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The Development of an Ontology for Thai's Indigenous Rice Knowledge in Thailand

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Abstract

The purpose of developing an ontology for Thai's indigenous rice knowledge was to create vocabularies that clearly represented the scope and knowledge structure for the production, processing, and cultural practices of rice in Thailand. The terminology could be described comprehensively by integrating domain ontology outline and the analytico-synthetic method of facet analysis. The process of developing ontology was accomplished through the Hozo program then evaluated by selected experts. It was found that the ontology of indigenous rice culture knowledge could be classified to 20 knowledge groups comprising 3 classes: (1) Rice production; (2) Rice culture; and (3) Special contexts of indigenous rice knowledge beyond 8 sub-classes: (1) Rice varieties; (2) Rice production process; (3) Rice rituals; (4) Rice local scholars; (5) Local wisdom; (6) Periods; (7) Ethnic groups; and (8) Geographic labels. Other beneath layers of the ontology consisted of 17 sub-classes, 244 types of relationships, 155 characteristics, and 10 types of associated relationships. Moreover, 11 groups of associated concepts were found: (1) Production resources; (2) Principles and methods; (3) Traditional technologies; (4) Processes; (5) Products; (6) Value; (7) Belief; (8) Safety; (9) Security; (10) Continuity; and (11) Social identity.

Keywords: Domain Ontology; Indigenous Rice Knowledge; Classification

1. Introduction

The indigenous rice culture knowledge of Thailand comprises local wisdom on various aspects of rice cultivation. In terms of agriculture, rice cultivation is the result of Thai farmers' knowledge and understanding of the environment, ecology, and the social and cultural context including their ability to adapt agricultural technology based on trial-and-error, in order to increase their rice production amidst natural resource constraints (Polthanee, 2010). From the viewpoint of folklorists, rice is considered to be a fundamental factor in life. Thus, rice cultivation determines the way of life of rice farmers, it is the origin of rice culture, and it becomes the core of Thai culture ([Thongdee], 2008). On the other hand, for economists, indigenous rice knowledge could be transformed to scientific and economic information. The empirical value of local rice knowledge has value and creates commercial opportunities. When combined with research findings on the topic of indigenous rice knowledge, it becomes possible to formulate public policies and legislation to protect and conserve Thai indigenous knowledge (Kawsa-ard, 2005).

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Many Thai researchers have studied and commercially developed Thai's indigenous rice knowledge. These include the development of indigenous rice genetics to enhance yields, the invention of rice-based ultrasound gel (Prachasilchai et al., 2020) and the improvement of value-added rice culture information for tourism (Tho-un et al., 2021). These research reports revealed the characteristics of Thai's indigenous rice knowledge comprising the local knowledge derived from the successes of the farmers in different farming contexts with variations in Thai dialects and languages. Thai rice knowledge was therefore not only based on agriculture, but also interlinked with aspects of local economy, society, environment, science, technology, history, community culture, and education. Scholars in various disciplines (the target audience for an indigenous rice knowledge ontology) can plan and conduct research on Thai rice knowledge in an integrated cross-disciplinary way, resulting in many new sets of vocabularies elaborating the knowledge content of Thai rice in different regions. Some vocabularies will have identical meanings and reflect the same role but may be written differently, or may be written in the same manner but with different meanings depending on the local farmers' experience. Hence, scholars who revealed the knowledge derived from the farmers' experience in efficiently solving local problems, or applied Thai rice knowledge to develop innovations could have problems in repeating the research. Thus, developing indigenous Thai rice ontology will help unify the varying terms and concepts and may contribute to an interdisciplinary information system for Thai rice knowledge.

In Thailand, Kasetsart University has worked with other Thai higher education institutions to be the main stakeholder in the Thai Agricultural Research Repository. The university has developed various databases, such as the rice research studies database, the rice database, the Thai farmers database, and the rice products databases. However, studies of Thai rice knowledge from researchers in various disciplines often produce overlapping meanings. The vague information structure of these databases could have a profound impact on users' accessibility to these databases and the retrieval of information from them. Furthermore, researchers' extensive use of the existing information without a deep understanding might convey overall meaning of Thai's indigenous rice knowledge system ([Vaddhanaphuti] & [Bansirichot], 1997), which might cause Thai rice researchers finding problems with the use of searching terms for retrieving and accessing to Thai rice knowledge domain that they could not access to their required information (Chongchorhor & Kabmala, 2019).

The classification systems and the structure of folk relationships (Pongsapitch, 2003) used have also concerned some researchers. There have been many research studies about collections of knowledge content, the grouping of the knowledge content, the knowledge owners, and the location of knowledge sources have shown that the research conducted was insufficient to understand the processes involved, or lacked the level of thinking needed to understand and interpret the embedded knowledge (Panich, 2004). These perspectives were not sufficient due to the lack of insight into the process of data collection or the formation of concepts based on the data obtained.

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Furthermore, a lack of understanding of the relationships between indigenous knowledge and moral values, the lessons learned in organizing social relationships, and the benefits of indigenous knowledge as a component of contemporary knowledge has resulted in a lack of understanding of the reasons for Thailand to preserve indigenous knowledge as ancestral heritage, particularly knowledge related to natural resource management and agriculture ([Santasombut], 1999).

As mentioned above, the research reported here aimed to develop a Thai's indigenous rice knowledge ontology to refine the scope and knowledge structure which was distinctive from the scientific knowledge system. The rationale was that Thai farmers had conceptualized the category system according to functions while scientists had set it according to physical and biological theories. Furthermore, the farmers categorized knowledge in other dimensions as well, with overlapping justifications in the dimensions of cultures, beliefs, customs, traditions, value systems and relationship systems, as well as their experiences in adapting modern technology into the local context to discover their new knowledge with commercial value and worth. These complex subjects need to be studied meticulously. The results from the development of Thai's indigenous rice knowledge ontology had a two-fold benefit: preservation of Thai ancestral cultural heritage, and the content-based integration of existing Thai's indigenous rice knowledge with contemporary knowledge databases which could permit accessible, convenient and effective information retrieval for information users. As a result, the development of an ontology of Thai rice knowledge would create an essential foundation for the balanced and sustainable development of Thai economy and society.

2. Literature Review

2.1 Process on developing ontology

Ontologies strive to formalize domain knowledge and create a common understanding of a subject that applications and organizations may use. They are a hierarchical description of significant domain ideas and their attributes. The term ontology is used in computer science to describe a set of agreed-upon terminology for a certain subject. In this way, an ontology allows individuals to agree on the meaning of terms in a certain area, even if they are synonyms (Aufaure et al., 2006). In the majority of extant ontologies, the development process was manual.

Uschold and King (1995) recommended four processes for developing ontologies: (1) Identifying purpose; (2) Building the ontology; (3) Evaluation; and (4) Documentation. However, the evaluation is performed differently in each one of them. The methodology of Uschold and King (1995) involves assessment activities but does not specify how they should be conducted. Grüninger and Fox (1995) suggest evaluating an ontology process by developing a collection of competence questions that serves as the foundation for a rigorous description of the knowledge that the ontology must encompass.

First, guidelines for the development of the knowledge ontology had been established to obtain comprehensive vocabularies from literary warrant resources and closely related resources in various sciences. This development approach was consistent with the research studies on developing agriculture ontology by Shrestha et al. (2010),

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who analyzed knowledge from books, laboratory manuals, and research reports on economically important plant species, including the use of interdisciplinary knowledge descriptions from experts in plant physiology, geologists, and researchers in agricultural economics, as well as on developing rice production ontology (Kulnawin et al., 2014; Thunkijjanukij et al., 2009).

The classification of knowledge was then utilized in the initial procedures provided for the building of enterprise ontologies in the examined resources (Ranganathan, 1987; Taylor & Joudrey, 2009; Uschold & King, 1995). Ranganathan (1987) had set the facet analytico-synthetic principle method or the facet analysis to classify the knowledge, and Taylor and Joudrey (2009) specified the scope and structure of the knowledge in small groups, showing the relationships between internal concepts and special characteristics of the ontology. We enabled the association of all related content (Principle of Containing Relation) by grouping from general to specific which reflected the characteristics of particular subjects (Discipline) in which concepts and terminology were related within the knowledge groups (Broughton, 2006).

The class constraint on the ontology and the resulting model are available in different formats that make it portable and reusable by "Hozo" computer program – a unified platform for developing and utilizing task and domain ontologies based on fundamental ontological theories (Kozaki et al., 2002). It is made up of three components, "Ontology Editor," "Onto-Studio," and "Ontology Server" to deal with the concept of role appropriately. Then, an instance that satisfies the class constraint plays the role and becomes a role holder. "Hozo" computer program supports defining such a role concept as well as a fundamental concept. (Mizoguchi & Kozaki, 2009).

2.2 Thai rice ontology

The results of the research synthesis on Thai rice ontology were found in five studies completed between 2009 and 2014 (Akanit et al., 2011; Buranarach et al., 2011; Kulnawin et al., 2014; Shrestha et al., 2010; Thunkijjanukij et al., 2009). All of these studies organized the knowledge systems in the rice domain according to the aspects of agriculture, namely (1) the process of rice production in Thailand; (2) the process of rice processing in Thailand; (3) the knowledge of the rice varieties in Thailand; (4) the knowledge in rice research to support Thailand's policy decisions; and (5) international knowledge on rice research in the aspect of economic crops. Three of the five studies found ways of using ontology to solve rice knowledge conservation problems in Thailand. The others developed the interlinking of knowledge from the content of rice research reports with international knowledge bases or databases of national research institutes. Additionally, Chongchorhor and Kabmala (2019) used a facet analytico-synthetic technique to study Thai's indigenous rice knowledge. There are three types of knowledge. In the first category, rice fundamental knowledge has two subcategories: rice plants and rice production. The second category, rice culture, has two subcategories: material and non-material. There were four divisions of endemic knowledge: indigenous academics; age groups; ethnic groups; and geographic locations. This work can serve as

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a foundation for designing and developing future ontologies.

In conclusion, the researchers discovered rice ontology development on rice varieties, rice production, rice processing, an ontology on rice research policy, and an ontology on rice as an economic crop from a global standpoint. No research had focused on developing an ontology of Thai's indigenous rice knowledge, despite the fact that cultural ecologists had studied the culture of Thai farmer communities and discovered local knowledge embedded in the culture of rice production as a result of farmers adopting the knowledge to improve their quality of life and strengthen their communities. The Thai's indigenous rice knowledge has been passed down from generation to generation in Thai agriculture. Numerous research studies on Thai rice culture exist, including cultural diversity and coexistence in Asia (Pongsapich, 2003), indigenous knowledge and biodiversity ([Panyakul], 1997), the rice culture ([Thongdee], 2008), and indigenous agricultural knowledge in Northeast Thailand ([Panyakul], 1997; Polthanee, 2010). [Santasombut] (1999) described four levels of the structure of indigenous knowledge in biology: knowledge at the resource level; knowledge at the level of resource management systems; knowledge at the belief–ritual level; and knowledge developed from the relationship between people, nature, and the supernatural. Chongchorhor and Kabmala (2019) organized Thai's indigenous rice knowledge using a facet analytico-synthetic approach. It was discovered that the Thai's indigenous rice knowledge was closely linked to the community rice culture and had the potential to be integrated with the scientific knowledge base. However, academic scholars who had to apply the indigenous rice knowledge in conjunction with knowledge from other disciplines determined that it still lacked connections between the Thai's indigenous rice knowledge, thought process, and community rice culture, which supported the concept of the farmers' Thai's indigenous rice knowledge in various areas (Chongchorhor & Kabmala, 2019; [Vaddhanaphuti] & [Bansirichot], 1997).

3. Method

3.1 The development of Thai's indigenous rice knowledge ontology

The process of developing the ontology was based on the concept outlined by Uschold and King (1995) and the facet analytico-synthetic method (the Ranganathan's facet analysis) for intangible knowledge by Prieto-Diaz (2003) to establish guidelines for developing and explaining the elements of Thai's indigenous rice knowledge ontology. The development was undertaken step-by-step as follows:

Determining Thai's indigenous rice knowledge based on user behavior. Determining the scope of knowledge for Thai's indigenous rice knowledge to define the objectives and scope of the knowledge based on the user's behavioral study on retrieving and accessing to Thai's indigenous rice knowledge. We found that the users had problems in using tools for retrieving and accessing the knowledge that they could not get resources that they really required. Users' information behaviors have changed, especially their need for interlinking knowledge content among knowledge groups of various disciplines with no consideration of the physical

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components or the original information materials (Chongchorhor & Kabmala, 2017). The problems lead to the two ontology objectives: (1) to be used as a tool to access Thai's indigenous rice knowledge, and (2) to explain the scope and definite knowledge structure.

Applying the structure of Thai's indigenous rice knowledge to determine the knowledge domain as the main knowledge. The conceptual model was designed and developed for domain ontology by reviewing and evaluating an ontology in order to enable it to perform correctly and comprehensively. We defined the classification for the knowledge by applying the results of the study of the scope and structure of the knowledge which derived from the analysis of its content from Thai rice knowledge information resources – subject headings, glossaries, taxonomies, articles, research reports, monographs, and conference papers. Words were extracted by defining the structure and the relationship of Thai's indigenous rice knowledge ontology and assigned in domains, subdomains, main classes and subclasses. Then, classes under the knowledge domain were specified by defining the sub-knowledge group names, from the Thai's indigenous rice knowledge structure, as the class name. We defined the sub-classes that are under the main class by determining the sub-knowledge group names, from the Thai's indigenous rice knowledge structure, which is another hierarchy from the sub-knowledge group of the main class.

Classifying and analyzing the facets of knowledge groups. Analyzing the knowledge groups was conducted according to the knowledge classification approach of Taylor and Joudrey (2009) and by applying the facet analysis approach of Ranganathan (1987) to consider the concept that was the fundamental key of each knowledge subgroup. After that, the researchers synthesized them with the terminology or concepts by grouping the same content together, related content nearby together, and the content with specific aspects in distinctive groups. For any class with a large amount of vocabulary or concepts, there might be further assignment of sub-classes to organize the sub-contents then re-categorized these concepts and emphasized sharing knowledge with some characteristics together. The structure of knowledge in each class was organized by defining the relations of various characteristics of the class with the concept of hierarchies, and by reordering the vocabulary in each class in alphabetical order.

Determining class associations based on domain hierarchy. Determining the relationship between classes according to the hierarchy and related relationships by considering the hierarchical relationships in the same domain. We started first with the class at the bottom of the hierarchy, then worked to identify a relationship with a class at a higher level such as the norm class, the values class, the beliefs class, the traditions class, the rituals class, the folk literature class, and the recreation class which were all under the main class of rice culture. An associated relationship was also determined by re-prioritizing and re-categorizing classes from all domains. While there might be some classes that were in different domains, once combined, we were able to create a new concept group called "associative concepts" which was a semantic relationship between the rice production class, rice culture class, and a special characteristics class

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of knowledge that had sub-classes with common concepts from different domains.

Defining qualification, sample data, and class descriptions in terms of a detailed description by considering the meaning of the vocabulary. Attributes or characteristics of a class must be described by a definition of the value of those attributes by using the concept of knowledge classification approach and using the facet analysis to find the special characteristics of each knowledge category in various aspects. After that, the class sample data (instances), for knowledge in each category, was determined by considering the name and the meaning of the vocabulary. The researchers found that they were not a description of the class characteristics, but they were words with the same characteristics or characteristics as classes. Hence, in Thai's indigenous rice knowledge domains, researchers wrote a clear description of the scope of knowledge in each class as well as a description explaining the class details while considering the connection with other classes, and the comprehensive aspects of knowledge that were actually displayed in the domain.

3.2 The ontology evaluation

Qualitative research was used as the research methodology to summarize the details, completeness, and comprehensiveness of the assessment results of Thai's indigenous rice knowledge ontology from two content evaluation forms which were used as research tools.

The research methodology focused on selecting experts to examine Thai's indigenous rice knowledge ontology in order to verify the accuracy and comprehensiveness of the knowledge content in the ontology by using the content evaluation form. Meanwhile, the content users were selected for evaluation on the ontology to examine the consistency, completeness, compactness, scalability, and sensitivity to the changes in Thai's indigenous rice knowledge ontology by using the user satisfaction form.

According to Grüninger and Fox's ontology evaluation process (Grüninger & Fox, 1995), eight informants or evaluators, selected by purposive sampling, were divided into two groups: (1) five experts in Thai rice knowledge who were selected from those who have worked in academic or Thai rice knowledge research institutes; and (2) three experts in ontology holding academic positions (assistant professors or higher), or those with academic experience that had been nationally recognized and had their research studies published in the SCOPUS database.

In conclusion, the ontology development process based on Thai's indigenous rice knowledge consisted of four steps of Uschold and King (1995): (1) the specification of objectives to clarify the scope and details of the knowledge; (2) the modeling in the concept of ontology development and design for the knowledge; (3) the creation of an ontology for the knowledge which included 3 classes, that is, the "Rice production class," the "Rice culture class," and the "Special contexts of indigenous rice knowledge class," then divided into 8 sub-classes that are comprised with another 17 sub-classes, 244 types of relationships, 155 characteristics, 10 types of associated relationships; and (4) the evaluation of the ontology for Thai's indigenous rice knowledge by a group of ontology experts and experts from multidisciplinary ontologies.

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4. Result

4.1 The results of Thai's indigenous rice knowledge ontology development

The structure of Thai's indigenous rice knowledge was determined by the domain and defined into three main classes (Classes), namely "Rice production class;" "Rice culture class;" and "Special contexts of indigenous rice knowledge." There were eight groups according to the Knowledge Classification Approach (Ranganathan, 1987; Taylor & Joudrey, 2009), namely (1) Rice varieties; (2) Rice production process; (3) Rice rituals; (4) Rice local scholars; (5) Local wisdom; (6) Periods; (7) Ethnic groups; and (8) Geographic labels as shown in Table 1.

In addition, the sub-class level, another layer of sub-class in the ontology, consisted of 17 sub-classes, 244 types of relationships, 155 characteristics and 10 types of associated relationships that were derived from an analysis of 460 Thai rice knowledge resources. The knowledge group could be classified into 20 groups, including: (1) Rice varieties; (2) Rice cultivation methods; (3) Rice planting processes; (4) Rice maintenance; (5) Rice harvesting; (6) Tools and equipment used for rice cultivation; (7) Products and by-products from rice; (8) Rice-related norms; (9) Rice-related value classes; (10) Rice-related beliefs; (11) Rice-related traditions; (12) Rice-related rituals; (13) Folk literature; (14) Rice-related recreation activities; (15) Indigenous wisdom on Thai rice knowledge; (16) Pre-

Table 1. New Class and Sub-classes of Thai's Indigenous Rice Knowledge Ontology

Classes	Sub-classes	Description
Rice production	Rice varieties	Any object or thing in the rice culture that facilitated the transfer of Thai's indigenous rice knowledge.
	Rice production process	Any process related to rice production which facilitated the transfer of Thai's indigenous rice knowledge.
Rice culture	Rice rituals	Any related abstract concept in the rice rituals which facilitated the transfer of Thai's indigenous rice knowledge.
	Rice local scholars	Any person with a high level of knowledge or skill in Thai's indigenous rice knowledge.
Special contexts of indigenous rice knowledge	Local wisdom	Any ability to make intelligent decisions which facilitated the transfer of Thai's indigenous rice knowledge.
	Periods	Any period of time, classified by historians, that had conveyed Thai's indigenous rice knowledge.
	Ethnic groups	A group of people having similar traditions, culture, way of life, languages, beliefs, and history, as well as a sense of belonging to the group which facilitated the transfer of Thai's indigenous rice knowledge.
	Geographical labels	Any Location or Geographical conditions where the Thai's indigenous rice knowledge local scholars reside.

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historic period; (17) Historic period; (18) Modern period; (19) Ethnic groups in Thailand; and (20) Geographical area in Thailand.

According to the hierarchical structure (hierarchical relationship) in the semantic relationship between the classes, there are 244 types of hierarchical relationships divided into 5 groups: (1) 34 relationships on rice genetics; (2) 142 relationships on rice production processes; (3) 76 relationships on rice culture which appears on tangible objects; (4) 66 relationships on rice culture that is not related to objects; and (5) 26 relationships on special contexts of indigenous rice knowledge.

Associative concept, semantic relationships of concepts from different sub-domains from every class, was then rearranged and categorized into 81 new concepts. It could be divided into 11 groups: (1) Production resources; (2) Principles and methods; (3) Traditional technology; (4) Process; (5) Product; (6) Value; (7) Belief; (8) Safety; (9) Security; (10) Continuity; and (11) Social identity with sub-group as shown in Table 2.

In the evaluation of Thai's indigenous rice knowledge ontology, the researchers presented the concept map of the ontology to three experts in ontology to determine the correctness and relevance of the content. Content validity was then

Table 2. The New Associative Concept of Thai's Indigenous Rice Knowledge Ontology

The groups associative concept	Details
Production resources	Rice; Soil; Water; Lighting; Climate; Plant nutrition; Animals; Insects; Plant diseases; Weeds
Principles and methods	Techniques; Systems; Models; Cycling; Life cycle; Steps; Criteria; Guidelines
Traditional technology	Equipment; Currencies; Measuring standard; Materials; Devices
Processes	Surveying; Area selection; Ploughing; Sowing; Seedling production; Transplanting; Irrigation; Fertilizer application; Harvesting; Separation; Solarization; Threshing; Unloading; Storage; Utilization; Treatment; Assessment; Processing; Protection; Disposal; Control; Analysis; Synthesis; Improvement
Product	Paddy rice; Processed rice; Beverages; Sweets; Snacks; Cosmetics; Drugs; Byproducts; Wastes
Value	Aesthetic value; Use value; Cultural values; Social values; Nutritive value
Belief	Faith; Trial and Error Method; Case studies; Taboo
Safety	Product safety; Farmer occupational safety
Security	Food security; Farmer occupational security
Continuity	Continuum of rights; Continuum of time; Continuum of practice
Social identity	Ethnic groups; Geographical areas; Folk recreation; Social norms; Customs; Village scholars; Rituals; Periods; Folk literature

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estimated using the Item Objective Congruence (IOC) index which was determined to be 0.67 as shown in more detail in Table 3.

According to the experts' assessment, the content validity of the ontology was of a sufficient standard and could be developed to be a qualifying one by using ontology engineering principles and suggestions from the ontology experts. Furthermore, the experts suggested improving the concept map of the Thai's indigenous rice knowledge ontology by defining the concept of semantic relation so that each sub-class had equal amounts of its depth hierarchies, defining the vocabularies used in each sub-class to be the objective or subjective concept according to its class characteristics, and that any subclass with no sibling class must be a class itself. The researchers had reviewed and redefined the ontology process. After the ontology redevelopment, it was found that precision is 61.92 and the recall is 46.14 of usage satisfaction from 5 experts in Thai's indigenous rice knowledge.

Table 3. Content Validity on Ontology Design for the Knowledge-based System

Questions	IOC
The process identifies the scope of the development	
The ontologies of the design are consistent with the knowledge of Thai's indigenous rice knowledge.	0.76
The ontology design was appropriate with the knowledge of Thai's indigenous rice knowledge.	0.76
The ontology design was appropriate for the development of a prototype knowledge-based system.	0.66
Defining process of class/concept	
The ontologies that are designed are appropriate for the concept that can be described in detail.	0.59
Ontologies designed to classify Super-Class were appropriate.	0.66
Ontologies designed to classify Sub-Class were appropriate.	0.66
The process to define class properties	
The ontologies that design the properties were appropriately related to the concept.	0.59
Defining instance process	
The ontology design is appropriate for defining instances which refer to the meaning of information.	0.59
The ontologically designed protocols are appropriate for defining the data instances with the correct language/grammars.	0.59
Application and development of future ontology structures	
The ontology is designed to be accurate and reliable.	0.63
The ontologies that have been designed can be applied to other systems.	0.83
Overall	0.67

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5. Discussion

The research results indicated that the scope and knowledge structure of Thai's indigenous rice knowledge was applied knowledge and derived from the integration of Social Science knowledge (for example, Ethnic Anthropology, Cultural Studies, Sociology, Education) combined with Agricultural Science knowledge (for example, Plant Science, Soil Science, Hydraulics, Geography, and Ecology). All contexts of rice production were multiple linkages across disciplines, which were different from the occurrence of other types of knowledge. According to the study of Thai's indigenous rice knowledge structure with new processes of content analysis and domain analysis, together with a synthesized analytical technique based on the complexity of the subject (the analytico-synthetic method) in accordance with Prieto-Diaz's guidelines (2003) and using the principles of Thai's indigenous rice knowledge content grouping according to the knowledge classification approach by Taylor and Joudrey (2009), the study found that there was new knowledge of Thai's indigenous rice knowledge that was expanding to include Thai rice varieties, rice production processes, beliefs and values for rice and things related to rice.

The researchers had found new words for a growing number of these new knowledge areas when studied in depth in each geographical area for each ethnic group, and in subcultures of each community. In addition, there has been emerging knowledge on cultural objects in the disciplines of History, Archaeology and Community Business Administration. The knowledge content involved tools and equipment for rice and its production (direct and by-products) from rice processing of each community or each ethnic group. Other interesting new knowledge was the semantics of the Thai dialect on rice and anything rice-related which had rapidly increased as a result of linguistic researchers who had studied and classified language families by analyzing the meaning, then interpreting the vocabulary of the dialects in order to link them with the standard Thai language. Linguists are interested in the rice culture of various ethnic groups, beliefs, and Thai studies to understand the way of thinking and valuable and unique culture in the communities. Therefore, Thai's indigenous rice knowledge has continuously expanded as a result of many studies interlinked to many disciplines, as Thai society grew from the rice culture.

In addition, the research results indicated that Thai's indigenous rice knowledge was related to many disciplines of science. Due to the study of farming communities in various areas, it was observed that local knowledge was hidden in the culture around rice production. This local knowledge was called "Thai's indigenous rice knowledge" which means the foundation of Thai agriculture that has been inherited for generations. Researchers who have been involved in the study of Thai's indigenous rice knowledge from different disciplines (Historians, Archaeologists, Educators, Linguists, Business Executives and Community Enterprises), were involved in the evaluation of the Thai's indigenous rice knowledge ontology.

Due to the structure of the ontology, there are many aspects of the Thai's indigenous rice knowledge ontology which could be improved so that links can be made to the current rice research databases. Therefore, experts in computer engineering and ontology had proposed to

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simplify the structure of the ontology to match with the actual conditions of the information and communication technology infrastructure that currently provides the Thai's indigenous rice knowledge. As a result, the application of this ontology should be selectively appropriated with the conditions of technology. For the research and development of Thai's indigenous rice knowledge ontology, it also reflected the knowledge group under the rice culture class with the characteristic that could be associated with concepts of the main class, that is, the belief class, value class, tradition class and ritual class. All of these four sub-classes were considered common concepts of rice varieties and the rice production process class.

Thai's indigenous rice knowledge was the Thai farmers' knowledge which resulted from repeated trial and error, and their adaptation to overcome obstacles that were believed to be caused by humans and from the supernatural. Thai farmers then choose to combine their knowledge with rice culture to reduce obstacles and increase convenience in adding value to rice knowledge that had been regarded as a social-cultural identity and had also been worshiped as supernatural by the community. The special knowledge characteristics classes included individual class, ethnic groups class, periods classes, and geographic regions class were also considered as common concepts that help to explain the expanded boundaries of Thai's indigenous rice knowledge. The development of Thai's indigenous rice knowledge ontology had some characteristics that distinguished local knowledge in many aspects. Therefore, it required content analysis to organize Thai's indigenous rice knowledge groups. By using a facet analytico-synthetic method (FASM) to help illustrate the knowledge structure according to evidence or reasons (Warrant structure), the researchers enabled the association of all related content (Principle of Containing Relation) by grouping from general to specific which reflected the characteristics of particular subjects (discipline) in which concepts and terminology were related within the knowledge groups (Broughton, 2006). Thai's indigenous rice knowledge, in a specialized knowledge base (discipline), should take into account the specific aspects of cooperation such as rice cultivation, rice culture, values, beliefs, traditions and rituals related to rice. This was consistent with [Santasombut]'s (1999) description of the structure of knowledge in four levels: knowledge at the resource level, knowledge at the level of resource management systems, knowledge in the belief-ritual level, and the knowledge level developed from the relationship among people, between people and nature, and between people and the supernatural.

The development of Thai's indigenous rice knowledge ontology could be developed to communicate with knowledge systems outlined by Taylor and Joudrey (2009) by specifying the scope and structure of Thai's indigenous rice knowledge in small groups and showing the relationships between internal concepts and special characteristics. The guidelines on the development of Thai's indigenous rice knowledge ontology that covered interdisciplinary knowledge from literary warrant resources and resources in various sciences that were closely related to Thai's indigenous rice knowledge (for example, Agricultural Science, Social Sciences, History, Geography, Education, Philosophy and Religion, and Library Science) could also be developed.

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This development approach is in line with the research studies on developing Thai rice production ontology (Thunkijjanukij et al., 2009), and the research studies on developing ontology to support decision-making regarding Thai rice policy (Buranarach et al., 2011), research on the development of Thai rice processing ontology (Akanit et al., 2011), and research for the development of Thai rice ontology (Kulnawin et al., 2014).

In addition, the evaluation results of Thai's indigenous rice knowledge ontology also focus on solving problems for users and improving the experience of retrieving and accessing Thai's indigenous rice knowledge. Users' information behaviors have changed, especially their need for interlinking knowledge content among knowledge groups of various disciplines with no consideration of the physical components or the original information materials. The guidelines for the development of the ontology were consistent with the research on developing agriculture ontology by Shrestha et al. (2010) which analyzed knowledge from books, laboratory manuals, and research reports on plant species that were economically important including the use of interdisciplinary knowledge descriptions from experts in plant physiology, geologists and from researchers in agricultural economics. The development of ontology had comprehensive vocabularies and was interlinked with interdisciplinary knowledge based in agricultural plants, agronomy and agricultural economics. Moreover, ontology development via the facet analytico-synthetic principle method or the facet analysis by Ranganathan (1987) also had positive effects on classifying and determining the relationships in Thai's indigenous rice knowledge ontology. It consisted of three knowledge groups: rice production, rice culture, and the special characteristics knowledge group. The results from the combined process of the knowledge analysis, from the content of 460 entries of the indigenous Thai's indigenous rice knowledge articles, research reports, monographs, and conference papers could be divided into three groups which could be subdivided into 8 main classes, 17 subclasses, 344 types of relationships, 155 characteristics, and 10 types of mutual relationships. This classification was consistent with the research results presented by Ghosha and Panigrahi (2015). The facet analytico-synthetic method for ontology development on Library Science and Information Science, and the evaluation results of the ontology development process from experts were applicable according to the four development principles: (1) the structure and scope of Thai's indigenous rice knowledge were comprehensive; (2) the concepts and terminology were consistent; (3) the relationship determination between most classes was consistent; and (4) the definition of co-concept could be used to link concepts in meaningful relationships that were different from the content group under the same Thai's indigenous rice knowledge domain.

6. Limitations, Recommendations and Suggestions

6.1 Limitations

The ontology has been developed using Thai indigenous rice documents in order to validate the methodology. This leads to three problems. The first was the problem of authoritative control of vocabulary. Secondly, the problem of synonymy in Thai's indigenous rice knowledge ontology in

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terms of retrieval. Finally, the ontology has established a restricted foundation for further integrated sex/gender analysis work to develop a comprehensive ontology to address sex/gender issues.

6.2 Recommendations for applying the research results

The results of this study indicate that the scope of Thai's indigenous rice knowledge has expanded to include three groups: (1) knowledge of rice production; (2) knowledge content related to rice culture; and (3) special characteristics knowledge content. While departments that do research or develop innovation in Thai's indigenous rice knowledge often have specialized expertise in rice, and other departments focused on cultures are also knowledgeable on matters regarding to Thai's indigenous rice knowledge. Moreover, many government agencies encourage farmers to work together to transform rice yields into local products. Therefore, researchers in different disciplines can be positioned in different departments with various electronic information resources. This resulted in users having problems retrieving the content of Thai's indigenous rice knowledge from only one source and wasting time and money in the search and retrieval of information from each source. The researcher therefore proposed that a university research library take a role in knowledge and information management for human resource development and to be the center for linking electronic information resources in Thai's indigenous rice knowledge. This would require creating a central knowledge base for exchanging knowledge content in each region developing metadata in Thai's indigenous rice knowledge. The expected outcome would be to make better use of the integration of knowledge and comprehensively link the content in each ethnic group.

6.3 Suggestions

The development of domain ontology requires the creation of a conceptual model for its design and development. Using Thai's indigenous rice knowledge as a framework for operations, inspection and evaluation of the ontology development should be done correctly and entirely according to the concept. There are many aspects of knowledge content such as defining complex knowledge structures which are time-consuming to develop and improve, taking into account the advice of experts. Hence, without a well-defined framework, there can be confusion in determining the knowledge structure, applying the knowledge obtained from the analysis to create an ontology, and in validating the developed ontologies. Additionally, authority control should be implemented during the ontology building process to improve future ontology development work's recall rate.

There are likely to be developments of Thai's indigenous rice knowledge in each community or each ethnic group that can further expand the information and basic knowledge of local rice products or village rice products which are linked to the people's way of life in the community. The knowledge may encourage buying decisions of domestic consumers on online platforms. Therefore, the ontology should be designed to support intelligent technology which enables consumers from around the world to understand the value and outputs of Thai rice products.

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There should be further study and development of Thai's indigenous rice knowledge and geoinformatics systems by using a set of terminology in Thai's indigenous rice knowledge that defines the structure and boundaries of vocabulary and explains the characteristics of the content and information. It should be used as a standard for storing or exchanging information collected about Thai's indigenous rice knowledge in each geographical area because the knowledge system has the capacity to clarify the standard detailed information used in storing or exchanging information. Whenever local agencies collect information about rice products and outputs in the area, they would be able to exchange their information. The system would enable access to information and local knowledge, allowing further informed decisions to be made in local products purchases. Beside this, consumers would be able to choose Thai's indigenous rice knowledge with more information, understand local rice culture, respect the diversity of beliefs, and be proud of the history of rice and it's inherited values.

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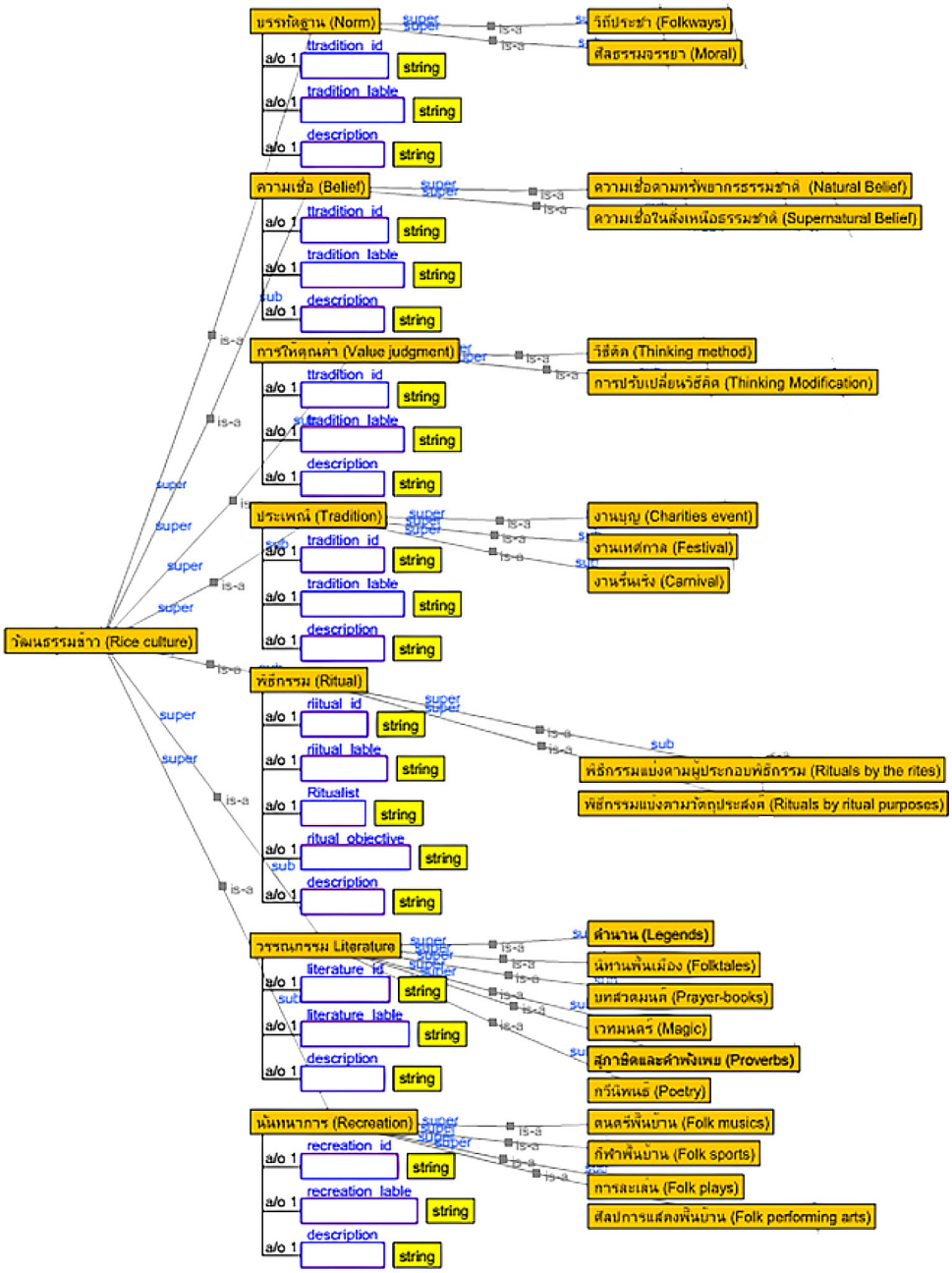
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Appendix A

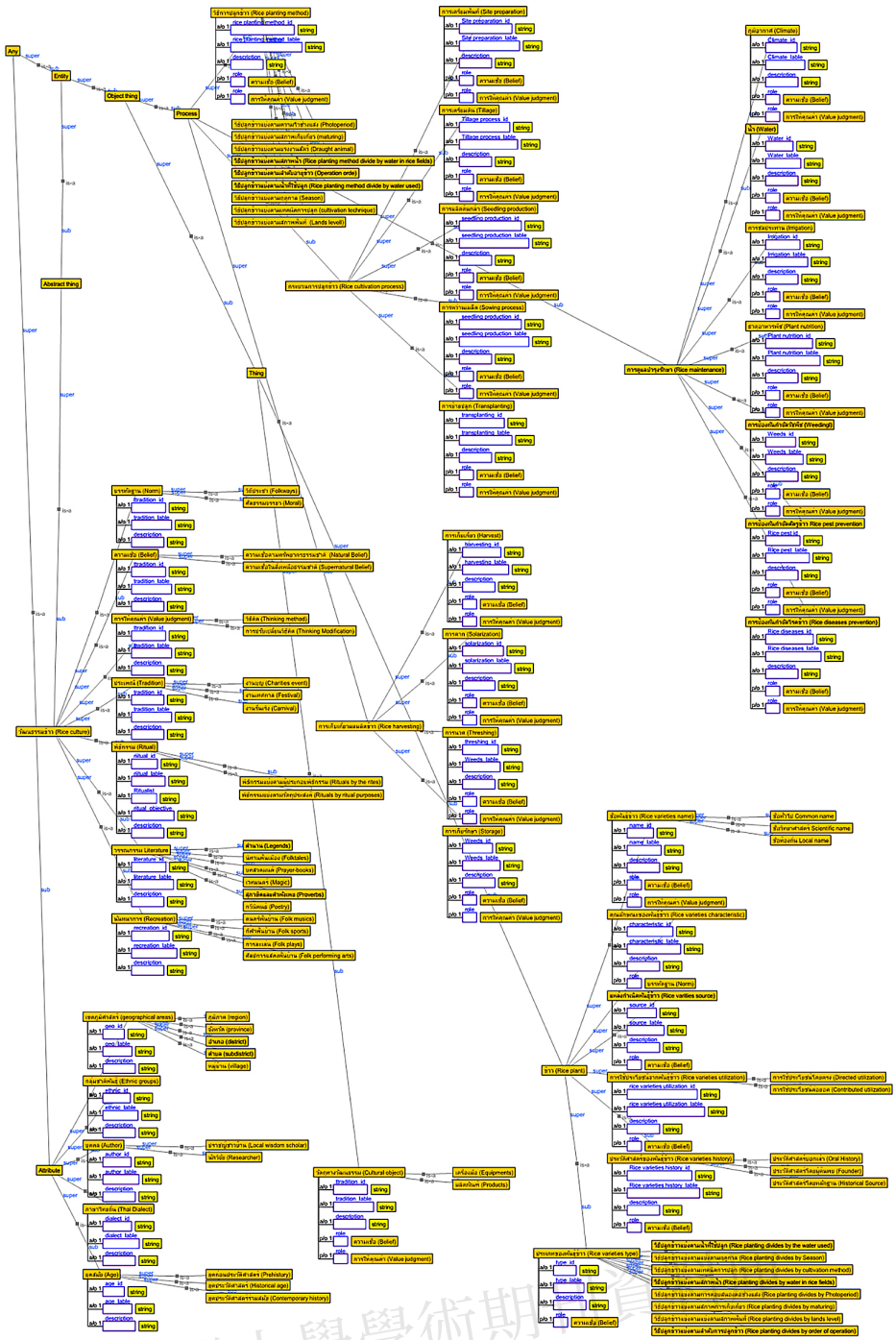
Rice Culture: One of the Three Classes in Thai's Indigenous Rice Knowledge Ontology



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Appendix B

Whole of Thai's Indigenous Rice Knowledge Ontology



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泰國原生種稻米知識本體的發展

The Development of an Ontology for Thai's Indigenous Rice Knowledge in Thailand

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摘　要

發展泰國原生種稻米知識本體目的為創造代表泰國稻米生產、加工及文化慣習之範疇與知識架構的詞彙表。融合領域本體論輪廓及層面分析之分析－組合法（analytico-synthetic method）以全面描述術語，透過Hozo程式發展，並由專家進行評估。最終發現，此本體架構包含稻米生產、稻米文化、及原生種稻米知識特殊脈絡三種類別的20種知識分群；並具8種子類別：(1)稻米種類、(2)稻米生產過程、(3)稻米例行作業、(4)稻米當地學者、(5)當地智慧、(6)期間、(7)種族團體、(8)地理標籤。下層層面則包含17種子類別、244種關係、155種特性及10種關聯關係。更發現了具關聯概念的11個群體：(1)生產資源、(2)原則與方法、(3)傳統技術、(4)加工、(5)產品、(6)價值、(7)信仰、(8)安全、(9)保護、(10)持續、(11)社會認同。

關鍵字：領域知識本體、原生種稻米知識、分類

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