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An analysis of the appearance characteristics of Korean ceramics per era through statistical analysis of metadata annotated with a visual element classification system of ceramics

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Abstract

This study is to create metadata with a ceramic visual element classification system, such as color, form, material, and pattern, and then to analyze the visual characteristics of Korean ceramics by era through this metadata statistical analysis. To achieve this, first, the visual element classification system for ceramics was established. Second, 7,346 ceramic photos were acquired and annotated using the visual element classification system to create metadata. Third, through statistical analysis of the metadata, the preferred visual elements in each era were organized, and their characteristics were analyzed. In particular, the differences in form implementation, color technology, and pattern representation, which vary depending on material properties, were identified. Through this study, the flow of visual elements of Korean ceramics and the reason for each type of appearance and production method could be comprehended more systematically.

Keywords: Korean Ceramics, Ceramic visual elements classification system, Ceramic metadata, Goryeo celadon, Joseon buncheon, Joseon white porcelain, Ceramic annotation

Introduction

This study is to create metadata with a ceramic visual element classification system in order to apply artificial intelligence (AI) technology to Korean traditional ceramics and to analyze the characteristics of the appearance of Korean ceramics by era through this metadata statistical analysis. As shown in Fig. 1, the Smart Culture Lens [1] that applied AI technology to the data of Korean traditional ceramics developed by this research team used visual search technology such as Google Lens (https://lens.google.com). If this visual search technology is applied to the analysis of artifacts, such as ceramics, it is possible to intuitively distinguish the appearance characteristics from an artifact photo and provide related analysis information, just as humans intuitively see, judge, and distinguish an object using their eyes [2–6].

This Smart Culture Lens uses computer vision and machine learning technology to automatically recognize visual elements, such as shape, material, pattern, and color of ceramics, when one ceramic is photographed with a smartphone in a museum [1]. In addition, it provides related visual element information analyzed through automatic analysis technology, as well as the results and displays of ceramics with the same visual elements for each element through search technology. To provide specific information through automatic analysis by applying AI technology to such cultural assets or artworks, it is necessary to acquire a large amount of related data and create metadata annotating the properties to be analyzed. The most important factor in the application of AI technology to cultural assets or artworks during this

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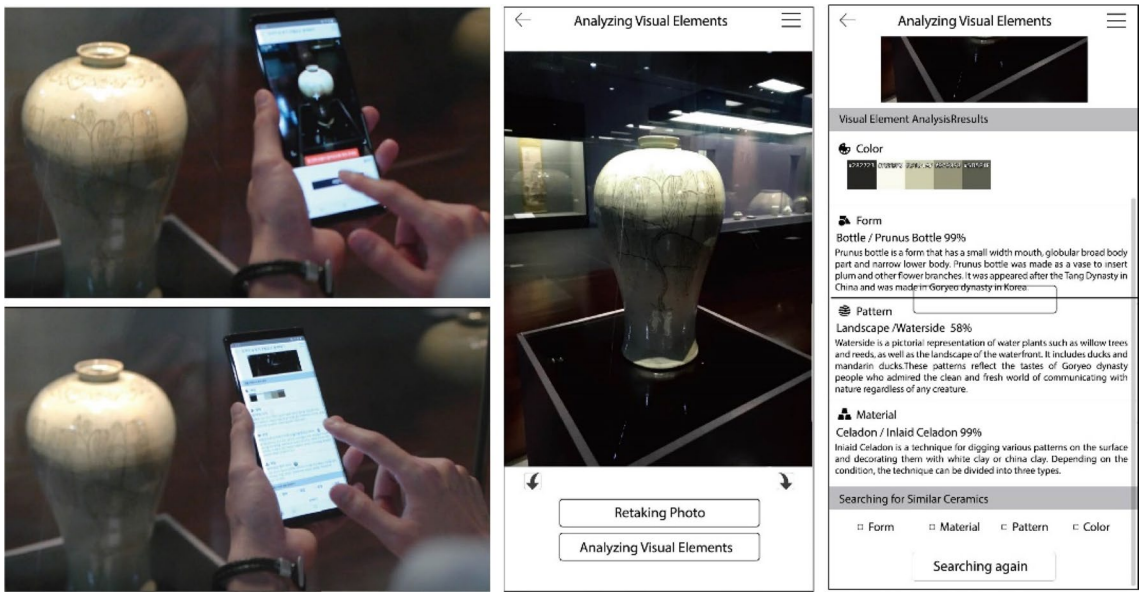


Fig. 1 Smart culture lens

development process is to acquire a lot of objects to be analyzed and to create metadata on characteristic properties that have been annotated before applying the AI technology.

Such pottery and ceramics not only display the characteristics of an archeological perspective but also hold the characteristics of functional product design geared to the specific usage of containers and the visual characteristics of artworks, which are the aesthetic characteristics of each era. That all objects are created in accordance with their purposes and functions through the use of visual elements, such as colors, forms, and materials, is the basic production method of creation in the fields of design and the arts [7–14]. In addition, when looking at ceramics, the public determines their usage through their appearances and comes to explore visual elements, such as materials, colors, and patterns, intuitively. Because the approach most basic to the creation and interpretation of objects concerns visual elements, the present study seeks to analyze ceramics based on them.

To create valuable and systematic metadata, a visual element classification system was established by examining and analyzing data and studies related to traditional Korean pottery and ceramics. Representative periods in the history of Korean ceramics are the Goryeo Dynasty (918–1391) and the Joseon Dynasty (1392–1910). Overall, studies on ceramics in Korea are conducted from an archeological perspective. While analysis is not conducted with a focus on the characteristics of the visual elements of ceramics, the characteristics of appearances are distinguished by period to a certain extent. Ceramics exhibit characteristics that are clearly distinguished by color or material, as with celadon in Goryeo and buncheong and white porcelain in Joseon [15–17]. In addition, patterns, too, have been separately studied together with materials [18, 19]. In the present study, a systematic visual element classification system was developed through research and analysis of many previous studies and related data, and structural metadata were created based on this system. Also, through this metadata statistical analysis, visual elements preferred in each age, such as forms, materials, and patterns, were analyzed.

Among the remaining artifacts, pottery and ceramic artifacts remain the most numerous. A lot of pottery and ceramics have charm as a rich material that can be variously applied to industrial fields using advanced technologies such as AI. The creation and utilization of ceramic visual element metadata in this study served as an opportunity to analyze the flow of appearance characteristics of ceramics for each period. This study will serve as a good example of creating and utilizing metadata through the application of visual elements, which is an intuitive interpretation method for the appearance of ceramics.

Methodology

The present study was conducted in five stages. First, materials and studies on ceramics were analyzed, and a visual element classification system regarding forms, materials, and patterns was established. Second, data were collected by photographing the appearances of

ceramics through visits to museums across the nation or by downloading data from ceramic-related websites. The third stage of metadata statistical analysis was completed by annotating the corresponding properties of the visual element classification system on all of the acquired ceramics. Fourth, through metadata statistical analysis, characteristics that arose in the Goryeo and Joseon eras, representative production periods of Korean ceramics, were analyzed statistically per visual element. And finally, based on these statistical analyzes, characteristics of the overall change and flow of ceramic visual elements from the Goryeo Dynasty to the Joseon Dynasty were organized and analyzed.

1st stage: establishing Korean ceramics visual element classification system

As for the basic standard for classifying ceramics in the present study, visual elements, which are addressed as the most elementary in the visual fields, were established. In the visual fields, the constitutive elements of the appearance of an object are called visual elements, and they are classified into colors, forms (shapes), and materials (textures) [20–23]. Artifacts like ceramics are products created from earth by humans, out of a need for objects to carry or hold other things, for the purpose of being used as containers. Products take on forms that are determined by needs in accordance with the purposes, materials are selected in accordance with such needs and used to make the products, and colors naturally develop according to the materials or are added according to the needs as well. In addition, patterns are used in order to add symbolic, aesthetic effects in accordance with the producers' intentions. Consequently, all products come to have the visual elements of forms, materials, colors, and patterns.

The three basic categories of forms, materials, and colors were selected as the visual elements of Korean artifacts. In addition, traditionally used patterns hold symbolic meaning so that diverse artifacts' value and meaning can be interpreted according to their patterns. Patterns therefore were added. Functions were added as well. Artifacts were created for humans' survival, and a variety of tools were created according to functions necessary for humans' food, clothing, and housing. Consequently, it is necessary first to distinguish among functional categories in terms of whether artifacts were basically used for eating, storage, bodily protection from the environment, housing, or status display. After functional classification has been made, differences are distinguished per visual element within the same category of usage. Consequently, in order to classify the entirety of the artifacts, functions indicating categories according to the purposes of artifacts were added to the classification system.

The Korean culture visual element classification system distinguishes among five categories: functions (depending on the purposes of use); colors (as seen in artifacts); forms (depending on the functions); materials (depending on the surface colors and production techniques); and patterns (depending on the symbolic meanings). As in Fig. 2, when the Korean culture visual element classification system is applied to a ceramic named "CheongJa SangGam KukMoranMun JangGyeongByeong," the function is a bottle for bearing liquids, the colors are colors visible from the artifact (RGB #adb09a, ##5e7666, #7d806f, #273,229), the form is of the JangGyeongByeong (long-necked bottle) type, the material is celadon, and the pattern is peonies and chrysanthemums. As for the colors of ceramics and pottery, characteristic colors emerged in accordance with the clay body used, glazes, and production method. Consequently, materials and colors can be interpreted as identical.

The classification system regarding the visual elements of ceramics and pottery was thus distinguished among forms according to functions, materials according to components and production methods, and patterns holding symbolic meanings. In addition, in order to extract subcategories per visual element, numerous studies on diverse pottery and ceramics were analyzed, and names and type classification systems in the academia were all investigated [15–19, 24–44]. Based on this, photographs of pottery and ceramics were collected per visually distinguished type, characteristic differences of each type were compared and analyzed, and subcategories of each visual element were distinguished.

Because research preceding the present study is written only in Korean, it cannot be of help as a reference material to researchers outside South Korea who read the present paper. Nevertheless, the earlier studies mentioned are the result of research conducted by South Korean scholars who have studied ceramics and pottery over a long period. Despite their long history, Korean ceramics are regrettably lesser known to ceramic researchers abroad than are Chinese and Japanese ceramics. Consequently, it was not possible to allude to English-language research materials as references materials. Readers' understanding of the fact that many of the references materials are in Korean therefore is requested.

Ceramic form classification system

Basically, by analyzing numerous research data on a variety of pottery and ceramics, a basic form classification system was established. Because, in design, form is shaped by the purpose of an artifact in terms of its functions, subcategories were divided based on functions.

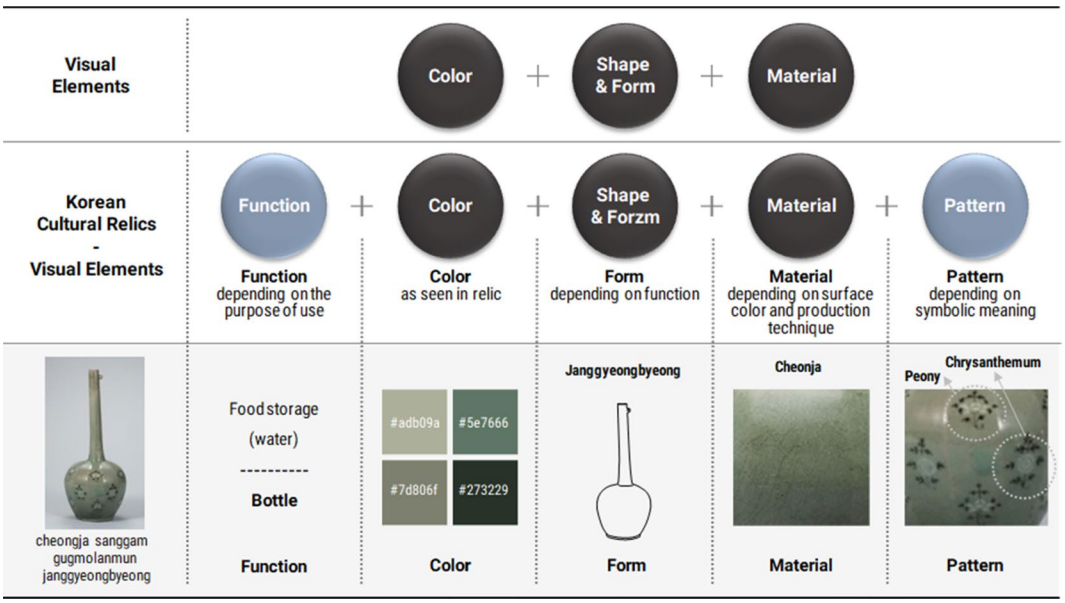


Fig. 2. Korean culture visual element classification system

When the classification system according to forms is examined, shapes determined per usage are clearly distinguishable. Pottery and ceramics basically have the function of being containers and are notably characterized by the fact that their forms are determined by the objects that they contain. The basically distinguished higher categories are bottles, jars, dishes, bowls, cups, lidded bowls, and ewers. Each higher category has subcategories that are differently characterized according to diverse purposes.

In order to focus only on forms in the present study, the outlines of the forms of 922 items of pottery and ceramics were drawn and analyzed regardless of periodization. In addition, in order to extract such form analysis structures, first, the categories of ceramics and their characteristics were determined based on data on pottery and ceramics in many earlier South Korean studies on ceramics [15–19, 24–42], the eMuseum website of the National Museum of Korea [43], and the Encyclopedia of Korean Culture [44].

Ceramics with the shapes of bottles, which amounted to 15 types, the largest number, were selected as the basic sample structures. In addition, when bottle-type pottery and ceramics were examined per distinguished type, it was possible to confirm, in accordance with their usages: first, a distinction among the forms of the bodies and disparate forms per part, on or in the surfaces of the bodies, snouts, and handles.

As in Fig. 3, even when artifacts have bodies with identical forms, disparate names distinguished according to snouts, handles, or other parts of the bodies are also used. Because of the characteristics of snouts, they are classified disparately into the six types of HwaHyung (flower-shaped), NaPalHyung (trumpet-shaped), OeBanHyung (saucer-shaped), IpSulHyung (lip-shaped), KwangKooHyung (wide and tall), and WonBbulDaeHyung (truncated cone-shaped). In addition, artifacts are also distinguished between the types of YangIHyung (two handles) and DaIHyung (multiple handles) because of the characteristics of their handles regardless of their bodies or snouts. In the present study, from a functional perspective, the forms of the bodies were seen as the standard to be considered first. Because the shapes of the snouts and the numbers of handles are not elements having considerable effects on the bodies, they were all excluded from the structural conditions in the form classification system. In addition, the types of PyeonHyung (flat side-shaped), DaKakHyung (polygon-shaped), and KwaIlHyung (fruit-shaped) visible in the bodies were included in the basic form classification system because they are characteristic forms that appear frequently in Korean ceramics and are produced under a special distinction. With such a classification structure as the standard, the ten basic forms which have bodies clearly distinguished by usage, were established first, as in the samples of bottle types in Fig. 4 In addition, at the next stage, the types of PyunByeong, DaKakByeong, and KwaHyungByeong, which are based on additional characteristics applied to the bodies, were added at the next stage to define the thirteen basic types.

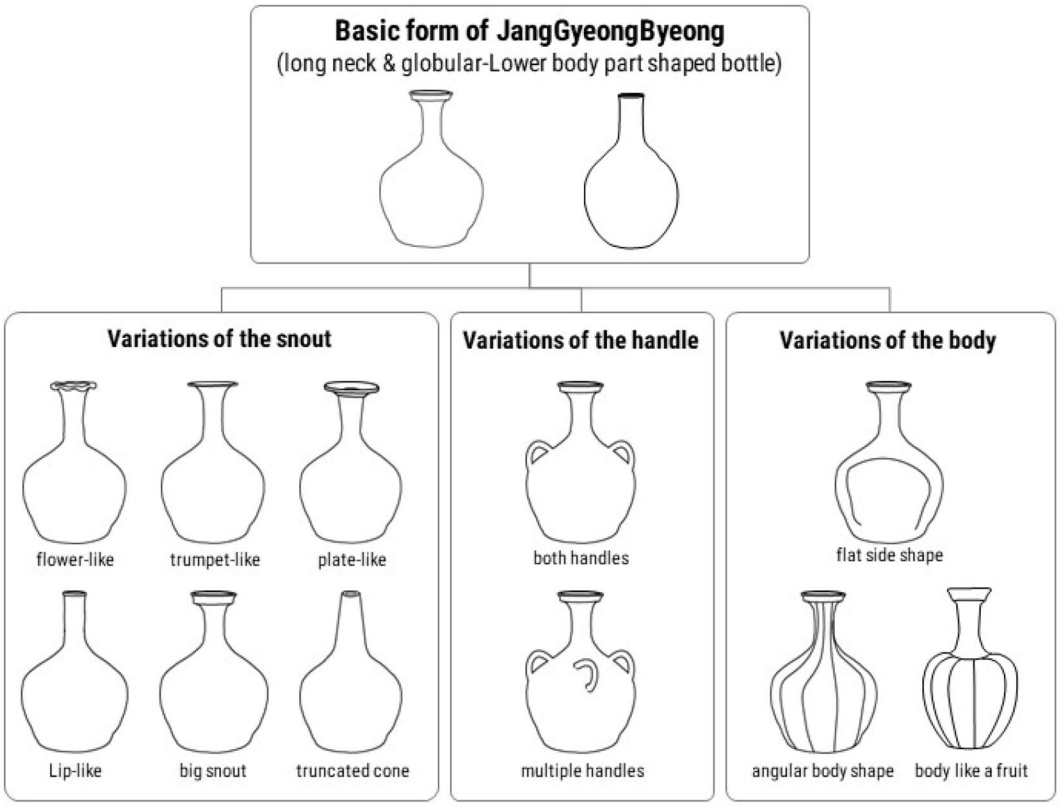


Fig. 3 Structural differences affecting the names of ceramics

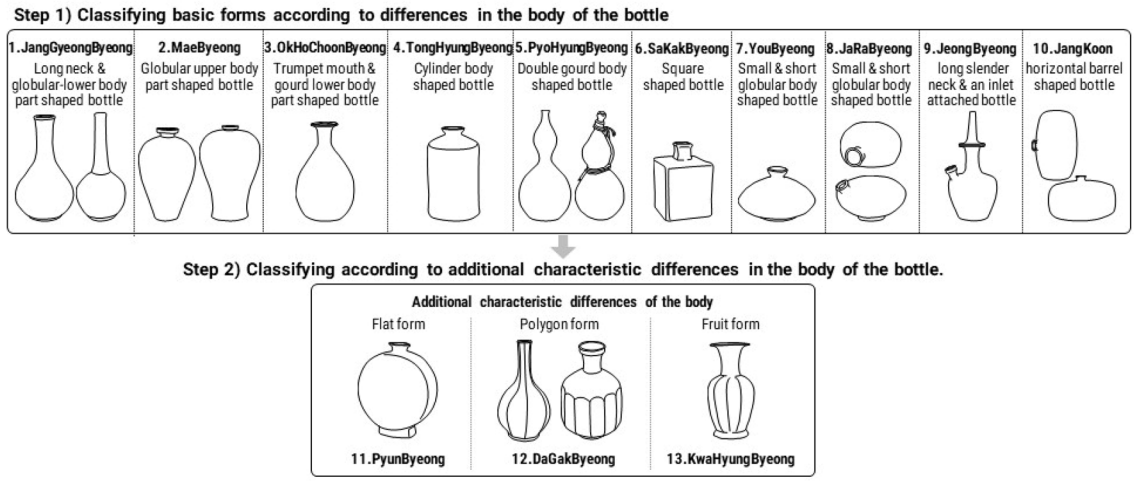


Fig. 4 Classification structure for the forms of bottles in Korean ceramics and pottery

In this way, as in Fig. 5, artifacts were divided into the seven first-level categories of bottles, jars, bowls, dishes, cups, lidded bowls, and ewers per function, and 57 s-level categories were established according to the characteristics of forms distinguished by each category. As for the names of ceramics in the form classification system, the ceramics' names used in South Korea are presented and, below them, descriptions of the characteristics of each form for easy comprehension. For a practical understanding of the categories of ceramic forms according to

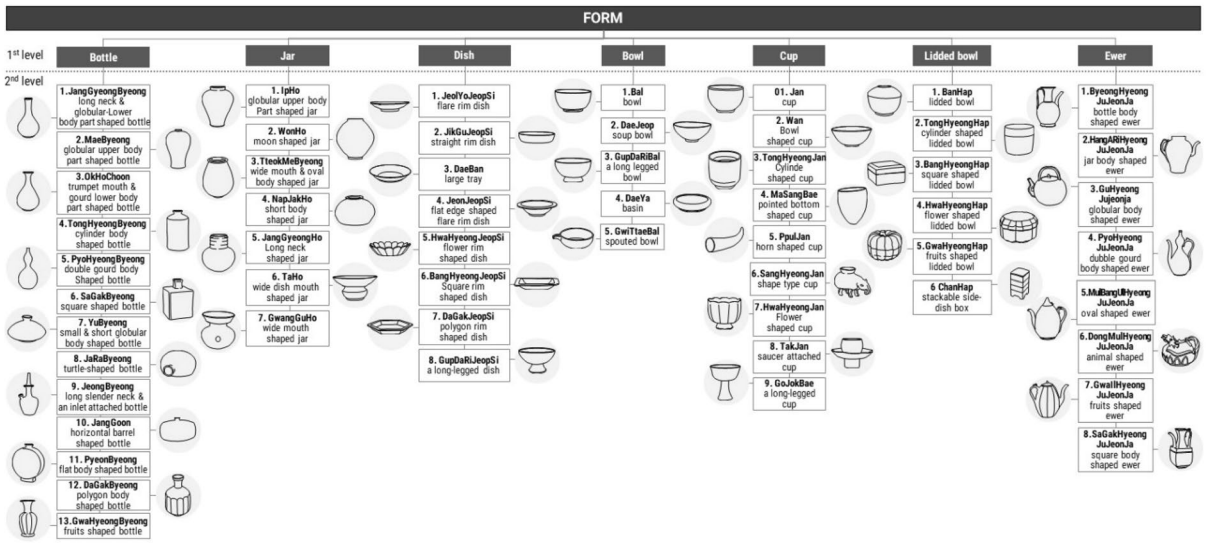


Fig. 5 Form classification categories of Korean earthenware and ceramics [1]

the classification system above, photographs of ceramics representative of each type are placed in Fig. 6.

Ceramic material classification system

Ceramics in Korea are basically classified as materials even though the resources used for each era are clearly different. Materials have changed over time due to various factors, and these changes have had a great influence on the methods of making pottery shapes and patterns. Since the color of ceramics is dependent on the materials used, in this study, material and color were not analyzed separately. Representative ceramic materials are celadon, buncheong, and white porcelain. The characteristics of each material are as follows.

Differences in the clay bodies of ceramics from the Goryeo and Joseon dynasties

The forms of visual elements and the pattern production techniques analyzed above were deeply related to both materials and production methods of ceramics. The characteristics were examined according to components and production methods per era. For reference, the types of clay bodies used were investigated through the locations of kiln sites during the Goryeo and Joseon eras. When the topography of Korea in Map A in Fig. 7 [24, 45] is examined, plains are numerous toward the West Sea (Yellow Sea), and mountain ranges extend lengthwise along the East Sea (Sea of Japan). When Goryeo celadon kiln sites on Map B are examined, they were concentrated along the coast of the West Sea. When Map C is examined, however, Joseon buncheong kiln sites were concentrated from the central region to the southern region, and white porcelain kilns extended nationwide, all the way to the northern region, except for highly mountainous areas [16].

The main components of clay bodies, which are used to make ceramics, are: certain components that serve as melting agents; refractory materials; and plastic materials. Plastic materials are mainly clay-like materials most important for maintaining forms. Argillaceous materials are classified into primary clay and secondary clay according to formation processes. The two types exhibit differences in purity, color, plasticity, and shrinkage. For example, in comparison with primary clay, secondary clay consists of finer particles and is higher in organic matter and other impurity content, thus becoming darker and more plastic, increasing in dry strength and firing shrinkage, and decreasing in the sintering point.

When the locations of Goryeo kiln sites on Map B are examined, celadon production centers were mostly along the West Coast, and some were near the South Coast. As for earth from these areas, mainly secondary clay was used, high in both plasticity and iron content. Goryeo used maritime transportation as the means of supplying and moving the components so that ceramic production centers were located along coasts [46]. Later, during the Joseon, buncheong likewise used secondary clay, but production centers gradually moved inland, as on Map C, due to Japanese invasions. In particular, during the period when white porcelain was produced, primary clay, low in iron content, was mainly used so that clay came to be collected from inland highlands. In the Joseon era, components and products were transported mainly on inland rivers [46]. As for the white porcelain of Joseon,

Fig. 6 Examples of artifacts in the form classification of Korean earthenware and ceramics

the Bunwon supplying products to the royal household was managed and came to lead the production of quality white porcelain. At this production center, ceramics were produced by mixing white porcelain clay collected from across the nation and quality, high-purity kaolin, and the firing temperatures rose considerably. As for white porcelain produced during the Joseon, the aluminum (III) oxide (Al_2O_3) content of some ceramics increased to be as much as 35–39% [47].

Materials and production methods of celadon

While celadon and white porcelain began in the ninth century, with a gradual increase in the amount of celadon, Goryeo became the formation of a ceramic culture led by celadon. Despite a Chinese influence at first, a celadon-colored glaze, utterly different from glazes of Chinese celadon, developed by the tenth century. The first half of and mid-twelfth century was the height of Goryeo celadon, seeing the production of diverse celadon products [48]. With Goryeo celadon, a variety of types and ornamentation techniques arose.

As for celadon, the coloring agents are known to be iron (III) oxide (Fe_2O_3) and titanium (IV) oxide (TiO_2) included in the components. When fired with the reduction firing technique, Fe_2O_3 contained in the ceramic bodies and glazes turns into iron (II) oxide (FeO), thus developing from gray to green. While high-purity clay bodies were used for some high-quality celadon (Gangjin celadon), most clay bodies were produced mainly based on secondary clay, thus being higher in iron and organic

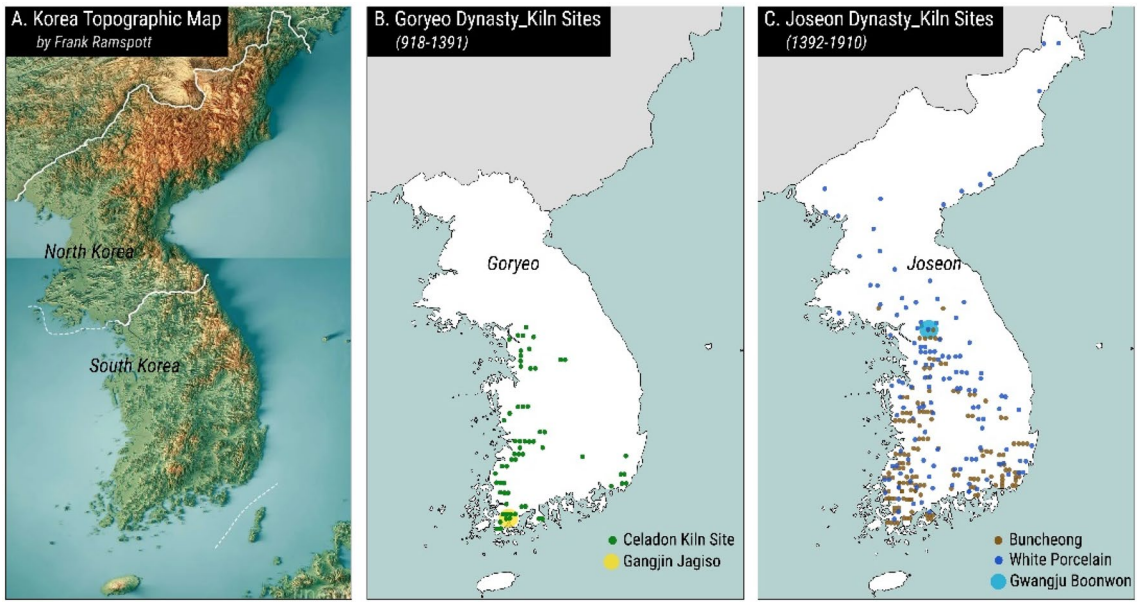


Fig. 7 Kiln sites of Goryeo and Joseon [24, 45]

matter content. This affected clay bodies' coloring agents and plasticity. The clay bodies of celadon from Gangjin and the southwestern region tended to be higher in Fe_2O_3 content in comparison with those from other regions, amounting to approximately 2–3% [49]. As a representative government organ managing the production of inlaid celadon in Goryeo, the Jagiso in Gangjin (Fig. 7, B) can be cited. The components of celadon were characterized by the fact that clay bodies were low in Al_2O_3 content and contained a large amount of melting agents. As exhibited by vessels produced on celadon kiln sites in southwestern Korea, the clay bodies of celadon produced in mid-Goryeo had an Al_2O_3 content of approximately 15–18% and a slightly high melting agent content. Such characteristics in composition led to successful vitrification even with single firing [50]. Goryeo kilns for firing celadon were largely divided into brick kilns and clay kilns. After the early years of the dynasty, they gradually shifted to clay kilns and single-chamber kilns without partitions, where control was easy because these kilns were short and narrow and crystal growth in glazes was suppressed through rapid heating and rapid cooling, thus facilitating the development of jade green colors [51]. Though firing temperatures were low due to short kilns, vitrification could amply be executed because of the characteristics of the components.

Materials and production methods of Buncheong

With the inheritance and development of Goryeo celadon, buncheong came to be produced in diverse ways with the arrival of a new era. Though the Joseon witnessed the birth of white porcelain, which was appropriate for the Confucian ideology, this type of ceramics coexisted with the Buddhist buncheong, which was carefree and full of boldness, romanticism, and humor [48]. Characterized by the application of engobe made of white clay to colored clay through a variety of techniques, buncheong arose in the last years of celadon and was produced along with white porcelain, generally using clay bodies and glazes similar to those of Goryeo celadon. The clay bodies of buncheong found in the Chunghyo-dong kiln in Gwangju are characterized by an Fe_2O_3 content of 3–4% and the relatively high content of melting agents such as calcium oxide (CaO) and magnesium oxide (MgO). Because of such characteristics, buncheong differs considerably in composition and firing temperatures from white porcelain clay produced in the same age [52]. Buncheong had firing temperatures lower than those of white porcelain and were fired in short amounts of time. Buncheong from the kiln site in Hakbong-ri along Mt. Gyeryong, one of the main production centers, likewise had a melting agent content of 22.5% and an iron content of 4.82% [53]. While it has a higher Al_2O_3 content than does the clay bodies of celadon, it mainly has a brown appearance because of the amount of Fe_2O_3 that it contains. Buncheong found in Hakbong-ri, located in the midwestern region, is nearly black.

Materials and production methods of white porcelain during the Joseon dynasty

As representative ceramics of Joseon, white porcelain, which is densified, is cited besides buncheong, and pure white porcelain was the mainstream throughout generations [48]. With the suppression of Buddhism, which had flourished in Goryeo, and the establishment of Confucianism, cultural changes appeared in ceramics. The greatest material characteristic of white porcelain from Joseon is the use of refined components. With the relocation inland of ceramic production centers, which had centered on coasts in order to defend against foreign infiltrations, even greater changes occurred to the supply of components. Major production centers of white porcelain are confirmed by changes to kiln sites.

As for white porcelain, elutriation technicians in charge of elutriation during production were separately established in order to refine white earth, the main component. In elutriation, the original soil of white porcelain is washed with water in order to increase purity. This not only improves the component's whiteness but can also raise the argillaceous material content of clay bodies. The elutriation process, which uses water, unlike other grinding or refining processes, by maintaining clay mineral grains intact in the natural state, is determined to play the most important role in forming the unique texture of Joseon white porcelain, which is white and firm yet allows one to feel warmth and softness [54]. It was demonstrated that undergoing such a process not only filtered out impurities but also decreased the silicon dioxide (SiO_2) content and increased the Al_2O_3 content of the component [55]. As it became possible to obtain white porcelain clay that surpassed the original soil of white porcelain in quality, entire ceramic products came to be created with white porcelain soil instead of having engobe applied only on their surfaces, as with buncheong.

Great differences in the component ratios of Al_2O_3 and SiO_2, the main components of clay bodies, developed, and the iron content decreased considerably to 1% or less. Relatively increased, Al_2O_3 raises clay bodies' whiteness and firing temperatures. Through the use of kaolin (primary clay) and the elutriation process, white porcelain from the Joseon rose in the Al_2O_3 content to be approximately 30%, the kilns' firing temperatures increased, and, as for firing methods, the method of glaze firing came to be established as well. By meeting firing temperatures that had risen as a result of the refining of components and the development of firing techniques, it became possible to produce hard white porcelain that was vitrified and therefore densified.

Clay bodies that have undergone the elutriation process affect forming, too. Low viscosity and plasticity made them appropriate for producing simple forms without superfluities [54], As the purity of whiteness increased, the drawing method came to be quite suitable. During the latter half of Joseon, techniques such as engraving, embossing, and openwork became fashionable as well. From the seventeenth century and onward, white porcelain established itself as a ceramic type that could be used by not only members of the royal household but also provincial commoners [56].

Despite partial differences in regional characteristics, the approximate Fe_2O_3 content, the major cause of color development of clay bodies of celadon, buncheong, and white porcelain, as revealed by earlier studies and diagrams comparing the component ratios of Al_2O_3 and SiO_2 are as in Fig. 8.

Al_2O_3 and Fe_2O_3 not only serve as coloring agents of clay bodies but also affect firing temperatures. Al_2O_3 increases whiteness and firing temperatures, and, though different according to the firing conditions, Fe_2O_3 darkens ceramics' colors and affects sintering, thus lowering firing temperatures. As for celadon, it undergoes single firing, thus having relatively lower firing temperatures, which is confirmed by the composition of Al_2O_3 and iron in clay bodies. While buncheong partly rose in the Al_2O_3

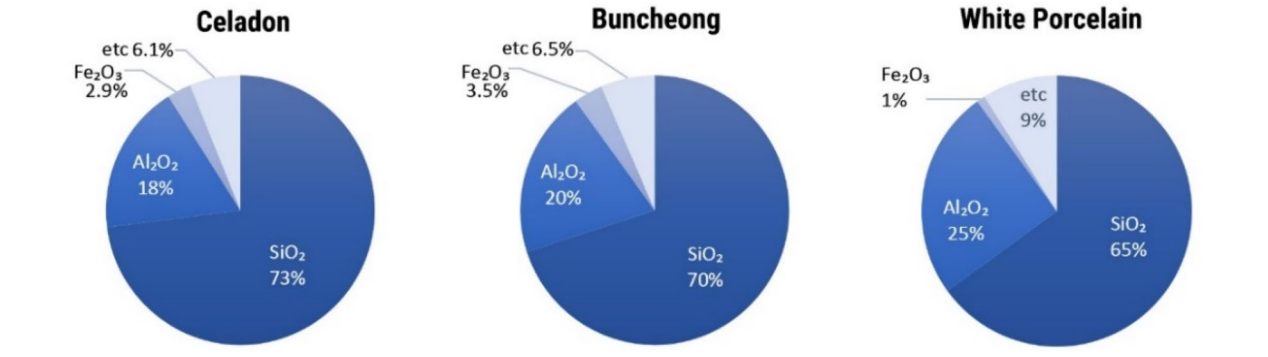


Fig. 8 Component ratios of the main composition of celadon, buncheong porcelain, and white porcelain clay bodies

composition and the iron content in comparison with celadon, it did not exhibit great differences from celadon. On the contrary, white porcelain displayed clear changes such as an increase in the Al_2O_3 content and a decrease in the iron content.

Differences in form production methods according to the material of Celadon and white porcelain

With the transition from the Goryeo to the Joseon, a change to components that affected the development of ceramics was the use of primary clays, such as pottery stone and kaolin, which seems to have strengthened vessels along with the elutriation process and a rise in kiln firing temperatures and also influenced formal production. Though they displayed slight differences in the component ratios of Fe_2O_3 and Al_2O_3, celadon clay and buncheong clay did not exhibit considerable changes. Unlike celadon and buncheong, white porcelain exhibits the difference of an increase in sintering temperatures even in the component ratios of the components themselves. In particular, having undergone the elutriation process of clay and therefore the removal of impurities, high-purity white porcelain soil decreased in plasticity due to differences in the organic matter content; however, ceramics produced with white porcelain clay increased in firing temperatures so that they came to withstand even higher temperatures without collapsing. Such changes to the components of white porcelain are judged to have affected the design forms and ornamentation techniques of white porcelain vessels as well.

As in Table 1, as for the production of jars, celadon jars, while not greater than white porcelain jars in the basic forms, were produced as single vessels through the wheel throwing method because of the high plasticity of their clay bodies [57]. On the contrary, the clay bodies of white porcelain, while making possible the firing of large vessels at high temperatures, were low in plasticity in the production process so that they could sag, with the strength maintaining the forms of large vessels during the wheel throwing being deficient. Accordingly, in the production of moon-shaped jars, the method of dividing up and attaching separate parts was used frequently [58]. Such characteristics of clay bodies, while affecting production techniques, seem to have contributed also to the spread of the use of white porcelain because, in terms of the strength of vessels after firing, white porcelain fired at high temperatures was harder so that the scope of its usage broadened. Indeed, judging from the nationwide distribution of kilns from the seventeenth century and onward, white porcelain seems to have become available for use even by provincial commoners notwithstanding qualitative differences from white porcelain used in the royal household.

Ceramic material classification system according to main material and production techniques

As has been mentioned above, the classification system for Korean pottery and ceramics first and most basically distinguishes objects by their materials. This is because materials used are clearly distinguished by period. In the first categories, materials were classified into five categories distinguished according to the production processes, glazes used, and firing methods: earthenware, celadon, buncheong, white porcelain, and glazed pottery. In addition, artifacts were distinguished into second-level categories under the first categories according to

Table 1 Differences in the production techniques of celadon and white porcelain jars

Goryeo Jar -WonHo			
	H48cm x W50cm	H24.4 cm x W11.5 cm (Treasure No.1028)	One jar at a time was created by wheel throwing [57]
Joseon Jar - WonHo (Moon shaped Jar)			
	H46cm x W46cm	H43.8 cm x W44cm (Treasure No.1440)	After shaping the two parts separately by wheel throwing, the two parts were combined up and down [58]

characteristics distinguished by a variety of additional production techniques (inlay, sgraffito, glazed, underglaze, marbled (agateware), paste-on-paste, brushstroke, splashing, openwork, and drawing). As in Fig. 9 a classification system divided into a total of 28 materials was established.

Ceramic pattern classification system

Research data (reference materials) on ceramic patterns and actual ceramics were investigated, the types used were searched for and collected, and their classification was systematized as shown in Fig. 10. When images used in patterns were examined, plants and animals observable in the surrounding environment were mainly used. The first categories of patterns were divided with ontological categories [59–62] as the standard and classified into plants, animals, humans, landscapes, objects, letters, geometry, techniques, and plain. And plant and animal patterns were too large in scope, they were once more divided into second categories. In the third categories, patterns were finally distinguished by the names of the particular 53 species belonging to each of the first or second categories.

Characteristics can be seen in the layout methods of patterns as well, and, as in Fig. 11, either a single pattern was arranged, usually in the center of a ceramic, or a pattern was continuously and repetitively arranged

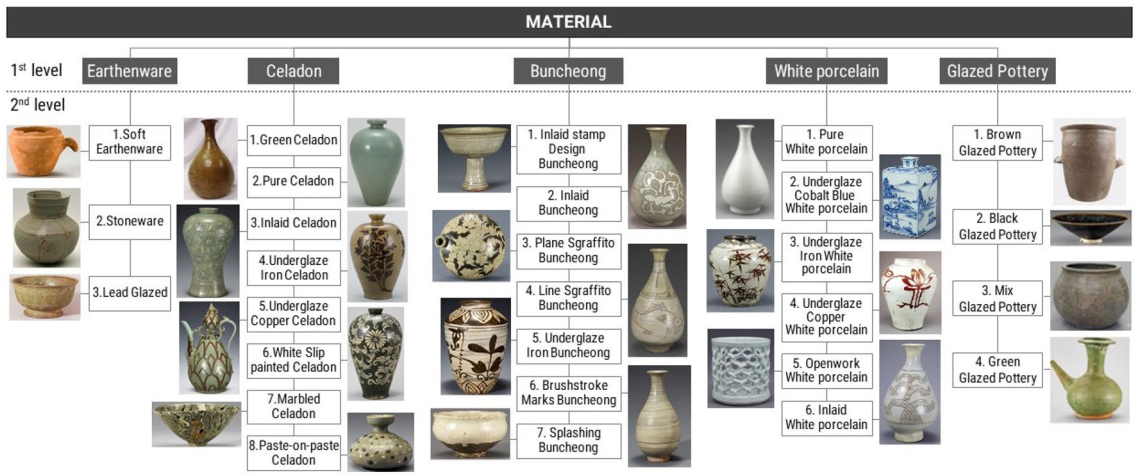


Fig. 9 *Material classification categories of Korean pottery and ceramics* [1]

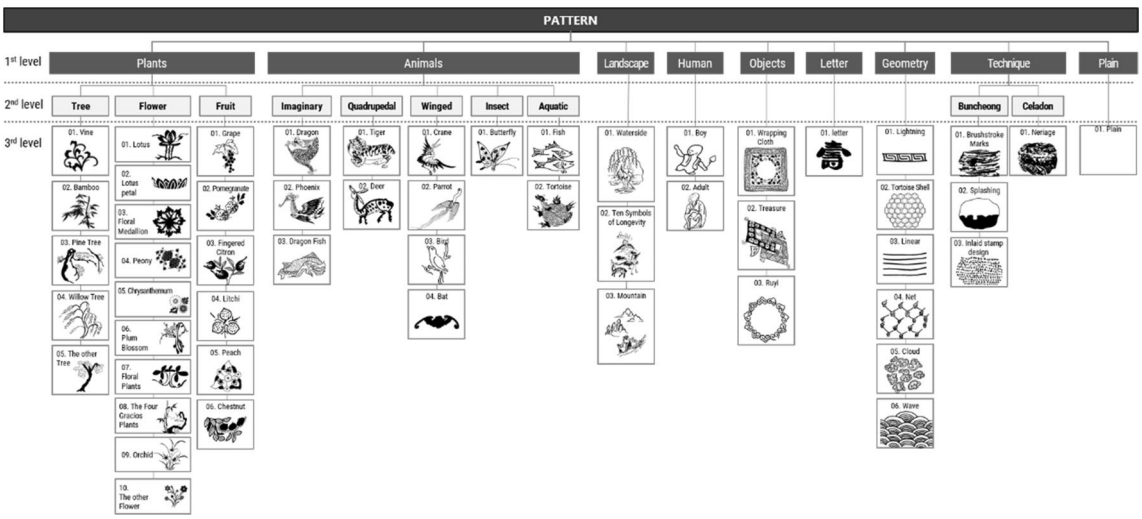


Fig. 10 Pattern classification categories of Korean earthenware and ceramics [1]

Fig. 11 Pattern arrangement types

throughout a ceramic. In addition, two or more patterns were arranged in combination as well.

2nd stage: acquiring ceramic data

In order to find out visual currents in Korean pottery and ceramics by applying the systematized pottery and ceramic classification system, data on the appearances of pottery and ceramics around the nation were acquired. From the eMuseum website[43] managed by both the Ministry of Culture, Sports and Tourism and the National Museum of Korea, where artifacts at museums can be searched for, 109,190 items of information on and images of artifacts housed in national museums across the country were downloaded. In addition, private museums were visited, and artifacts were photographed on site by the present researchers. Out of the 109,190 downloaded items of artifact data, black and white photographs, scanned images of printed photographs, data on damaged, and therefore partial artifacts, and data whose periods or national origins were beyond the scope of the present study were excluded. Thus, only 5,211 items were usable in the end. In addition, ceramic artifacts housed in the exhibition halls of over 19 organs nationwide were selected and personally photographed, thus leading to an acquisition of 2,135 items of ceramics. In total, information on and images of 7346 ceramics were acquired (Fig. 12).

3rd stage: creating metadata annotated with ceramic visual elements classification system

After the acquisition of ceramic data, as shown in Fig. 13, annotation work was performed on 7,346 pieces of pottery and ceramic using the visual elements classification system.

As shown in Fig. 13 above, each collected ceramic was annotated by applying a visual element classification system. In addition, information on size, basic classification, period, and holding institution was also organized.

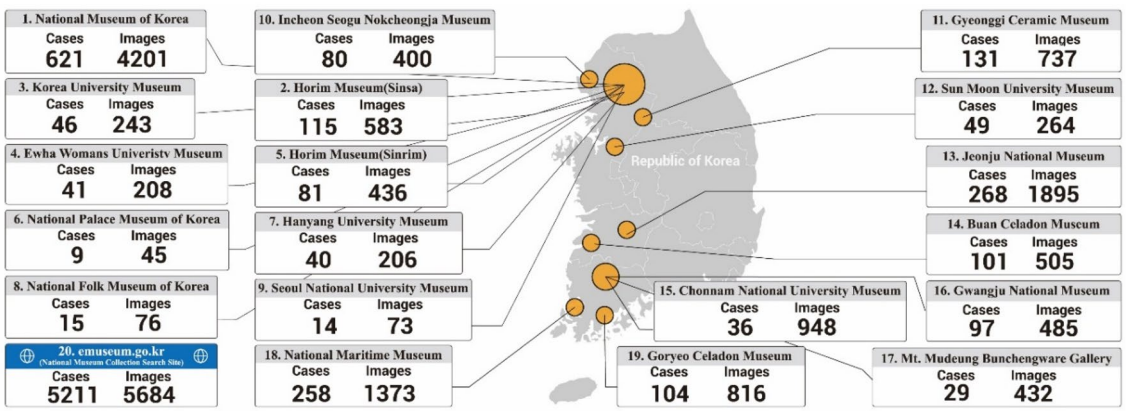


Fig. 12 Ceramic data acquisition locations

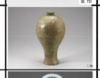
no	Image	Collection Number	Code	Korean Name	Form Category		Material Category		Pattern Category			Size	Classification	Period	Holding Institution
					Form 1st	Form 2nd	Material 1st	Material 2nd	Pattern 1st	Pattern 2nd	Pattern 3rd				
6747		Zn_007088-00	Zn	청자 표형 연적	Ewer	PyoHyeong JuJeonJa (dubble gourd body shaped ewer)	Celadon	Pure Celadon	Plain	Plain	Plain	H: 6.8cm, MW: 5.3cm, CW: 2.7cm	dietary life - food utensils - food - ewer	Goryeo	National Museum of Korea
6748		Zn_007089-00	Zn	청자상감 당초문 유병	Bottle	YuByeong (small & short globular body shaped bottle)	Celadon	Inlaid Celadon	Plants	Tree	Vine	H: 5.1cm, TW 2.58cm, MW: 8.07cm, BW: 4.7cm	dietary life - food utensils - food - bottle	Goryeo	National Museum of Korea
6749		Zn_007090-00	Zn	청자상감 뇌문 유병	Bottle	YuByeong (small & short globular body shaped bottle)	Celadon	Inlaid Celadon	Geometry	Geometry	Lightning	H: 4.2cm, TW 2.24cm, MW: 7.4cm, BW: 3.7cm	dietary life - food utensils - food - bottle	Goryeo	National Museum of Korea
6750		Zn_007091-00	Zn	청자 연리문 완	Bowl	DaeJeop (soup bowl)	Celadon	Marbled Celadon	Technique	Celadon	Neriage	H: 4.9cm, TW 10.7cm, BW: 2.1cm	dietary life - food utensils - food- bowl	Goryeo	National Museum of Korea
6751		Zn_007092-00	Zn	「최원·용개」명 분청사기 상감 용문 매병	Bottle	MaeByeong (globular upper body part shaped bottle)	Buncheong	Inlaid Buncheong	Animals	Imaginary	Dragon	H: 30.3cm, TW 5.0cm, BW: 9.54cm	dietary life - food utensils - food - bottle	Joseon	National Museum of Korea
6752		Zn_007093-00	Zn	백자 주자	Ewer	GuHyeong Jujeonja (globular body shaped ewer)	White porcelain	Pure White porcelain	Plain	Plain	Plain	H: 19.1cm, MW: 15.9cm, CW: 7.8cm	dietary life - food utensils - food - ewer	Joseon	National Museum of Korea
6753		Zn_007094-00	Zn	백자 푼주	Bowl	DaeJeop (soup bowl)	White porcelain	Pure White porcelain	Plain	Plain	Plain	H: 22.1cm, TW 35.1cm, BW: 16.4cm	dietary life - food utensils - food- bowl	Joseon	National Museum of Korea
6754		Zn_007095-00	Zn	백자 제기 접시	Dish	GoopDaRiJeopSi (long-legged dish)	White porcelain	Pure White porcelain	Plain	Plain	Plain	H: 13.2cm, TW 35.4cm, BW: 12.7cm	social life - ritual life - rite - rite utensil	Joseon	National Museum of Korea
6755		Zn_007097-00	Zn	백자 전접시	Dish	JeonJeopSi (flat edge shaped flare rim dish)	White porcelain	Pure White porcelain	Plain	Plain	Plain	W: 24cm, BW: 10.9cm, H: 2.6cm	dietary life - food utensils - food-dish	Joseon	National Museum of Korea
6756		증007098-00	Zn	백자 청화 풍경문 접시	Dish	JikGuJeopSi (straight rim dish)	White porcelain	Underglaze Cobalt Blue White porcelain	Landscape	Landscape	Mountain	W: 18.8cm, BW: 13.4cm, H: 3.8cm	dietary life - food utensils - food-dish	Joseon	National Museum of Korea

Fig. 13 Annotation work sample

4th stage: analyzing the preferred visual elements between the Goryeo and Joseon dynasties through statistical analysis

In this step, statistical analysis was performed with the metadata annotated with the ceramic visual element classification system in the previous step. In order to find the characteristics of the visual elements of Korean ceramics, except for eras when pottery was used, a statistical analysis of all visual elements used during the Goryeo and Joseon Dynasties was conducted. Through statistics on forms, patterns, and materials per era and changes to visual elements used during both periods were compared and analyzed. In addition, visual elements used in the two Dynasties were arranged in chronological order, and the entire flow was analyzed comprehensively.

Statistical results on ceramic forms during the Goryeo and Joseon dynasties

Form categories were applied to ceramics from the Goryeo and Joseon Dynasties, periods when representative Korean ceramics were produced, and the numbers were summarized per type. As shown in Table 2 below, ceramics used mainly in Goryeo and Joseon, respectively, were summarized according to their prevalence. As for forms, bottles (649), bowls (618), dishes (322), cups (279), jars (182), ewers (163), and lidded bowls (149) were the most frequent in Goryeo. In Joseon, ceramics were prevalent in the following order: bottles (738); bowls (692); jars (667); dishes (430); lidded bowls (129); cups (116); and ewers (47). When the characteristics of each subcategory are examined, it was found that the types preferred in each era were different.

Statistical results on ceramic materials during the Goryeo and Joseon dynasties

As for the characteristics of materials in Table 3, it was apparent that celadon was mainly used in Goryeo, and buncheong and white porcelain were mainly used in Joseon. As for celadon and white porcelain, patternless pure celadon and pure white porcelain were commonly used. As for buncheong, equally prevalent were ceramics using diverse surface ornamentation techniques. As for celadon, pure celadon and inlaid celadon were used the most. As for buncheong, inlaid-stamp-design buncheong were used the most, with the remaining types of buncheong being used in similar proportions. As for white porcelain, pure white porcelain was used the most, followed by underglaze-cobalt-blue white porcelain. As in the samples in Fig. 14 below, frequently used ceramic types per material were selected, representative ceramics were arranged, and their characteristics were examined.

Table 2. Statistics on the use of forms during the Goryeo and Joseon Dynasties

Function		Goryeo Dynasty (918~1391)			Chosun Dynasty (1392~1910)		
Bottle	1		30% (192/649)	YuByeong (Oil Bottle) Small & short globular body shaped bottle		30% (220/738)	OkHoChoonByeong Trumpet mouth & gourd lower body part shaped bottle
	2		24% (153/649)	JangGyeongByeong Long neck & globular-lower body part shaped bottle		28% (209/738)	JangGyeongByeong Long neck & globular-lower body part shaped bottle
	3		23% (149/649)	MaeByeong Globular upper body part shaped bottle		11% (80/738)	PyunByeong Flat body shaped bottle
	4		8% (55/649)	OkHoChoonByeong Trumpet mouth & gourd lower body part shaped bottle		6% (42/738)	DaGakByeong Polygon body shaped bottle
Jar	1		43% (78/182)	IpHo Globular upper body part shaped Jar		44% (294/667)	IpHo Globular upper body part shaped Jar
	2		33% (60/182)	NapJakHo Short body shaped Jar		30% (201/667)	WonHo Moon shaped Jar
	3		13% (24/182)	WonHo Moon shaped Jar		24% (159/667)	NapJakHo Short body shaped Jar
	4		10% (18/182)	TaHo (Spit Jar) Wide dish mouth shaped jar		1% (7/667)	TaHo (Spit Jar) Wide dish mouth shaped jar
Dish	1		39% (125/322)	JeolYoJeopSi Flare rim dish		77% (331/430)	JeolYoJeopSi Flare rim dish
	2		23% (75/322)	JikGuJeopSi Straight rim dish		8% (34/430)	GupDaRiJeopSi A long-legged dish
	3		18% (57/322)	JeonJeopSi Flat edge shaped flare rim dish		4% (19/430)	JikGuJeopSi Straight rim dish
	4		14% (44/322)	HwaHyeongJeopSi Flower rim shaped dish		4% (19/430)	JeonJeopSi Flat edge shaped flare rim dish
Bowl	1		91% (562/618)	DaeJeop Flare rim bowl		72% (501/692)	DaeJeop Flare rim bowl
	2		8% (48/618)	Bal Straight rim bowl		26% (178/692	Bal Straight rim bowl
Cup	1		31% (86/279)	Wan Bowl shaped cup		34% (39/116)	Jan Cup
	2		28% (78/279)	TakJan Saucer attached cup		22% (25/116)	GoJokBae A long-legged cup
	3		18% (49/279)	Jan Cup		16% (18/116)	TakJan Saucer attached
	4		10% (29/279)	TongHyeongJan Cylinder shaped cup		14% (16/116)	Wan Bowl shaped cup
Lidded Bowl	1		77% (114/149)	TongHyeongHap Cylinder shaped lidded bowl		62% (80/129)	BanHap Lidded bowl
	2		12% (18/149)	HwaHyeongHap Flower shaped lidded bowl		21% (27/129)	TongHyeongHap Cylinder shaped lidded bowl
	3		8% (12/149)	BanHap Lidded bowl		12% (16/129)	BangHyeongHap Square shaped lidded bow
Ewer	1		23% (38/163)	PyoHyeong JuJeonJa Dubble gourd body shaped ewer		45% (21/47)	GuHyeongJujeonja Globular body shaped ewer
	2		22% (36/163)	ByeongHyeong JuJeonJa Bottle body shaped ewer		19% (9/47)	HangARiHyeongJuJeonJa Jar body shaped ewer
	3		20% (32/163)	MulBangUlHyeong JuJeonJa Waterdrop shaped ewer		13% (6/47)	ByeongHyeongJuJeonJa Bottle body shaped ewer
	4		12% (20/163)	GwaIlHyeongJuJeonJa Korean melon shaped ewer		9% (4/47)	DongMulHyeongJuJeonJa Animal shaped ewer

With celadon, the inlay technique, where the surfaces were engraved and colors were inserted, was mainly used instead of directly painting on the surfaces. With the inlay technique, the surfaces of vessels are ornamented by being dug out and filled with white and black earth (inlay clay). Appearing in the transition period between

Fig. 14 Frequently used ornamentation techniques per material

celadon and white porcelain, buncheong were ceramics where the surfaces of gray or gray-black clay bodies were dressed with engobe (dressed with white clay), glazed, and baked, and diverse production methods, such as the stamping method, sgraffito method, and drawing method, were used on clay bodies coated white. On the contrary, with white porcelain, the drawing method was frequently used on white ceramics. This most probably was because white ceramics were perceived as akin to sketchbooks and painted. In contrast, because celadon is dark in color, painting directly on ceramics does not seem to have been favored.

Statistical results on ceramic patterns during the Goryeo and Joseon dynasties

When the statistical results on patterns in Table 4 are examined, types frequently used in both periods were plant types, with floral types used the most. In both eras, out of plant patterns, much used were vine patterns, which were used frequently as auxiliary patterns. In Goryeo, chrysanthemums, peonies, and lotuses (lotus petals + lotuses) were frequently used. Because of the influence of Buddhism, the state religion, Goryeo seems to have been characterized by the frequent use of lotuses, and chrysanthemums appear mainly on inlaid celadon. Joseon used peonies, floral plants, chrysanthemums, and lotuses. Grapes were used together with those of boys in Goryeo but were used singly in Joseon. As for animals, it is apparent that both ages frequently used winged animals. Goryeo used cranes the most, and Joseon used dragons the most. As for landscape types, watersides were commonly used in Goryeo, and these patterns were frequently used especially on celadon JeonByeong (bottle 10). In Joseon, landscapes were commonly used. As for human patterns, mainly boys were used in Goryeo, and mainly adults were used in Joseon. As for objects, Goryeo frequently used patterns of both ruyi (ceremonial scepter), a Buddhist symbol, and treasures, and Joseon frequently used patterns of treasures. As for letter patterns, Joseon used them more than in Goryeo. As for geometric patterns, they were commonly used in both periods as repetitions or auxiliary patterns rather than as independent patterns. Out of them, linear patterns were used the most during both periods, followed by cloud patterns.

When examples of actual artifacts used by type and period in Fig. 15 are examined, patterns were simpler in Goryeo than in Joseon because the former age mainly used the inlay technique. In comparison, Joseon used the drawing technique, thus rendering patterns more complex, and used thicknesses of lines and shading in colors, thus yielding far more pictorial depictions.

Result: the overall change and flow of visual elements of Korean ceramics

When the statistical tables in Fig. 16 per visual element are examined by period in terms of each of the currents in the use of the visual elements of ceramics, they are as in the following tables. The visual elements of ceramics frequently used per era are listed. Through these timetables, it is possible clearly to distinguish currents in celadon, buncheong, and white porcelain.

The ceramics mainly produced during the Goryeo Dynasty were celadon. With the production of celadon in Goryeo era, some white porcelain was produced as well. However, early white porcelain failed to be sufficiently vitrified at celadon firing temperatures due to differences in the components so that ceramics were low in both strength and workmanship. Early celadon and white porcelain were produced in the same kilns, and the kilns' firing temperatures were of a standard appropriate for celadon. Sufficiently sintered, high-quality celadon vessels were preferred and were developed. As for celadon, plain, patternless vessels came to take up the majority.

Table 3. Statistics on the use of materials during the Goryeo and Joseon Dynasties

Material Category				**Goryeo Dynasty** (918~1391)	**Chosun Dynasty** (1392~1910)
Celadon	1		Pure celadon	43% (979/2252)	
	2		Inlaid celadon	34% (758/2252)	
	3		Underglaze iron celadon	7% (150/2252)	
	4		Green celadon	6% (146/2252)	
	5		Paste on paste celadon	1.46% (33/2252)	
	6		White slip painted celadon	0.57% (13/2252)	
	7		Underglaze copper celadon	0.35% (8/2252)	
	8		Agateware celadon	0.26% (6/2252)	
Buncheong	1		Inlaid stamp design buncheong		29% (218/740)
	2		Sgraffito buncheong(Line)		17% (126/740)
	3		Brushstroke marks buncheong		14% (107/740)
	4		Underglaze iron buncheong		13% (94/740)
	5		Inlaid buncheong		12% (87/740)
	6		Splashing buncheong		11% (79/740)
White Porcelain	1		Pure white porcelain		42% (833/1961)
	2		Underglaze cobalt blue white porcelain		38% (743/1961)
	3		Underglaze iron white porcelain		7% (138/1961)
	4		Underglaze copper white porcelain		2% (39/1961)
	5		Inlaid white porcelain		0.96% (19/1961)
	6		Openwork white porcelain		0.25% (5/1961)

Pure celadon was ornamented with floral patterns of lotus leaves and peonies through the method of intaglio. As for the forms of ceramics, as with samples of ewers in Fig. 6, the clay bodies of celadon were high in plasticity, which is the strength maintaining the forms of clay bodies, so that it was possible to create detailed and elaborate forms in the process of shaping forms with earth. Because Joseon ceramics were lower in plasticity than Goryeo ceramics, simple forms were shaped and depicted through pictorial techniques. Starting in the fifteenth century, there arose a transition period in which buncheong was produced and used together. Ceramics turned to inlaid buncheong, inlaid stamp design buncheong, and sgraffito buncheong, where the surfaces were ornamented with white porcelain clay and the inlay method of celadon was used. This technique continued into inlaid white porcelain out of white porcelain. Brushstroke marked buncheong and splashing buncheong naturally led to white porcelain. As is apparent in Fig. 16 above, with the transition into the Joseon Dynasty, mainly white porcelain came to be produced. This was because Confucianism, the ideological basis of Joseon, well matched the pure image of white porcelain. In addition, under this dynasty, white porcelain came to be produced systematically, with a focus on

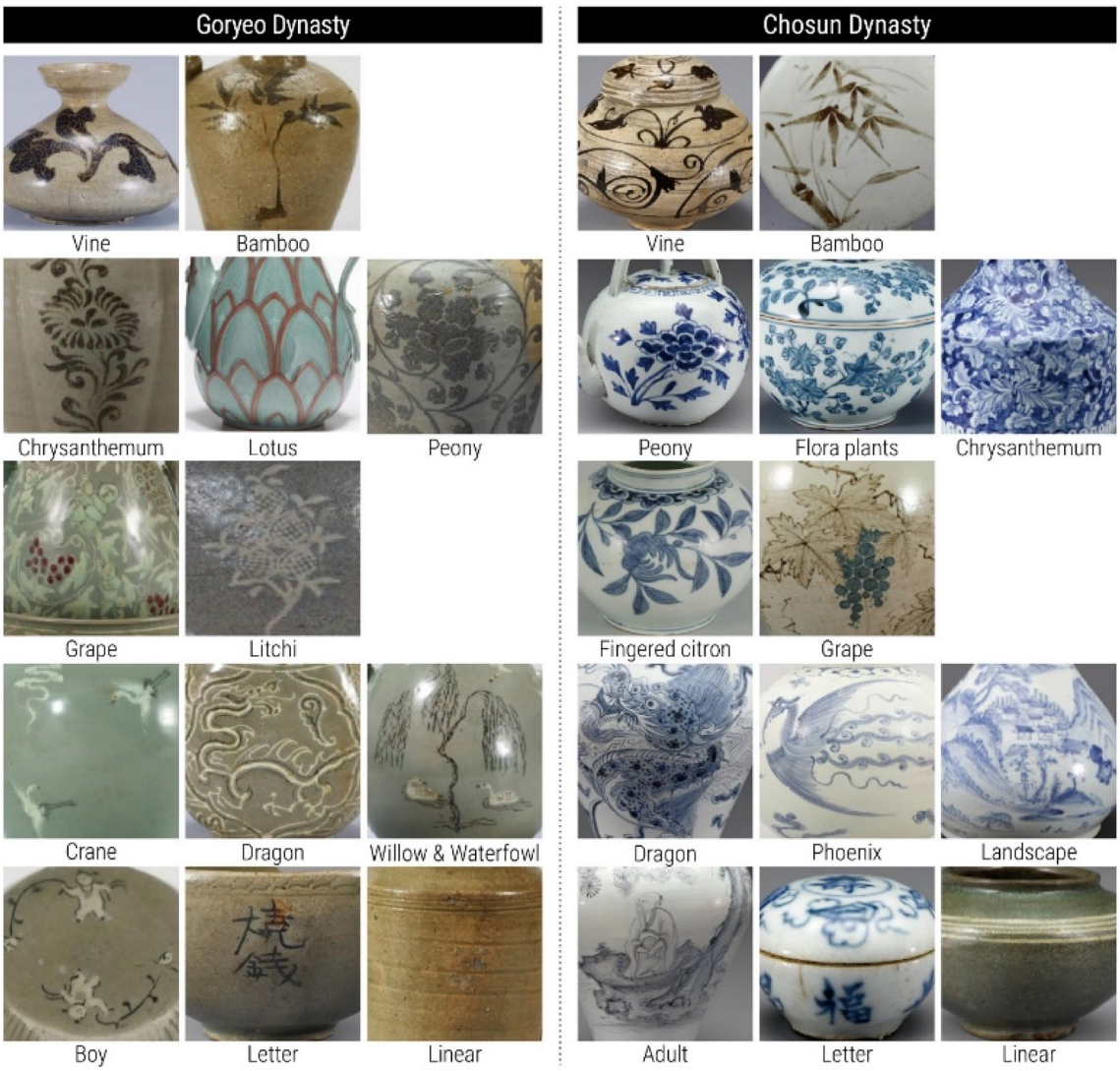


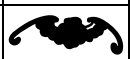
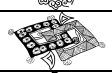
Fig. 15 Statistics on the use of patterns during the Goryeo and Joseon Dynasties

the Bunwon (government-operated ceramic production center) producing white porcelain for the royal household under state leadership. Accordingly, the production of kilns as well as firing techniques and component refining techniques developed and high-purity white porcelain clay came to be used, thus leading to the development of white porcelain. In addition, pictorial patterns on cobalt blue white porcelain, or white porcelain bearing paintings in the cobalt blue pigment, developed because court painters affiliated with the Dohwaseo, the state organ for art, were in charge of patterns. The brown paintings on underglaze iron white porcelain came to replace paintings in the cobalt blue pigment because the latter material, an import, could not be easily supplied. Thus, with Joseon ceramics, painting on the surfaces of celadon ceramics was preferred rather than engraving patterns on them.

Conclusion

Among extant historical artifacts, ceramics take up the largest share. Consequently, they are the best materials for grasping currents in the visual elements of the past. It is possible to confirm: functions needed according to contemporary society and culture, even for identical usage; form production methods manifesting themselves differently according to the characteristics of disparate clay bodies; materials differing according to contemporary circumstances and techniques; and differences in preferred patterns and pattern depiction techniques per era.

Table 4. Statistics on the use of patterns during the Goryeo and Joseon dynasties

			Goryeo Dynasty (918~1391)			Chosun Dynasty (1392~1910)		
Plants	Tree	1		**87%** (115/132)	**Vine**		**74%** (148/200)	**Vine**
		2		**7%** (9/132)	**Bamboo**		**17%** (34/200)	**Bamboo**
	Floral	1		**35%** (327/934)	**Chrysanthemum**		**23%** (126/557)	**Peony**
		2		**28%** (264/934	**Lotus**		**23%** (113/557)	**Flora plants**
		3		**23%** (217/934)	**Peony**		**10%** (53/557)	**Lotus**
	Fruits	1		**35%** (327/934)	**Grape**		**23%** (126/557)	**Fingered citron**
		2		**23%** (217/934)	**Litchi**		**20%** (113/557)	**Grape**
		3					**10%** (53/557)	**Chestnut**
Animals	Imaginary Animals	1		74% (23/31)	**Dragon**		77% (89/116)	**Dragon**
		2		74% (8/31)	**Phoenix**		22% (25/116)	**Phoenix**
	Winged Animals	1		77% (82/107)	**Crane**		45% (17 /38)	**Bird**
		2		15% (16/107)	**Parrot**		37% (14/38)	**Crane**
		3		8% (9/107)	**Bird**		18% (7/38)	**Bat**
Landscape		1		98% (54/55)	**Willow & Waterfowl**		53% (40/76)	**Landscape**
		2					36% (27/76)	**Ten symbols of Longevity**
Human		1		75% (12/16)	**Boy**		100% (4/4)	**Adult**
Object		1		53% (8/15)	**Ruyi**		90% (26/29)	**Treasure**
		2		40% (6/15)	**Treasure**			
Letter				100% (21/21)	**Letter**		100% (132/132)	**Letter**
Geometry				59% (62/105)	**Linear**		58% (49/84)	**Linear**
				21% (22/105)	**Cloud**		20% (17/84)	**Cloud**
				15% (16/105)	**Lightning**		7% (6/84)	**Net**

During the Goryeo Dynasty, earth was highly plastic so that sensitive work with forms was possible, and techniques, such as inlay, were preferred in depicting patterns. As for buncheong, it was possible to confirm a whitening process in celadon, as with white porcelain, and the free use of diverse techniques for depicting patterns. It was possible to confirm that the earth used for white porcelain was low in plasticity so that simple

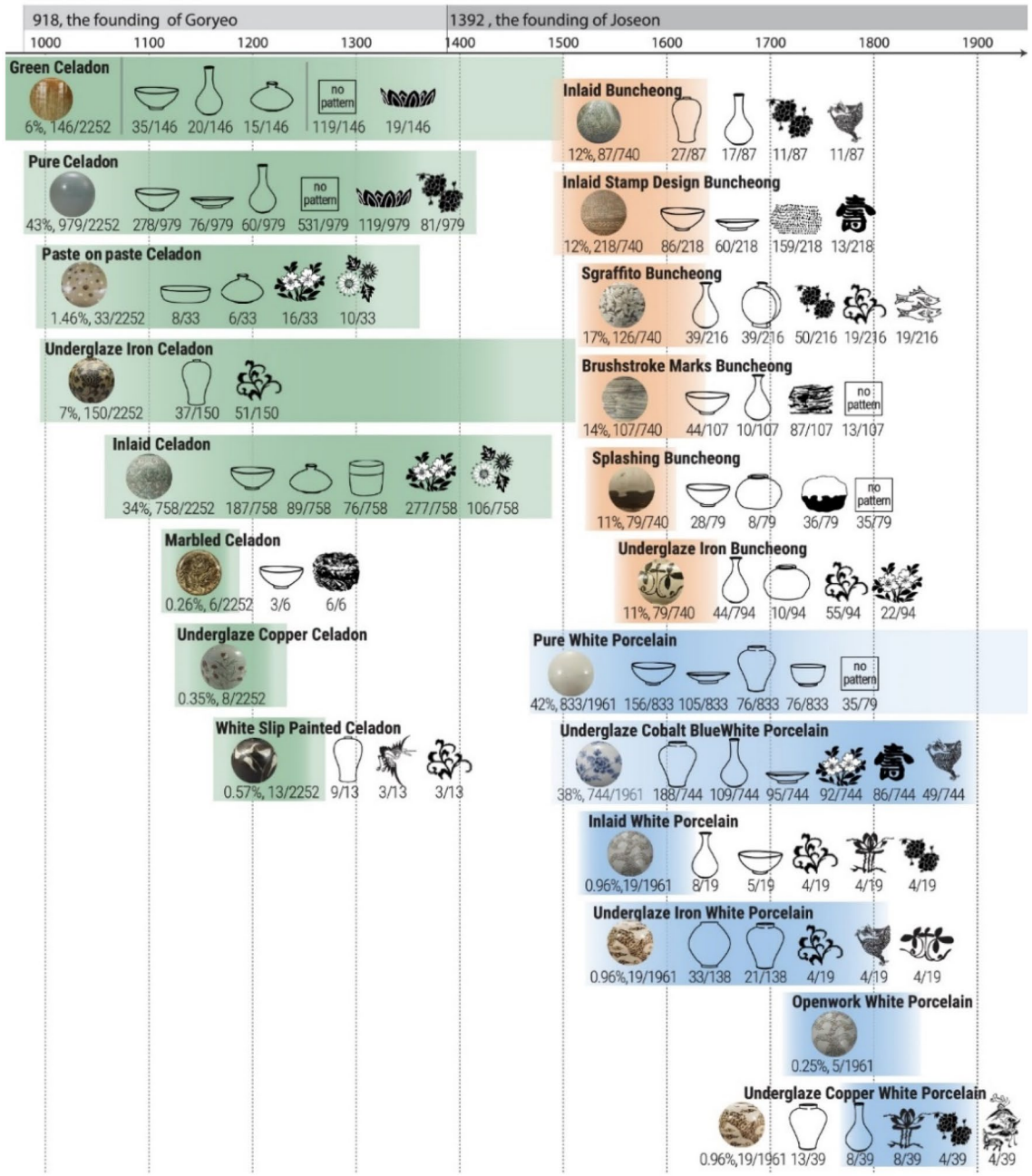


Fig. 16 Table of currents in the visual elements of Korean ceramics

forms were preferred, and patterns were depicted very delicately using the drawing technique. It was possible to confirm that the results of people's creative activities, such as ceramics, were the results of relevant combinations of visual elements such as functions, forms, materials, and patterns.

As with the analysis of visual elements of cultural artifacts, it is necessary to overcome the limitations of the existing archeological analysis of cultural property and to quantify and structure artifacts systematically from a more intuitive and contemporary perspective. When data annotating artifacts' visual element classification system is put to good use, objective explorations and statistical interpretations of artifacts become possible. In fact, by converging AI technology on the basis of ceramic classification system annotation data,

the present researchers developed the Smart Culture Lens application, which automatically analyzes the visual elements of photographs of surrounding ceramics taken by the user [1]. This app was favorably evaluated by users as allowing them to obtain information on artifacts from an intuitive perspective. In order to apply/test the future convergence of state-of-the-art technology, such as AI technology, and culture in the future to the vast cultural heritage data as well, it is necessary to reproduce them as cultural data with labels from a variety of perspectives that are usable. From this perspective, the present study presented visual elements for turning artifacts into data, the most basic basis for classification systems.

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Author contributions
JHY (First & Corresponding author), HL (Second author), SK (Third author). All authors read and approved the final manuscript.

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Declarations

Competing interests
The authors declare that they have no competing interests.

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