specific commentary of plate *i*	words
w_{95}	95th percentile of commentary length in the English-titled catalogue	words
α	Weight of domain breadth in the teaching suitability index	-
κ	Cohen's coefficient of agreement	-
ρ	Spearman rank correlation coefficient	-
χ^2	Chi-square statistic	-

Subscripts and superscripts

Subscript or superscript	Definition
d	Craft domain
i	Plate
p	Album part
e	Expected by chance
max	Maximum
o	Measured
s	Craft-salient
95	95th percentile

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