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Basic Mathematics Learning Media System Based Semantic Web For Junior High School

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Abstract

Mathematics is a very important science because it is related to human life. Therefore, it is imperative to master mathematics and understand mathematical concepts correctly. In Indonesia, students' ability to understand mathematics is still relatively low. From this, understanding of mathematical concepts needs to be improved again so that students clearly understand mathematical concepts. In order to improve understanding of mathematical concepts, various efforts were made. One of the efforts carried out by the author is a semantic web-based learning media system using concept maps in basic mathematical ontologies. This system will use ontology to build a system that will represent a mathematical concept as a domain of knowledge explicitly about other concepts related to previous concepts by giving meaning, properties, and relations so as to form a knowledge base. In this research, the writer uses methodological method to build the basic mathematical ontology and the system development will be done by prototyping method. The system built has 2 features, namely exploration and semantic search, aiming to access the existing knowledge in the system systematically and according to user needs. To ensure that the system built can run as expected, system testing with black box testing has shown which features in the program run according to their functions and ontology evaluation using OntoQA on Schema Metrics carried out by measuring Relationship Richness (RR), Attribute Richness (AR), and Inheritance Richness (IR). In the evaluation of this ontology, it shows that the Relationship Richness (RR) value is 0.06; Attribute Richness (AR) value is 0.5; and the value of Inheritance Richness (IR) is 14.5.

Keywords: *semantic web, ontology, mathematics, metontology, black box, OntoQA, Schema Metric*

1 Introduction

Mathematics is a very important science because it is directly linked to human life. Even in this era of technology and digital, mathematics has a important role in human being life [1]. This role makes mathematics a tool for studying other sciences. Therefore, mastering mathematics is essential and a correct understanding of the concept of mathematics. This is because the concept of mathematics is a continuous series in which specific concepts are arranged based on the previous concept. A misunderstanding of one concept leads to a subsequent misunderstanding of the concept [2].

In Indonesia, the ability of students to understand mathematics is still relatively low. The poor math skills of Indonesian students are evident in the 2018 *Program for International Student Assessment* (PISA) and *Trends in International Mathematics and Science Study* (TIMSS) 2015 reports. In the math category, math skills scores reached 379 in 2018, making Indonesia ranked 79th countries participating in PISA [3]. Indonesia is ranked 44th out of 49 countries with a math score of 397 in the 2015 TIMSS results [4]. The report suggests that Indonesian students misunderstand mathematical concepts. Based on these facts, in order for students to have a clear understanding of the concept of mathematics, they need to improve their understanding of the concept of mathematics again. To improve the understanding of mathematics the author proposes learning media systems using ontology based on concept maps. A concept map is a networked representation of a concept as a result of a structure that represents the relationship between the concepts and principles that govern mathematical structures and relationships in an easy-to-understand way [5].

Basic mathematics learning media system based semantic web is a system that help improve understanding of basic mathematics concepts through the use of concept maps. This system is mathematical as an area of knowledge that is explicitly related to other concepts related to previous concepts by using ontology to give meanings, properties, and relationships to form a knowledge base. Build a system that represents the concept. The ontology of this system can explicitly describe the domain of knowledge [6]. You can share your understanding of structured information and reuse your domain knowledge. This knowledge base is expected to help teachers determine the level of understanding and the direction of learning.

2 Research Method

The method used in this research is the menthontology method and the prototyping method where the menthontology method is used as a general ontology model development from scratch, This approach provides us with a set of guidelines on how to perform the activities identified during the development of the ontology and which technique is most appropriate in each case what activities and products each produce. By using this prototyping method, development and users can interact with each other during the system creation process for knowing more about the importance of the system and its functions. In Figure 1, there is a research flow that begins with data collection and then designs an ontology model which will be divided into the browsing process and the searching process. When the ontology model has been completed, a system performance evaluation will be carried out.

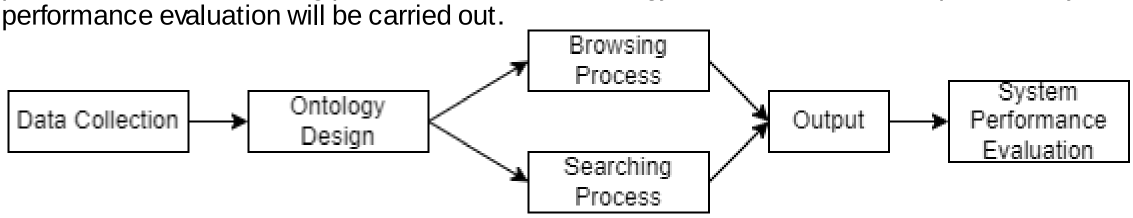

Figure 1. Flowchart System

2.1 Ontology Design Stage

In making ontology, the author uses a method of methontology that has the advantage of ontology being reusable for further system development. In addition, the advantage of the methodological description is that it explains each activity that must be carried out in detail. Some of the steps that must be carried out in the Methontology method are more clearly shown in Figure 2 which is adapted from the methodological flow [7].

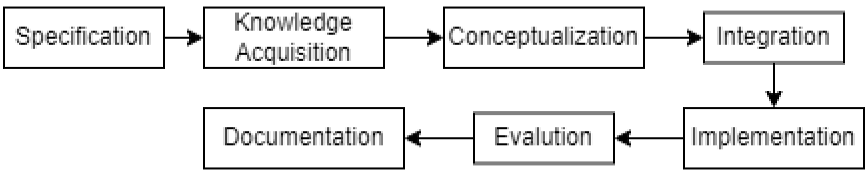

Figure 2. Methontology Method Activity Flow

In this method of methontology, the researcher wants to convert the concept map into an ontology model. While the definition of the ontology itself is an explicit specification of conceptualism. With the concept map which is a form of visualization of interrelated concepts, relationships between concepts, and meaningful relationships between these relevant concepts.

2.1.1 Specification

The goal of the ontology specification is to compile a document that includes the primary objectives of ontology, the objectives, and main scope of ontology. The document is written in natural language using a series of intermediate representations or using competency questions.

2.1.2 Knowledge Acquisition

Acquisition of knowledge is a separate activity in the development of ontology that coincides with other activities. Most of the knowledge is acquired at the beginning of the developing ontology and decreases with the progress of the process of developing ontology.

2.1.3 Conceptualization

This section will compile domain knowledge into a conceptual model, describing the problem and its solution related to the domain vocabulary defined in the ontology specification activity [8]. The first thing to do is to build a complete glossary. Thus, the glossary defines and brings together all useful and usable domain knowledge and what they mean.

2.1.4 Integration

In the integration stage, the definitions that have been made in an ontology are reconsidered to identify terms that may be present in other ontologies. In consideration of the definitions already in use, the author examines the terms that correspond to the concept of the domain. This happens so that the new definition or term is based on the same set of basic terms.

2.1.5 Implementation

This stage is the implementation process of the ontology design.

2.1.6 Evaluation

Evaluation includes conducting technical reviews of ontologies, software environments, and documentation against the terms of reference during each and between phases of their lifecycle. Review the Summary of Verification and Validation requirements.

2.1.7 Documentation

There are no uniform guidelines on how to create an ontological profile. In most cases, the only available literature is found in ontological codes, natural language texts with official definitions, and papers published in conferences and seminars, journals that address important ontological, ontological questions,and ontograph.

2.2 System Design Stage

The method used in the development of the system is prototyping. Prototyping is the process of creating a simple software model that allows the user to get a basic idea of the program and perform preliminary testing. Prototyping allows developers and users to interact with each other during production, so developers can easily model the software to be created.

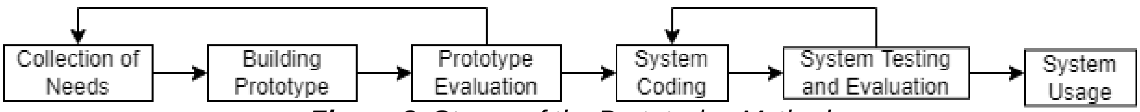

Figure 3. *Stages of the Prototyping Method*

2.2.1 Collection of Requirements

This stage aims to identify the format of the entire software, identify all requirements, and outline the system to be created.

2.2.2 Building Prototyping

Build prototyping by making temporary designs that focus on presentation, for example by making input and output formats. Forms of system design made include making system flowcharts, Use Case Diagrams, Activity Diagrams, and user interface designs. The following is a flowchart of the basic mathematics learning media system flowchart. In Figure 4, there is a flowchart system that will start with the home page then the user selects a menu, namely Browsing or Searching. If the user selects the browsing menu, it will display the Browsing Page, then the user selects content and sub contents. If the user selects the searching menu, it will display the Searching Page, then the user enters the output and input. when finished entering output and input, it will display the output according to the user's choice.

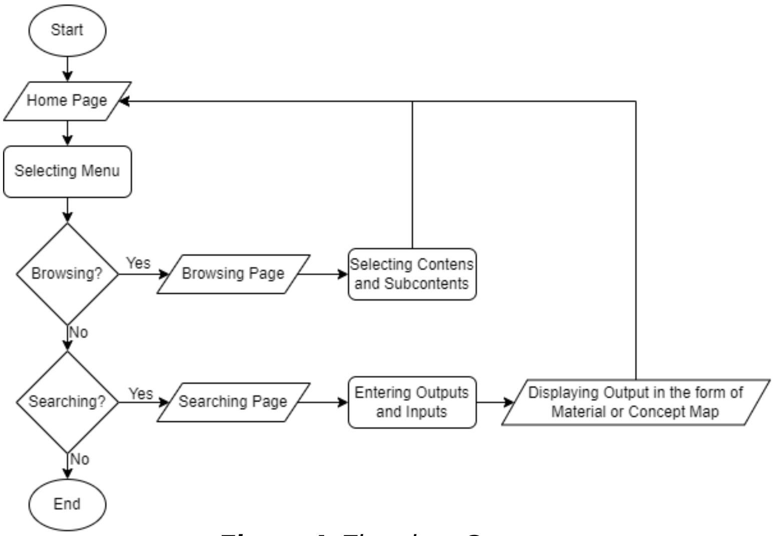

Figure 4. *Flowchart System*

2.2.3 Evaluation of Prototyping

At the evaluation stage, the prototype that has been made is evaluated to suit customer needs. Evaluation is also carried out on the developed system so as not to deviate from the concept of the initial system. If the prototype is correct, it will be continued in the fourth step. If the prototype does not match, it must be corrected by repeating steps 1, 2, and 3.

2.2.4 System Coding

In this stage the agreed prototyping is translated into the appropriate programming language.

2.2.5 System Testing and Evaluation

The system testing and evaluation stage is the stage for testing and evaluating the system. This stage aims to determine the extent to which the system that has been developed can run and solve predetermined problems [9].

At this stage a test will be held using black-box testing, this is done to determine the performance of the system made whether the functions in the system are appropriate or not, and to look for errors from the system display. At evaluation stage will discuss the evaluation of the ontology that has been built. Ontology evaluation will be carried out using *Schema Metrics* in *Ontology Quality Analysis (OntoQA)*. *Schema metric*s consists of measurement of *Relationship Richness* (RR), *Inheritance Richness* (IR), and *Attribute Richness* (AR). These measurements can provide an evaluation of the characteristics and potential of the knowledge representation of the ontology design.

3 Result and Discussion

3.1 Implementation of Methontology in Ontology Design

3.1.1 Spesificaion

Specification phase is to compile a document that includes the primary objectives of ontology, the objectives, and main scope of ontology. The document is written in natural language using a series of intermediate representations or using competency questions. Below the authors include a table of the specifications of this research in Table 1.

Table 1. Spesification

Domain	Basic mathematic of SMP
Goal	To build an ontology model as the basis for learning media for basic mathematics of SMP and developing a semantic web-based system.
level of formality	Semi formal
Scope	Basic math knowledge of SMP
Source of knowledge	Book

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3.1.2 Knowledge Acquisition

Knowledge acquisition is an independent activity within ontology development. However, it coincides with other activities. We acquired most knowledge at the start of ontology development. The level of knowledge acquisition fell as development progressed and we became more familiar with the application domain.

The ontology that is built will represent the knowledge of a set of concepts in a basic junior high school mathematics domain and the relationship between these concepts. The development of the ontology model is based on the concept map contained in the mathematics book so that at this stage the first glossary will be described with terms that are potentially relevant in the domain of basic mathematics of SMP.

3.1.3 Conceptualization

This section will compile domain knowledge in a conceptual model, that describes the problem and its solution concerning domain vocabulary identified in the ontology specification activity [8]. The first thing to do is build a complete glossary. Thus, the glossary identifies and collects all useful and potentially usable domain knowledge and their meanings. At this stage, the authors use the Protégé 5.5.0 software.

The process of forming an ontology class for junior high school mathematics knowledge is based on classes that represent every concept of junior high school mathematics knowledge.

Figure 5. *Class Ontology*

After the class concept is designed, the next step is to input individual data from each class that has been created. In the next picture, several individuals or instances have been worked on.

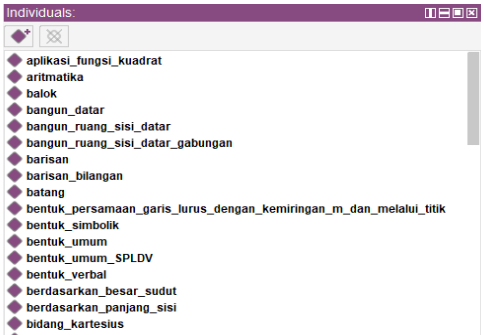

Figure 6. Individual Ontology

After the classes and individuals from the basic mathematics domain of SMP have been created, the next step is to define the class properties. A class if it stands alone will not provide sufficient information without the properties attached to it.

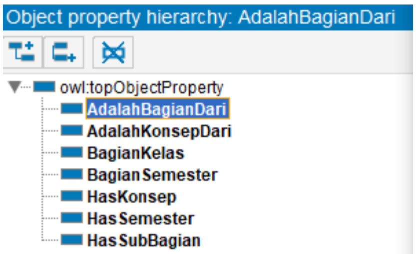

Figure 7. Object Property Ontology

3.1.4 Integration

At this stage, the existing definitions in the ontology will be reconsidered so that the use of such definitions corresponds to the concept of laptop domains. The purpose of this new definition check is to ensure that the new term set used is based on the same basis. Later, the author knows which ontology library gives the definition of semantic terms and how their implementation fits into the terms defined in the concept.

3.1.5 Implementation

In its implementation the author uses the software protege 5.5.0 Build Beta-9. In the implementation the author will execute the ontology that has been created using SPARQL Query. SPARQL is a query language to get information from Graph RDF, which provides facilities such as extracting information in the form of URI, graph RDF consists of triples formed from Subject, Predicate and Object, RDF can be defined in RDF Concepts and Abstract Syntax Concepts.

In this implementation process, a search experiment will be carried out by entering the characteristics or attributes of a concept. Then it will be known whether the concept exists or not. This is done in order to find out whether the ontology that has been built is connected and in accordance with the needs of the author's goals. Of the many individuals related to the concept, the author will try to find a concept which is a material concept from the seventh grade and first semester sections.

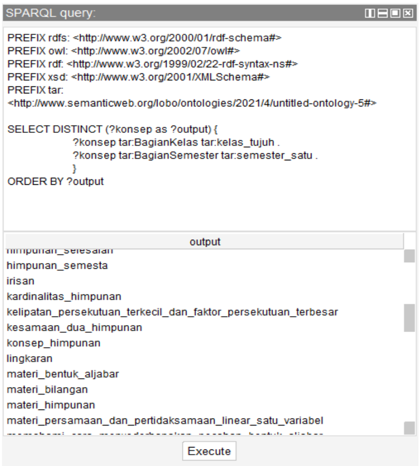

Figure 8. Query Process and Results

The results of the first trial query were 67 individuals. It turned out that in the first experiment it was still not in accordance with the needs of the author's goals because the query results contained individuals that were not intended, for example individual *materi_himpunan* which is an individual of material.

3.1.6 Evaluation

Evaluation means carrying out a technical assessment of the ontology, software environment and documentation in relation to the terms of reference. Evaluation summarizes the terms Verification and Validation. Verification refers to the technical process that ensures the correctness of the ontology, the related software environment. After the design is complete, an evaluation of the consistency and hierarchy is carried out using Reasoner and SPARQL queries. The reasoner used is HermiT 1.4.3.456 which by default is available on Protégé. The reasoner

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will check the consistency of the ontology concept and class hierarchy in the basic mathematics domain of SMP as a whole, where the results of the check will appear in the reasoner log.

3.1.7 Documentation

There are no uniform guidelines on how to create an ontological profile. In most cases, the only available literature is found in ontological codes, natural language texts with official definitions, and papers published in conferences and seminars, journals that address important ontological, ontological questions,and ontograph. A simple schematic of the ontology of basic mathematics learning media systems for junior high schools designed with Protégé is shown in the following figure.

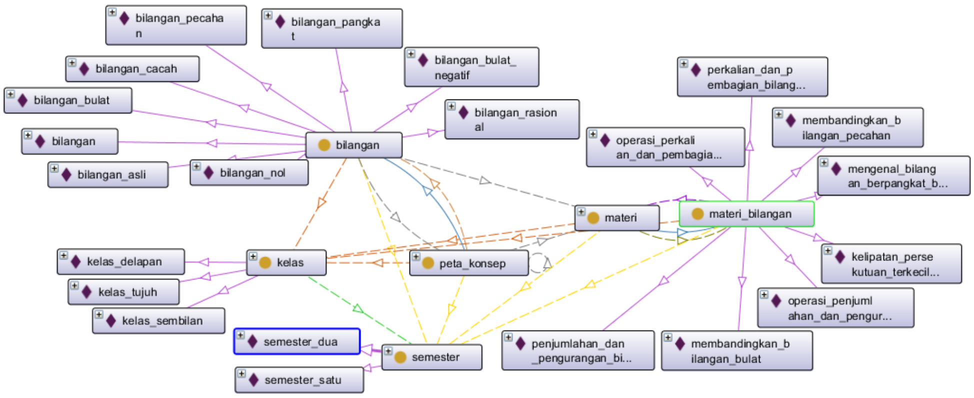

Figure 99. Simple Example of Basic Mathematical of SMP System Ontograph

3.2 Implementation of Prototyping Method

The system interface used in this study uses a PHP programming language. The author divides the services on the system into 2 main services, namely:

1. Browsing: allows system users to browse basic mathematics learning media that have been recorded in the system with available information.
2. Searching: allows system users to browse basic mathematics learning media that have been recorded in the system with available information.

There is 2 pages, namely : Browsing Page (Figure 10) and Searching Page (Figure 11).

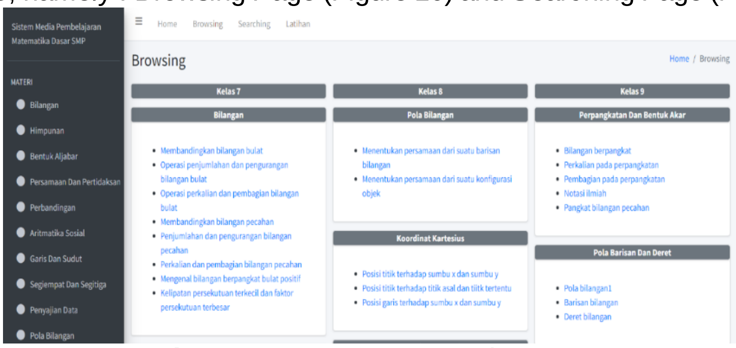

Figure 10. Interface Browsing Page

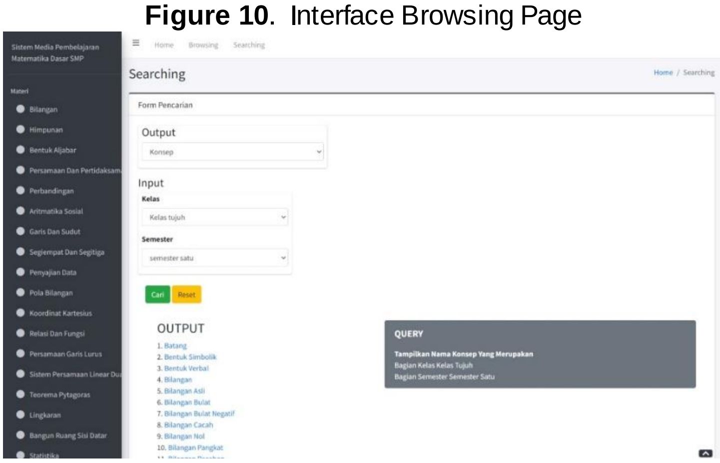

Figure 11. Interface Searching Page

3.3 System Testing And Evaluation

3.3.1 Testing With Black Box

The system is tested through a semantic search and search process by determining the outputs and inputs in the form of materials and concepts to be searched. The test will be carried out by black box testing, where the test aims to see the media system program for basic mathematics learning in junior high school is the same as the task of the system program without knowing the program code used. This test only checks the output values based on the respective input values. The black box testing process is done by trying the system that has been created in order to find out the semantic browsing and searching process according to what the author needs [10].

Table 2. *Test result*

No	Test Description	Expected results	Test result	Result
1	Go to the Browsing page, then select the “Memahami Korespondensi Satu-satu” sub-material on the “Relasi dan Fungsi” material tab or through the sidebar select “Relasi dan Fungsi” then select “Memahami Korespondensi Satu-satu”	The system will display the submaterial page “Memahami Korespondensi Satu-satu”	The system displays the submaterial page “Memahami Korespondensi Satu-satu”	Matching
2	Enter the output "materi" with the input "Kelas 8" and "Semester 1" click search and select the material “Memahami Korespondensi Satu-satu”	The system will display the output of any sub-materials that will appear and if you select the “Memahami Korespondensi Satu-satu” sub-material, the sub-material page will appear.	The system will display the output and display the appropriate material.	Matching

3.3.2 Ontology Evaluation

Ontology quality assessment is important for several reasons such as enabling ontology development to identify areas that need improvement, knowing which parts may have problems, and comparing several ontologies for consideration.

The metrics used are not a specific standard in ontology measurement. However, the metrics are intended to evaluate certain aspects of the basic mathematics ontology of SMP and its potential for further knowledge representation. Rather than describing an ontology as effective or not, metrics describe a particular aspect of an ontology because in most cases, the way an ontology is constructed largely depends on the domain in which it is designed [11].

In OntoQA there are two categories of metrics, namely schema metrics and instances metrics. In this paper, the metrics used are schema metrics because these metrics discuss the ontology design. Although it is not known whether the ontology design models knowledge correctly. Schema metrics represent the richness, width, depth, and inheritance of an ontology. There are 3 types of OntoQA schema metrics testing as follows.

3.3.2.1 Relationship Richness (RR)

Relationship Richness (RR) describes an ontology's diversity of relationships or relationships. An ontology that contains more class-subclass relations is richer than a taxonomy that only has class-subclass relations. RR is defined as the ratio of the number of classes (P) in the ontology schema divided by the number of subclasses (SC) plus the number of classes as in equation (1).

$$RR = \frac{|P|}{|SC| + |P|} \text{ ……………….…..… (1)}$$

The RR value that is closer to one indicates that the ontology contains more non-inheritance relations. This means that the ontology brings richer knowledge than the ontology which has an RR value close to 0. The calculation of the RR value for the basic mathematics ontology of SMP is as follows.

$$RR = \frac{|P|}{|SC| + |P|} = \frac{4}{58 + 4} = 0{,}06$$

In the basic mathematics ontology of SMP, non-inheritance relations or relations between classes are 4, while the number of inheritance or subclass relations is 58, resulting in an RR value of 0.06. This RR value that is close to zero means that it carries very little information or knowledge on the basic mathematics ontology of junior high school.

3.3.2.2 Attribute Richness (AR)

Attribute Richness can measure the amount of information available. AR indicates the quality of the ontology design and the amount of information associated with the data instances. In general, it is assumed that the more attributes defined, the more knowledge expressed in the ontology. AR in equation (2), is defined as the average number of attributes per class. AR is obtained by dividing the number of attributes for all classes (att) by the number of classes (C).

$$AR = \frac{|Att|}{|C|} \text{ ……………….….… (2)}$$

The higher the AR value, the more information that can be provided per class. The calculation of the AR value in the basic mathematics ontology of SMP is as follows.

$$AR = \frac{|Att|}{|C|} = \frac{2}{4} = 0{,}5$$

Based on the AR calculation value in the basic mathematics ontology of SMP, where there are 2 attributes from 4 classes, it is 0.5. This means that the developed ontology characteristics have 0.5 attributes per class. In other words, every 1 class has the opportunity to have attributes or not with a ratio value of 0.5.

3.3.2.3 Inheritance Richness (IR)

Inheritance Richness is a way to measure the distribution of information. In this measurement, it can be distinguished ontologies that have deep or shallow ontology characters. An ontology that has many levels of inheritance is a deep ontology. That is, the ontology has a representation of information that is more in-depth or specific to a domain. This can be seen with a small IR value. On the other hand, a large IR value indicates that the representation of the information held is less in-depth but covers a wider area of a domain or is shallow. The IR value shown in equation (3) is obtained from the average number of subclasses per class.

$$IR = \frac{|H(c)|}{|C|} \text{…………………..(3)}$$

Ontology with a small IR value reflects a more detailed type of knowledge representation of a domain (specific domain), while a larger IR value indicates that the ontology represents general knowledge. The total subclass of 4 classes is 58. So, the calculation of the IR value in the basic mathematics ontology of SMP is as follows.

$$IR = \frac{|H(c)|}{|C|} = \frac{58}{4} = 14{,}5$$

From the results of the calculations above, it can be said that the basic mathematics ontology of SMP represents a more general knowledge or it can be said that the existing knowledge of the basic mathematics ontology of SMP is less deep and covers a wide area.

4 Conclusion

The semantic web-based learning media system with the development of elementary mathematics ontology for junior high schools presents two main features, namely browsing and searching features. The browsing process helps users search for information or knowledge related to basic junior high school mathematics material, and the searching process helps users find material or concepts according to the input that the user will choose in the system.

The design of a semantic web-based learning media system is carried out by developing a semantic ontology of basic mathematics for junior high school. One of the advantages of using a reasoner is that it can check whether all statements and definitions in the ontology are consistent with each other and can help maintain the hierarchy correctly to minimize errors in the process of building a basic junior high mathematics ontology database.

The features in the system have been running well to the author's wishes and the system has succeeded in displaying the desired materials. System feature testing has been done with black box testing. The ontology of the elementary mathematics domain of SMP has also been well designed according to system requirements. The implementation of the ontology with SPARQL queries proves that the ontology has been successfully created according to system requirements. But unfortunately, it is true that the ontology is well designed, but not yet efficient. This is because the results of ontology evaluation with Schema Metrics OntoQA through three measurements (1) Relationship Richness (RR) has a value of 0.06. This RR value that is close to zero means that it carries very little information or knowledge on the elementary mathematics ontology of junior high school. (2) The Attribute Richness (AR) value, measuring the amount of information available, in the elementary mathematics ontology of SMP where 2 attributes from 4 classes are 0.5. This means that the developed ontology characteristics have 0.5 attributes per class. In other words, every 1 class has the opportunity to have attributes or not with a ratio value of 0.5. (3) Inheritance Richness (IR), is a way to measure the distribution of information. The IR value of the elementary mathematics ontology of junior high school is 14.5. This large IR value indicates that the representation of information owned by the system is not deep and feels broad or shallow.

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