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An Ontological Approach for Creating a Brassware Craft Knowledge Base

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ABSTRACT Terengganu brassware is a local craft product with high artistic value and traditional craftsmanship that involves a lot of creativity and elaborate artistry. This cultural heritage is in danger of disappearing because the current younger generation lacks interest, creativity and artistic skills to continue the craftsmanship. Therefore, gathering detailed knowledge of the craft from ageing practitioners can preserve the heritage. This article reports the study on brassware intangible heritage knowledge base development using an ontological approach. The ontology modelling used Ontology Development 101. Content validation result by experts found that the brassware ontology is complete, consistent, concise, precise and clear. Evaluation results show that the experts agreed on content representation (mean $\geq$ 3.80), and the ontology meets all the quality criteria (mean $\geq$ 4.03). The brassware craft ontology contributes to the intangible heritage preservation effort for one of the almost extinct local culture and practices. This intangible heritage knowledge base can be applied for the development of semantic search, mobile and gaming applications to attract and disseminate heritage information to young people. Additionally, the ontological design can serve as a guide for the design and development of a knowledge base for other types of heritage.

INDEX TERMS Intangible cultural heritage, knowledge base, knowledge representation, ontology evaluation.

I. INTRODUCTION

This article is an extended version of an earlier work [1]. In the previous paper, we briefly discussed ontology modeling of intangible cultural heritage Terengganu brassware craft and verification of the ontology using SPARQL query. In this article, we discussed further the development of the brassware craft knowledge base that begins with data gathering, ontology modeling, and ontology evaluation. We elaborate on brassware craft data gathering from domain experts using interview and observation techniques. Next, we discuss in detail the ontology modeling using Ontology Development 101 (OD 101) method according to the phases. Finally, we explain the results of modeling, namely brassware craft ontology and the evaluation conducted on brassware craft ontology. Evaluation is performed by a group of domain experts to assess the validity of the content and the quality of the ontology.

In recent years, the progress of technology and the Internet has dramatically facilitated knowledge management in cultural heritage. The utilization of current technology, for example, a knowledge base, has a potential to preserve cultural heritage knowledge effectively and systematically. A knowledge base is a centralized repository for information or a database of specific subjects [2]. It also can be defined as a collection of knowledge about the world processed by computers [3]. Since cultural heritage, especially intangible heritage has a great deal of experience to preserve, the utilization of a knowledge base as a medium of digital preservation and documentation is significant. One of the lesser-known domains in intangible cultural heritage is traditional craftsmanship which includes the skills and knowledge involved in

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craftsmanship to produce a craft product. Locally, there are several well-known crafts such as silver, brassware crafts and songket weaving.

Brassware craft is a traditional craft product with a high artistic value which involves immense creativity and meticulous artistry. It is a cultural heritage inherited from generation to generation. The brassware craft industry can be traced back to more than 300 years to a cottage industry among the Malay community. Brassware craft first arrived in Terengganu through trading activities in the Straits of Malacca. The Minangkabau people in Negeri Sembilan originally produced this craft [4]. However, another view was that the art originated from Funan, China, travelling with the people that migrated from the area during Dong Son's turbulent time [4]–[6].

Brassware craftsmanship shows the perfect blend of hand skills, the sharpness of mind, and the creativity of its skilled craftsmen. The artistic and aesthetic characteristics of their craft products showcased the distinctiveness of the Malay culture, whereby the expression of each trait used symbols and identity, etched onto the products [7]. In the past, Terengganu artisans produced brassware craft products known as Peninsular Malay art, which reflect the character and shape of prominent artistic creativity [8]. The golden age of the craft industry began in the palace when the Sultan empowered craftsmen as palace artists, making the Sultan the guardian of the craft at the time [6]. The craftsmen were based in the palace and produced products that the castle needed [9]. The Sultan also invited foreign artisans to teach his people the knowledge of craftsmanship. Thus, the Sultan inspired the people to produce craft such as weaving and brassware craft [6], [10].

However, traditional craftsmanship is almost extinct because young people are not interested in continuing this valuable traditional legacy [11]. Many factors have contributed to this situation; firstly, globalization has introduced many foreign cultures that lead the younger generation to lose interest in their cultural heritage. Secondly, brassware craftsmanship is currently at a critical stage because many experienced and active artisans are old (more than 50 years) and some renowned ones have passed away, thus burying their knowledge of the craft with them. Brassware craftsmanship is a family business, taught by apprenticeship from father to son; therefore, once the father died, the knowledge and experience died with him if the son does not continue the work. Lastly, the market demand for brassware products has dwindled due to society's lack of appreciation and knowledge regarding the value of brassware crafts. For instance, most consumers are reluctant to pay high prices for brassware products [12].

Therefore, this study aims to acquire Terengganu brassware craftsmanship (knowledge and skills) from the practitioners and to store them in a knowledge base. The ontological approach is most suitable for this purpose. The manipulation and transferring of knowledge can ensure that this heritage will be accessible and preserved for future generations. This article presents the design and development of a brassware craft knowledge base, starting with the acquisition of knowledge from the practitioners. Then, the modelling of the ontology used Ontology Development 101 (OD 101) method. Next, the validation of the brassware craft ontology involves evaluation of the content, based on quality criteria such as complete, consistent, concise, precise, and clear. Eventually, other applications such as mobile applications and semantic search and game applications, for the dissemination of the knowledge to attract the younger generation can use this ontology. Moreover, this ontological design could also serve as a guide for designing and developing a knowledge base for other types of intangible heritage.

This research made two contributions to the field of cultural heritage and informatics. The first is the processes and methodology used to design and develop the brassware craft knowledge base using an ontological approach. To our knowledge, there is no such study on ontological modelling of traditional craftsmanship; thus, this is the first study to do so. Another contribution of this study is the evaluation method, which involves validation from a group of specialists. The specialists validated the ontology content and evaluated ontology quality.

This article is structured as follows; Section 2 discusses related works on cultural heritage ontology, Section 3 describes the methods employed for developing this ontology, Section 4 presents the outcome of the brassware craft ontology and Section 5 explains the evaluation of the ontology and discusses the results of the assessment. Finally, Section 6 summarizes the study reported here and recommends directions for future works.

II. RELATED WORK

There are numerous definitions of ontology proposed in the past. Gruber [13] described ontology as a precise and formatted description of a shared concept, or an approach to represent knowledge, which could be shared to create a shared vocabulary for various applications [14]. According to [15], an ontology can model domains such as the type of objects or concepts and the object properties and relationships. Moreover, an ontology may provide a model—known as a knowledge representation model—that has already been effectively applied in different knowledge fields [16]. The main advantage of an ontology is that it enables the sharing of a shared understanding of information structures between humans or software agents and enables the knowledge domain to be reused [13], [17]–[20]. Therefore, shareability and reusability are the reasons for choosing ontology to represent knowledge.

To date, various ontology models have been designed and implemented across several knowledge domains, e.g., the medical, financial, geographical, and cultural heritage fields. An established ontology has been introduced for cultural heritage by Doerr [21], specifically the CIDOC Conceptual Reference Model (CRM). Extending existing ontology using CIDOC CRM can indicate the diversity of cultural

heritage knowledge. CIDOC CRM can also formally define and provide structure when representing concepts or relationships in the cultural heritage domain. CIDOC CRM could be used to perform multiple processes such as the integration, intervention, and interchange of numerous cultural heritage information with digital libraries and archive data. However, only a few (less than 5%) past researches had applied this model and only to the museum's environment [22], [23].

Besides CIDOC CRM, other cultural heritage models have been developed, such as the Pang Wang Festival Ontology [24], the Cultural Heritage Repository [25] and the Balinese Kulkul Ontology [26]. Sitthisarn *et al.* [27] have developed an ontology for folk wisdom and intangible cultural heritage in Phatthalung Province. The Pang Wang Festival Ontology focuses on social practices, rituals, and festive events [24]. The main aim of this ontology is to preserve traditional festival knowledge for future generations. The Pang Wang Festival Ontology used the CIDOC CRM method of selecting concepts and relationships based on the features of this intangible cultural heritage - place, time, type, activity, event, and document.

The study from Jamaludin and Zakaria [25] has developed a Cultural Heritage Repository based on an ontology that emphasized the tangible objects of cultural heritage. This ontology aimed to enable semantic knowledge representation and for searching in an information retrieval system. The ontology consists of physical objects listed as national heritage objects such as *Panji Di Raja (royal flags), Keris Panjang Di Raja, Tengkolok Di Raja, Gandik Di Raja,* and *Pending Di Raja* (Royal belts). The ontology development method was adapted from Öhgren [28], which is appropriate for small- and medium-scale applications. Then, the ontology was applied in an information retrieval system prototype to evaluate its completeness.

In addition, there is also ontology developed by Kyvernitou and Bikakis [29] for cultural heritage artefacts named GenderedCHContents. The ontology was designed by extracting relevant concepts from five different artefacts depicting Pandora and developed by extending the Europeana Data Model (EDM). However, this ontology focused on tangible cultural heritage on gendered concepts in cultural heritage resources to draw attention to the presence of women within CH artefacts.

Furthermore, the Balinese Kulkul Ontology contains the Kulkul, nonverbal communication practices of the traditional Balinese community in Indonesia. It has likewise been inadequately documented and is fragmented [26]. This ontology was developed from scratch using an ontological approach that allowed for the flexible expansion of knowledge since the Kulkul gathering occurred in several phases. Then, the ontology was transformed into a digital portal prototype to support the semantic navigation and search facilities in the prototype.

The most recent work in this field focused on intangible cultural heritage and folk wisdom in Phatthalung Province, Thailand by [27]. The ontology contains only the performing arts, traditions, beliefs, rituals, and literature. A corpus of cultural document annotations links the cultural heritage information across various dimensions based on these characteristics. Then, the experts assessed the structure and effectiveness of the ontology model. Table 1 summarizes the existing ontology in cultural heritage.

TABLE 1. Existing ontology in cultural heritage.

Ontology	Category	Domain
CIDOC CRM	Cultural heritage	General
Cultural Heritage Repository	Tangible cultural heritage	Tangible objects
GenderedCHContents	Tangible cultural heritage	Cultural heritage artefacts
Pang Wang Festival Ontology	Intangible cultural heritage	Social practices, rituals, and festive events
Balinese Kulkul Ontology	Intangible cultural heritage	Communication practices
Ontology for folk wisdom and intangible cultural heritage in Phatthalung Province	Intangible cultural heritage	Performing arts, traditions, beliefs, rituals, and literature

Despite the numerous ontologies developed, no ontology model has been specifically designed and developed for traditional craftsmanship. Therefore, this study aims to develop a knowledge base by ontologically modelling the traditional craftsmanship domain to preserve the dying brassware craftsmanship.

III. APPROACH

This section explains the ontology-based design and development of a brassware craft knowledge base. Figure 1 illustrated a two-phase methodology adopted to create the knowledge base. The first phase involved collecting the data, and the second phase was to model the data. In the first phase, interview and field observation were used to collect data from domain experts. The data collected was on brassware craft. Then, before starting Phase 2, the data was further analyzed. In Phase 2, Ontology Development 101 (OD 101) is used to model the collected data. The ontology was created in the Malay language since Brassware craft is a Malay cultural heritage. However, for the naming convention in this article, both English and Malay are used. The description of each phase is illustrated in Figure 1 and explained further in the following sections.

A. DATA GATHERING

The main objective of collecting data via the interview techniques was to acquire the knowledge of brassware crafts from practitioners. Additionally, field observations brought more detailed information on brassware crafts such as the artefacts, products, and production processes. These techniques are considered appropriate to the type of knowledge the researcher aims to collect, i.e., procedural knowledge, usually stored in the memory of the practitioners [30].

1) INTERVIEW

The interview technique helps the researcher gather and gain knowledge of the history, artefacts, products, and processes for producing brassware crafts, including the materials,

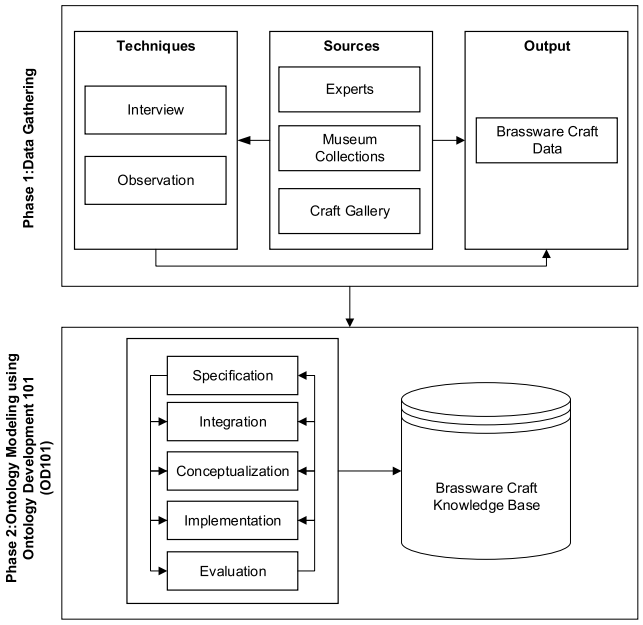

FIGURE 1. The methodology used to develop the Brassware craft knowledge base.

equipment, steps, and skills. Five experts involved were from the Terengganu State Museum (TSM), the Malaysian Craft Development Corporation (MCDC), and three artisans. Among the three craftsmen engaged in this interview are a master craftsman and two practicing craftsmen who have been actively sharing their knowledge with the public. These craftsmen were selected because the MCDC has recognized them as experts in their field. Information obtained is on the artefacts, history, and processes of brassware craft, besides the current state of brassware craft products.

Semi-structured interviews were employed as this method is useful when the interviewer has specific subjects and questions to ask since respondents can provide additional feedback based on their experiences [31]. A total of 20 items asked during the interview sessions cover three categories; the history of brassware craft, artefacts and brassware craft products, and the process of producing the works. The interview sessions were recorded for further analysis.

2) OBSERVATION

The observation technique was adopted to obtain more detailed information about the brassware artefacts, products, and production processes. Observations were carried out at several places in Terengganu state such as the Terengganu State Museum, the MCDC Terengganu Craft Gallery, the Sultan Mizan Royal Foundation Gallery, and Pasar Besar Kedai Payang (shop). More data of brassware artefacts and handicrafts were gathered from sites observations, including at the three brassware workshops, to collect data on traditional production processes of the brassware craft. Photographs, videos, and audios, in addition to the verbal notes emphasized during craft-making, were recorded. The data uploaded to a computer, cleaned and analyzed before proceeding to the next phase - ontology modelling.

TABLE 2. Competency questions on brassware craft.

No.	Competency questions
1	What is the Terengganu brassware craft artefact?
2	What are the uses of each brassware craft artefact?
3	What is the size of a brassware craft artefact?
4	When is the manufacturing date of the brassware craft artefact?
5	What is the category of the brassware craft artefact?
6	What is the type of motif on the brassware craft artefact?
7	Where does the Terengganu brassware craft originate?
8	When was the golden age of Terengganu brassware crafts?
9	What is the material used to produce Terengganu brassware craft?
10	What is the metal used to produce Terengganu brassware crafts?
11	What is the amount of the metal used, and what is the function of this metal?
12	What is the equipment used and its function in the production of Terengganu brassware craft?
13	What is the process of producing Terengganu brassware craft?
14	What are the steps involved in every process of Terengganu brassware craft production?
15	What is the description of each process of Terengganu brassware craft production?

B. ONTOLOGY MODELLING

Previous researchers have proposed several methods to model ontology such as the Ontology Enterprise [32], METHONTOLOGY [33], Ontology Development 101 (OD 101) [18], the CYC methodology [34], and UPON [35]. A comparative analysis of these methods was carried out by Iqbal *et al.* [36]. However, there is no one particular method for ontology modelling; only feasible alternatives [18], [37]. The best ontology depends on the model, the application of the ontology to be developed, and the ontology engineer's understanding and perception of the domain. This study used the OD101 method to model the brassware craft knowledge because it is more convenient, less structured, and flexible for representing the knowledge of a domain. The OD101 process consists of five phases; specification, integration, conceptualization, implementation and evaluation, as shown in Figure 1.

1) SPECIFICATION

In the specification phase, the researcher identified the specific area, the objectives, and the scope of the ontology. Traditional craftsmanship was selected as the ontology domain, focusing on brassware craft. The main aim of ontology development is to model the brassware craft knowledge as a knowledge base. Competency questions limit the scope of the ontology, and thus, the knowledge used to model the ontology. Competency questions are a set of fundamental questions on brassware craft posed in natural (Malay) language. The researchers developed these questions based on a discussion with domain experts and from the theoretical, public knowledge on brassware craft. Table 2 shows the 15 competency questions used in this study. The design of the items determines the scope of the brassware craft ontology.

2) INTEGRATION

An ontology can be developed manually from scratch or by integrating existing ontologies or automatic ontologies

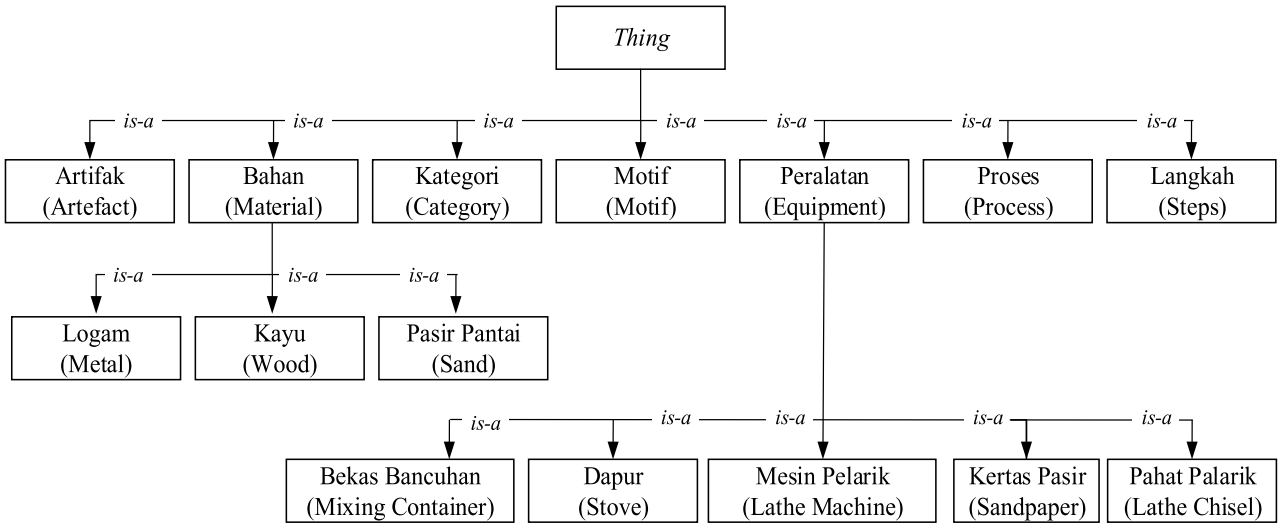

FIGURE 2. Class taxonomy of brassware craft.

known as ontology learning [38]. The integration phase involves using existing ontologies to model the new ontology. Several advantages of using existing ontologies include the creation of simple domain concepts, the achievement of enhanced solutions, and rapid development. Besides, existing ontologies serve as specific models to help with problem-solving [39]. Additionally, in some cases, an existing ontology can be implemented in a complete system for communication purposes, with more applications because the selected ontology or vocabulary already has established relationships [18].

In contrast, an ontology could also be developed from scratch if existing ontologies are not appropriate for integration into the study. This case could bring benefit to an organization because sometimes the expenses involved in adjusting to an existing ontology could be costlier than designing a new one [40]. In this study, the brassware craft ontology was developed from scratch because there is no suitable ontology available for integration. The CIDOC CRM guide the development of this ontology.

3) CONCEPTUALIZATION

In the third, conceptualization phase, the researcher records all the associated terms to be inserted into the ontology model to enumerate data collected in the previous step [41]. This process generates a complete list of keywords grouped under specific categories. For example, in the motif category, the subcategories are *Geometri* (Geometry) and *Floral* (Floral). Under *Kategori* (Category), the subgroups are *Cenderahati* (Souvenir), *Perhiasan* (Ornament), *Kegunaan Rumah* (Household), *Adat Istiadat* (Customs and Traditions), *Sejarah* (History), and *Zaman Kegemilangan* (Golden Age). Other categories include *Kegunaan* (Usefulness), *Saiz* (Size), *Artifak* (Artefact), *Bahan* (Material), *Proses* (Process), *Langkah* (Step), *Peralatan* (Equipment), and *Tahun Pembuatan* (Year of Manufacturing). These key terms then generate important concepts for brassware craft. Following the keywords identification, is the implementation activities involving class and the hierarchy class, and the class properties definition and creation of instances.

a: DEFINING THE CLASS AND THE CLASS HIERARCHY

A class is the phrase that represent the class. These selected terms come from a list of words derived from the previous activities. The phrase is recognizable by inspecting the name related to an object and not by merely explaining it [18]. For example, in this study, a predefined class under 'Thing' has several related terms - *proses* (process), *bahan* (material), *artifak* (artefact), and *peralatan* (equipment).

Next is the organization of these classes under a taxonomy. A taxonomy is a superclass-subclass hierarchy. According to Uschold and King [32], a class hierarchy representing different theories can be built either from the top-down, bottom-up or middle-out. The first method used defines the most common approach, followed by specific concepts. Meanwhile, the second method worked in contrast with the first method, beginning with a definition of the particular classes and then merging these specific classes into general concepts. The last technique unified both ways, starting with identifying the more significant ideas and then generalizing and specializing accordingly.

However, only the ontologist can select the best approach for the chosen domain. Therefore, this study applied the top-down approach because of the nature of brassware craft knowledge, where general knowledge is first defined, followed by specific knowledge. For example, the definition as part of brassware craft production, includes the concept of *Artifak* (Artefact), *Bahan* (Material), *Kategori* (Category), *Motif* (Motif), *Peralatan* (Equipment), *Proses* (Process), and *Langkah* (Steps). These are top-level concepts. Then, the identification of second-level concept under the Peralatan (Equipment) - *Bekas Bancuhan* (Mixing Container), *Dapur* (Stove), *Mesin Pelarik* (Lathe Machine), and so on. Figure 2 shows the class taxonomy for brassware craft.

Taxonomic relationships connect the classes in taxonomy, through namely subclass-of, superclass-of, disjoint class and

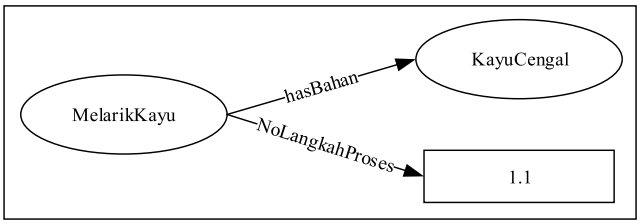

FIGURE 3. Data property and object property for *MelarikKayu*.

instance-of [18]. The ''is-a'' relation denote the subclass-of taxonomy. Class A is a subclass of B if each instance of A is the same as the instance in B. For example, *Bekas Bancuhan* (Mixing Container) is a subclass of the *Peralatan* (Equipment) class because each *Bekas Bancuhan* is under the *Peralatan* concept. Additionally, the inverse relationship to the sub-class is the superclass-of relationship. Thus, *Peralatan* is a superclass-of *Bekas Bancuhan.* The next item is the disjoint class relationship. This class describes a condition where one class cannot have the same instance as another class. This relationship allows the system to generate the ontology better. In this case, the *Artifak* (Artefact), *Bahan* (Material), and *Peralatan* (Equipment) classes are disjoint classes, so the instances in any of these classes cannot be in any other class.

b: DEFINING THE CLASS PROPERTIES

The class alone does not provide sufficient information for the researcher to answer the competency questions. Therefore, class properties must be defined. This step is an essential part of the conceptualization phase. Thus, every class must possess its properties to generate comprehensive information to describe the concept of an internal structure. Moreover, the features are binary relationships that determine the character of the classes. The Web Ontology Language (OWL) has two properties: object property and data property. The object property describes the relationship between individuals while data property describes the connection between the individuals and the data value, or literals.

The naming convention technique distinguish between the class name and the class property, as proposed in the OD 101. This technique suggests adding the word 'has' to the property name or the word 'is' to the inverse property. For this domain, there is a class named *LangkahProses* (ProcessStep) with a related instance called *MelarikKayu* (WoodTurning). Each instance in the *LangkahProses* (ProcessStep) class contains an object property named *hasBahan* (hasMaterial), which connects the instances between *MelarikKayu* and *KayuCengal*, which is an instance in the *Bahan* (material) class. For the data property, the instances are linked with the literals; for example, *MelarikKayu* has a data property named *NoLangkahProses*, which describes the number of steps for each process. Figure 3 shows the data and object property for the above example in graphical form.

c: CREATING INSTANCES

Creating individual instances for the taxonomy is the last activity in this phase. This phase also outlines the procedure

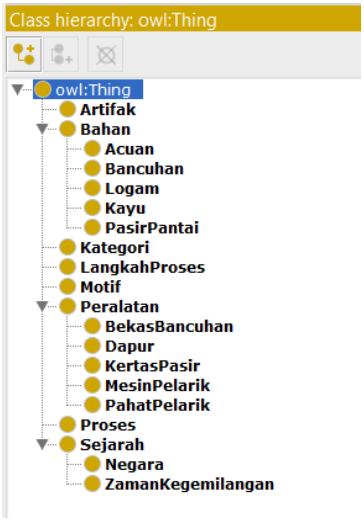

FIGURE 4. Protégé 5.2 class implementation.

for generating the individuals of each class. In the knowledge domain, an individual is a highly detailed concept. Three steps are involved in creating an individual, i.e., class selection, individual construction (for that class), and own assignation to an object or data property. In this case, the individuals *MelarikKayu* (WoodTurning) and *MenuangCairanTembaga* (BrasswareLiquidPouring) are LangkahProses (ProcesStep) class.

4) IMPLEMENTATION

Web Ontology Language (OWL) was used to design the formal, conceptual model. OWL is an ontology markup language implemented using eXtensible Markup Language (XML). This language can be applied to manage information content rather than just displaying them. OWL has three sublanguages, namely, OWL-Lite, OWL-DL (Description Logic), and OWL-Full. This research used OWL-DL because it contains a comprehensive vocabulary and can be used to optimize knowledge modelling and reasoning. Moreover, Protégé 5.2 software engineer an environment for executing the brassware craft ontology. Figure 4 shows how Protégé 5.2 software implements classes.

5) EVALUATION

The final phase is the evaluation to debug and evaluate the performance of the developed ontology. Verification and validation are the two main processes in this evaluation phase [42], [43]. Verification activities review the ontological contents and compare them to reference frameworks such as real-world, competency questions, or requirements specification. Meanwhile, the validation activity is a technical evaluation for diagnosing the ontology model.

The OD 101 method proposes three different evaluation approaches. The first is to use competency questions to verify the ontological content. The domain experts evaluated this ontology. The second is to establish modelling guidelines as a reference to validate the ontology. The third is the quality evaluation, conducted to assess the level of knowledge

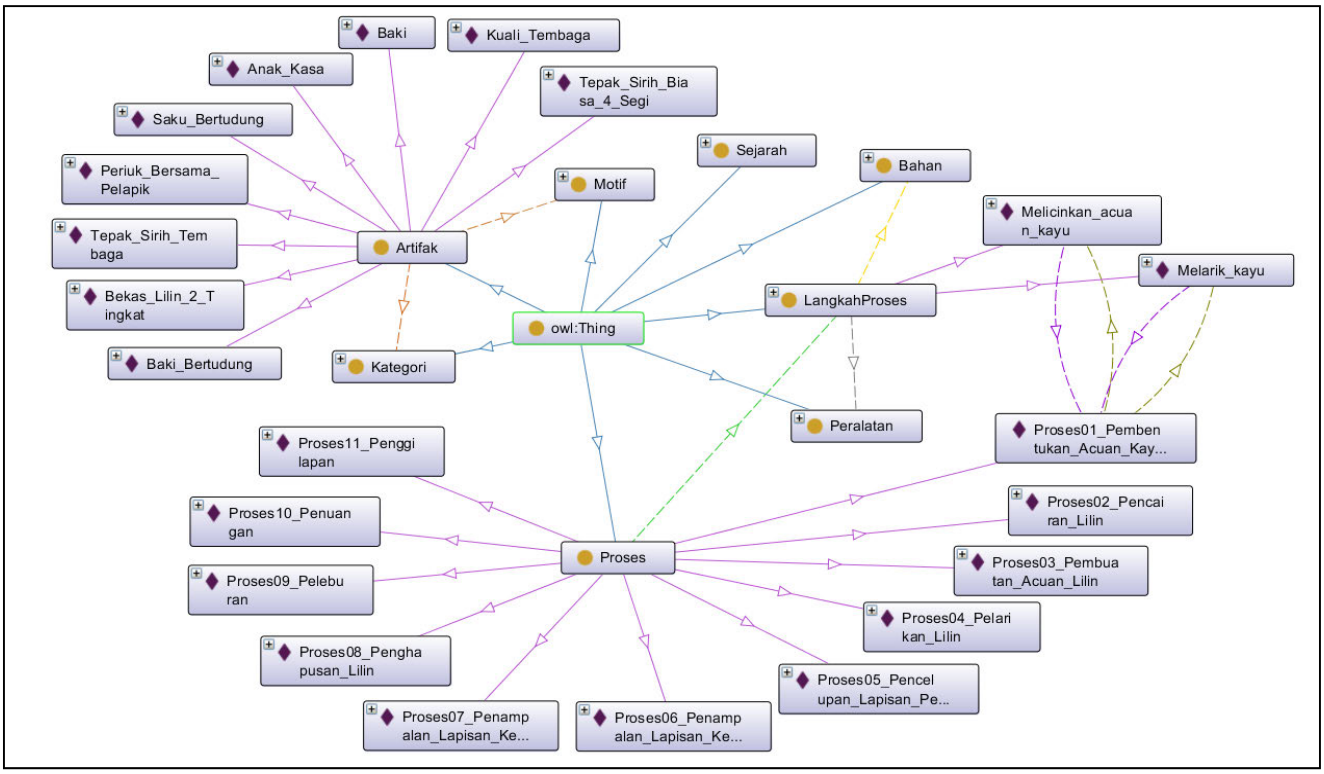

FIGURE 5. Superclass of the brassware craft ontology.

represented by the ontology. The brassware craft ontology is verified using the competency questions, implemented using SPARQL queries. The answers were reviewed and verified by the domain experts. Completeness, consistency, conciseness, preciseness, and clarity criteria guide the evaluation of the ontology quality [44], [45]. The following section discusses the process of evaluating the brassware craft ontology in more detail.

IV. THE BRASSWARE CRAFT ONTOLOGY

The result of ontology modelling is the brassware craft ontology, which consists of eight superclasses and twelve subclasses. The superclass is classes, consisting of *Artifak* (Artefact), *Bahan* (Material), *Kategori* (Category), *Langkah-Proses* (ProcessSteps), *Motif* (Motif), *Peralatan* (Equipment), *Proses* (Process), and *Sejarah* (History). Meanwhile, the subclasses comprise *Acuan* (Mold), *Bancuhan* (Mixture), *Logam* (Metal), *Kayu* (Wood), *PasirPantai* (Sand), *Bekas-Bancuhan* (Mixture Container), Dapur (Stove), *KertasPasir* (Sand Paper), *MesinPelarik* (Lathe Machine), *PahatPelarik* (Lathe Chisel), *Negara* (Country), and *ZamanKegemilangan* (Golden Age). Figure 5 shows the superclass ontology for brassware craft.

The *Artifak* class is the main class in this Brassware craft ontology that describes the artefacts of the brassware craft. It consists of nine individuals, specifically *Anak Kasa, Baki, Baki Bertudung, Bekas Lilin 2 Tingkat, Kuali Tembaga, Periuk Bersama Pelapik, Saku Bertudung, Tepak Sirih Biasa 4 Segi,* and *Tepak Sirih Tembaga*. Each individual in this class has the same object property as the individual in the *Motif* and *Kategori* class. The object property between the individual *Artifak* class and the *Motif* class is the *has motif*. Meanwhile, the *Kategori* class has an object property called *hasCategory*. The details of the *Artifak* class are shown in Figure 6.

Additionally, the individuals in the *Artifak* class also have a data property that links the individuals with the data value. The data property is the usage, diameter, height, width, and year of manufacture. Table 3 shows an example of the data property and the data value for the *Artifak* class.

Furthermore, other object properties involved in this ontology are *hasBahan*, *hasKategori*, *hasLangkah*, *hasMotif*, *hasPeralatan*, and *isLangkahOf*. Table 3 shows the object property, descriptions, and properties. The domain and range listed in Table 4 refer to the classes in the brassware craft ontology.

V. ONTOLOGY EVALUATION

The ontology model developed should be evaluated before applying to other applications or shared ontologies. The assessment of the quality and adequacy of the ontology determine whether it can be reused in specific contexts and for particular objectives [46]. This evaluation is essential to ensure that the knowledge presented is correct and accurate. [45] outlined a gold-standard, criteria-based, and task-based assessment as the three approaches for evaluating an ontology. The evaluation of ontology is by assessment against the benchmarked gold-standard. The criteria-based evaluation assessed the ontology based on specific criteria such as consistency, completeness, clarity, and so on, as suggested

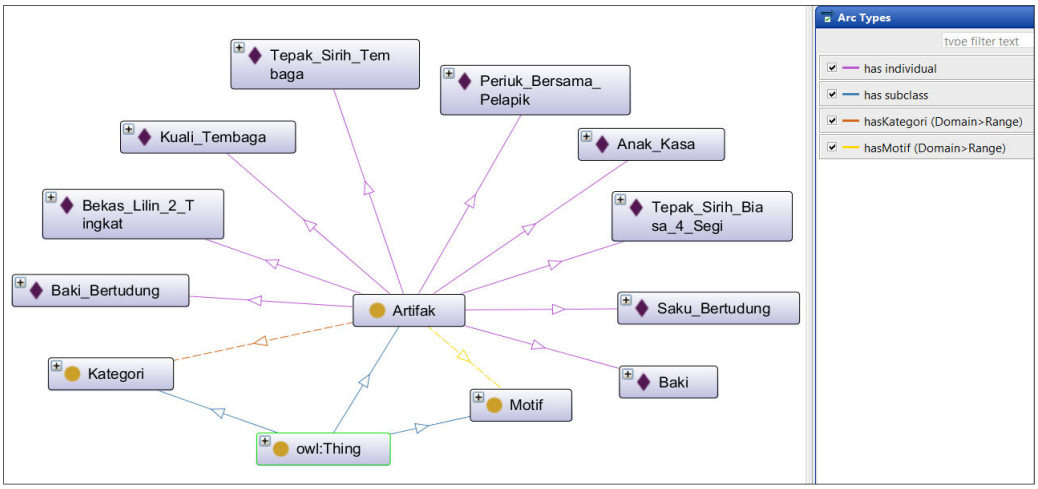

FIGURE 6. Individuals and object property in the artifak class.

TABLE 3. Data property and data value.

Individual	Data Property	Data Value
Kuali Tembaga (Wok brassware)	Usage	A tool to cook dishes and to mix cakes
	Diameter	45 cm
	Height	21cm
	Year of manufacture	In the 80s

TABLE 4. Data property in brassware craft ontology.

Data Property	Domain	Range	Description	Function
hasBahan	*Langkah Proses*	*Bahan*	Defines the relationship between *Bahan* and *LangkahProses*	The materials used in each step of the process
hasKategori	*Artifak*	*Kategori*	Defines the relationship between *Kategori* and *Artifak*	Categories of the artefact
hasLangkah	*Proses*	*Langkah Proses*	Defines the relationship between *LangkahProses* and *Proses*	The steps involved in each process
hasMotif	*Artifak*	*Motif*	Defines the relationship between *Motif* and *Artifak*	Motif of the artefact
hasPeralatan	*LangkahProses*	*Peralatan*	Defines the relationship between *Peralatan* and *LangkahProses*	The equipment used in each step of the process
isLangkahOf	*LangkahProses*	*Proses*	Opposite of *hasLangkah*	The steps involved in each process

by [47]–[51]. Finally, task-based evaluation involves assessing the proficiency of the ontology in accomplishing tasks. Besides, OD 101 method proposes the use of competency questions to validate ontological content, using domain experts.

In this study, the ontology evaluation used content validation and criteria-based evaluation. Five experts from the heritage and brassware crafts domain evaluated the brassware craft ontology. These experts have more than ten years of experience in this domain. The evaluation used a three-part questionnaire; Part A consists of demographic questions; The items in Part B are the competency questions and the ontology-generated answers. Part C consists of quality criteria items using a five-point Likert scale ranging from 1 ''Strongly disagree'' to 5 ''Strongly agree''.

Before conducting the evaluation, the experts briefing carried out before distributing the instrument. The researchers were on standby to answer queries during this time. The evaluation session took an average of 2 hours. After the evaluation session completed, the results were analyzed and the mean value computed.

A. DISCUSSION OF THE ONTOLOGY EVALUATION

The main objective of the ontology content validation is to verify the represented brassware craft content—the implementation of competency questions in SPARQL query language is in the ontology editor. Then, the domain experts verified the generated answers. This activity evaluates how the ontology responds to each of the competency questions developed in the specification phase to determine the suitability of the ontology scope. Table 5 shows the competency questions in natural language and SPARQL query language.

The content validity results show that most items had a mean score greater than or equal to 4.00, indicating that the experts agreed with the content represented in the brassware craft ontology. However, one of the items (item 11) had a mean score of 3.80, - Moderately agree. This score implies that the metric used may vary slightly depending on the type of product produced. Nevertheless, the overall data

TABLE 5. Natural language query vs SPARQL query.

No.	Natural language query	SPARQL query
1	What is the Terengganu brassware craft artefact?	SELECT ?Artifak WHERE { ?class rdfs:subClassOf* krafTem:Artifak . ?Artifak rdf:type ?class .}
2	What are the uses of each brassware craft artefact?	SELECT ?Artifak ?Kegunaan WHERE { ?class rdfs:subClassOf* krafTem:Artifak . ?Artifak rdf:type ?class . ?Artifak krafTem:Kegunaan ?Kegunaan .}
3	What is the size of a brassware craft artefact?	SELECT ?Artifak ?Lebar ?Panjang ?Tinggi ?Diameter WHERE { ?class rdfs:subClassOf* krafTem:Artifak . ?Artifak rdf:type ?class . OPTIONAL {?Artifak krafTem:UkuranDiameter ?Diameter.} OPTIONAL {?Artifak krafTem:UkuranLebar ?Lebar .} OPTIONAL {?Artifak krafTem:UkuranPanjang ?Panjang .} OPTIONAL {?Artifak krafTem:UkuranTinggi ?Tinggi .}}
4	When is the manufacturing date of the brassware craft artefact?	SELECT ?Artifak ?TahunPembuatan WHERE { ?class rdfs:subClassOf* krafTem:Artifak . ?Artifak rdf:type ?class . ?Artifak krafTem:TahunPembuatan ?TahunPembuatan .}
5	What is the type of motif on the brassware craft artefact?	SELECT ?Artifak ?Motif WHERE { ?Artifak krafTem:hasMotif ?Motif .}
6	What is the category of brassware craft artefact?	SELECT ?Artifak ?Kategori WHERE { ?Artifak krafTem:hasKategori ?Kategori .}
7	Where does the Terengganu brassware craft originate?	SELECT ?Asal ?Keterangan WHERE { ?class rdfs:subClassOf* krafTem:Negara . ?Asal rdf:type ?class . ?Asal krafTem:Keterangan ?Keterangan .}
8	When was the golden age of Terengganu brassware crafts?	SELECT ?ZamanKegemilangan ?Keterangan WHERE { ?class rdfs:subClassOf* krafTem:ZamanKegemilangan . ?ZamanKegemilangan rdf:type ?class . ?ZamanKegemilangan krafTem:Keterangan ?Keterangan .}
9	What is the material used to produce Terengganu brassware craft?	SELECT ?Bahan WHERE { ?class rdfs:subClassOf* krafTem:Bahan . ?Bahan rdf:type ?class .} ORDER BY ?Bahan
10	What is the metal used to produce Terengganu brassware crafts?	SELECT ?Logam WHERE { ?class rdfs:subClassOf* krafTem:Logam . ?Logam rdf:type ?class .}
11	What is the amount of the metal used, and what is the function of this metal?	SELECT ?Logam ?Sukatan ?Fungsi WHERE { ?Logam krafTem:Sukatan ?Sukatan . ?Logam krafTem:Keterangan ?Fungsi .}
12	What is the equipment used and the function of the equipment in the production of Terengganu brassware craft?	SELECT ?Peralatan ?Kegunaan WHERE { ?class rdfs:subClassOf* krafTem:Peralatan . ?Peralatan rdf:type ?class . ?Peralatan krafTem:Kegunaan ?Kegunaan .} ORDER BY ?Peralatan
13	What is the process of producing Terengganu brassware craft?	SELECT ?Proses WHERE { ?class rdfs:subClassOf* krafTem:Proses . ?Proses rdf:type ?class .} ORDER BY ?Proses
14	What are the steps involved in every process of Terengganu brassware craft production?	SELECT ?Proses ?NoLangkah ?Langkah WHERE { ?Proses krafTem:hasLangkah ?Langkah . ?Langkah krafTem:NoLangkahProses ?NoLangkah .} ORDER BY ?Proses ?NoLangkah
15	What is the description of each process of Terengganu brassware craft production?	SELECT ?Proses ?Langkah ?Keterangan WHERE { ?Proses krafTem:hasLangkah ?Langkah . ?Langkah krafTem:NoLangkahProses ?NoLangkah . ?Langkah krafTem:Keterangan ?Keterangan .} ORDER BY ?Proses ?NoLangkah

*Natural language query was translated from Bahasa Melayu

modelled by the ontology were sufficient to represent a basic knowledge of the brassware crafts. The experts also suggested improvements such as the spelling correction and enhancing the metal functions in brassware craft production. The result of the evaluation is shown in Figure 7.

Furthermore, the ontology quality evaluation was based on the five previously mentioned criteria; completeness, consistency, conciseness, preciseness, and clarity. The descriptions and questions for each criterion are presented in Table 6 [44], [45].

The ontology quality evaluation has been conducted for each concept in brassware craft ontology and each of the experts evaluate the ontology criteria based on a scale ranging from 1 (Strongly disagree) to 5 (Strongly agree). Based on the given scores, the mean value is calculated to obtain the score of each criterion of each concept. Table 7 shows the result of the ontology quality evaluation.

The results showed a mean value of above 4.00 for all the criteria, which indicates that the brassware craft ontology meets the ontology quality criteria. The completeness criterion yielded a mean score of 4.05, signifying that the ontology is adequately represented or encompasses all the concepts and relationships between concepts in the domain of brassware crafts. The consistency criterion returned an average mean score of 4.03, indicating a consistent representation of all the concepts; that there is no contradictory knowledge in the ontology. Additionally, the conciseness criterion achieved an average mean score of 4.13, demonstrating that there is no unnecessary or overlapping information in the ontology.

TABLE 6. Ontology quality evaluation criteria.

No.	Criteria	Description
1	Completeness	How well does the ontology cover the real world? All the ontology parts must be present and each part must be fully described for the ontology to be considered complete. • Does the ontology cover all general domain concepts? • Does the ontology speficy all subconcepts down to the required granularity? • Does the ontology speficy all relationships between domain concepts? • Are all the ontology concepts related to all entities from the subject domain?
2	Consistency	The ontology must not have contradictory information. The ontology must have consistent definitions and present definitions do not infer contradictory knowledge. • Are all definitions consistent? • Is there any contradictory information?
3	Conciseness	A concise ontology does not have excessive, redundant, superfluous or unnecessary information or details. For example, a concept or property that is redundant has been explicitly declared in the ontology, but other properties or relations could also reflect this concept. • All concepts or properties that are explicitly declared must not also be inferred. • There must be no unnecessary information or detail.
4	Preciseness	A precise ontology must cover fewer unintended models, and correct hierarchies and definitions. The precise ontology must be true to reality and efficient pragmatism. In other words, the ontology must be adequate. • Are the domains and the ranges of object properties defined correctly? • Are object properties defined at the necessary level? • Are data properties defined correctly? • There must be no classes with only one subclass. • Are types (classes) and instances not confused? • Are classes defined in other ways than directly? • Are there no loops in definitions?
5	Clarity	A clear ontology effectively communicates the intended meaning. Domain experts in the field of interest must be able to understand the ontology. • Is the terminology coherent? • Have uniform notations been used? • Are labels constructed according to the preferred rules?

In other words, the representation in the generated ontology is strong.

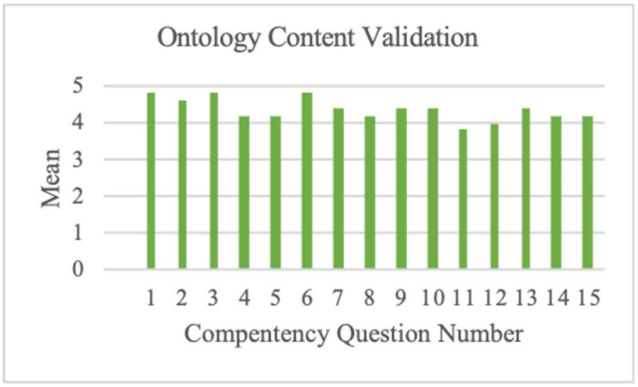

FIGURE 7. Result of ontology content validation.

The preciseness criterion obtained a mean score of 4.17, establishing the accuracy of the brassware craft heritage ontology definition. In addition, the hierarchy and the information in the ontology are sufficient and based on exact facts. The last criterion is clarity, which refers to the effectiveness of the knowledge level intended in the generated ontology model. This criterion obtained the highest average mean score of 4.18, indicating that the ontology is clear and understandable to the domain experts and that it exercises the domain-related terms. In summary, the quality evaluation results show that the brassware craft ontology meets all the ontological quality criteria.

Overall, the results of the ontology evaluation show that the ontology content is adequate and meet the ontology quality criteria. Therefore, the ontology design can guide in developing other intangible cultural heritage ontology, especially in the traditional craftsmanship domain. The main concepts in brassware craft ontology such as artefact, material, equipment, processes, category and motif are applicable for the development of other ontologies such as the production of silver, songket weaving, Kris, wood crafting, glazed tiles and ceramics.

Previous ontologies developed for cultural heritage did not focus on traditional craftsmanship domain. Thus, brassware craft ontology contributes to the data model for intangible cultural heritage specific to the traditional craftsmanship domain. Development of the brassware craft ontology used CIDOC CRM; the evaluation of the ontology by expert evaluators showed that the ontology met the scope and the quality of an ontology. The results indicated that the concepts and relations in the ontology were appropriate to use in representing domain knowledge.

The evaluated ontology can be used practically in the development of various applications such as semantic search, mobile and gaming applications. The ontology provides content for the development of the applications. Validated ontology content is essential in the development of a heritage application to ensure that users receive correct heritage information. Our study uses the content from the brassware craft ontology to design a game for Terengganu brassware craft, as described in [52]. The game aim is to disseminate the heritage information to users. The data in the brassware ontology

TABLE 7. The result of ontology quality evaluation.

No.	Concept/ Criteria	Completeness	Consistency	Conciseness	Preciseness	Clarity
1	*Artifak* (Artefact)	4.00	3.80	4.00	4.20	4.20
2	*Motif* (Motif)	3.40	3.60	4.00	3.80	4.00
3	*Kategori* (Category)	3.80	4.00	4.00	4.20	4.20
4	*Sejarah* (History)	4.00	4.00	4.20	4.20	4.20
5	*Bahan* (Material)	4.20	4.20	4.20	4.40	4.20
6	*Peralatan* (Equipment)	4.20	4.00	4.20	4.00	4.20
7	*Proses* (Process)	4.00	4.20	4.00	4.40	4.40
8	*LangkahProses* (ProcessSteps)	4.00	4.00	3.80	4.40	4.40
	Mean	**4.05**	**4.03**	**4.13**	**4.17**	**4.18**

such as products, artefacts, materials, equipment and process were extracted from the ontology and implemented as game levels.

VI. CONCLUSION

In this article, we have presented the brassware craft knowledge base developed using an ontological approach. This ontology aims to preserve the knowledge of the intangible cultural heritage, mainly traditional craftsmanship. We have discussed the methodology adopted for data gathering, the design and implementation of the knowledge base, and the results of ontology evaluation undertaken with a group of domain experts. Evaluation results show that the experts agreed on content representation (mean $\geq$ 3.80), and the ontology meets all the quality criteria (mean $\geq$ 4.03), thus can be reused or shared to develop various applications such as semantic search, mobile and gaming applications, to attract and disseminate heritage information. Besides, the ontological design can also serve as a guide for designing and developing a knowledge base for other types of heritage. Future works will involve using the ontology for serious game development to disseminate the heritage knowledge to the younger generation.

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