Automatic Question Generation In Education Domain Based On Ontology

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***Abstract*— Generating questions at various difficulty levels require significant time and are challenging. It requires specific knowledge and skills. The quality of the generated questions would depend on the question maker's ability to relate information and represent it in the form of a question. Thus, it is difficult to maintain the quality consistency of a large set of questions. This study introduces an ontology-based approach for automating the generation of questions to maintain consistency of question quality. Information related to the ontology is broken down into information categories in the format of SPARQL queries. The queries are then converted into questions. Experts were asked to validate the generated questions. Based on our experiments, the accuracy of the generated questions reaches 86%.**

Keywords—Ontology, Question Generation, SPARQL Query

I. INTRODUCTION

The learning evaluation process is often associated with questions that have various difficulty levels. Bloom taxonomic theory divides the question's difficulty into six levels, i.e., remembering, understanding, applying, analysing, evaluating, and creating [1]. The questions of remembering and understanding levels are classified as a Low Order Thinking Skills (LOTS). The question of applying level is classified as a Medium Order Thinking Skills (MOTS). Furthermore, the question of analyzing, evaluating, and creating is classified as a High Order Thinking Skills (HOTS). HOTS type questions require students to think critically. To answer these questions, students should relate some information and conclude them as an answer [2]. Research [3] shows that students' ability to answer HOTS questions, especially in Natural Science subjects, is still low. Generating HOTS questions is not trivial. Teachers require sufficient time to generate HOTS type questions because they require high creativity information combinations [4]. However, every teacher has a different degree of understanding and creativity. It is challenging to maintain consistency in the questions each teacher generates. Therefore, it is necessary to automate the question generation process.

Ontology is a part of information technology that represents a very flexible relationship between information. Ontology has been used for various case studies, e.g., knowing sentiment analysis in the field of transportation [5], classifying human diseases [6], creating a matrix for assessing cybersecurity [7], generating questions [8 - 15], and so on. Research in the field of ontology-based question generation has been developed in various domains, for example in the music [11], biology [12], health [15] [13], chemical [9], java, knowledge representation [10], and open domains [8]. The majority of studies were developed for English [8] [10-14]. Only two studies were designed for other languages, i.e., French [9] and Romanian [15]

In Indonesia, generating questions using ontology has not been developed. There are only studies that use mind maps to generate essay-type questions [16]. The study did not relate information but related questions that had the same discussion. The purpose of generating this mind map question is to bring up variations of the questions from one input sentence. The information related to the ontology can generate questions with various difficulty levels, including HOTS.

Generating questions using ontology in previous studies has always combined classes, instances, and properties to generate questions. The question stem is created using a predetermined template according to the rules. Questions have many types, as has been categorized in the study [17]. The majority of research on question generation with ontology uses simple factoid questions and focuses on generating distractors for classification of the question's difficulty level. To evaluate students' abilities, not only questions with various levels of difficulty are needed, but questions with multiple categories are also required. The existence of multiple types of questions allows teachers to know the level of understanding of students.

Therefore, this study focuses on generating essay-type questions with various types of questions as in the study [17] with the addition of other types of questions that come from experts. This study aims to generate multiple types of questions from the information in the ontology and speed up the question generation process but still maintain question quality.

This paper's structure consists of previous work in section 2, the application of our approach in section 3, evaluation of the results in section 4, conclusions, and future work in section 5.

II. PREVIOUS WORKS

Mavalankar, Kelkar, & Choppella [11] used ontology, logic tables, similarity finding and hierarchies to generate questions in the music domain. The method of generating the question stem remains rule-based. This study does not discuss the details related to the evaluation carried out.

Alsubait, Parsia, & Sattler [10] used Ontology for generating Multiple Choice Question (MCQ) type questions in a special domain, namely Java and knowledge based. This study focuses on the distractor generation as a determinant of the difficulty level of the questions. Generating question stem is done based on rule. The evaluation was carried out by two participants, which are expert and student. The assessment is

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carried out based on the correctness of the classification of the difficulty level and usefulness of the questions.

Omarbekova, Zakirova, & Abduraimova [8] in their research did not explain in detail how the process of forming questions, this study directly used the algorithm created by the researcher to generate questions. The questions were formed in an essay model. The evaluation method was not explained

Stasaski & Hearst, [12] generate MCQ by selecting 3 randomly connected nodes. Generating the question stem using a rule based on the relationship of the three nodes. This study focuses on distractor generation. The evaluation was carried out by three teachers by providing an assessment of the quality of the questions through a score of 1-7. The teacher also provides feedback on the quality of the questions. This study says that there is an increase in the quality of the distractor generation through the proposed method.

Pistol, Trandab •, & R schip [15] generate four types of questions, namely multiple-choice, fill in the blanks, true/false, and match. The domain of this research is in the health domain and uses the Romanian language. The results of the generated questions have various levels of difficulty. The difficulty level is based on the distance between the questions and the answers on Ontology. However, it is not explained how the distance calculation can be used as a benchmark for classifying the difficulty level of the question. The limitation of this research is that it relies heavily on good text resources. The queries are very stiff, making it difficult to use for other materials.

Shanthi Bala & Aghila [14] developed question generation based on semantic relationships. Generating questions was done using concept, association and case based. However, it is not explained in more detail whether the question generation uses the rule based method or other methods. No detailed evaluation was carried out in this study. The conclusion of this study concluded that the number and complexity can be increased with the use of semantic relationships.

Diatta, Basse, & Ouya [9] used classes, properties and individuals to generate questions. The questions generated are based on true false and MCQ. However, it is not explained in detail how the evaluation results of this study.

Leo el al [13] used ontology to generate questions, generate distractor in multiple choice question, and explanation of the answers to each question. This research used an exclusion engine to make a distractor.

This study uses a special template to generate questions in the health domain. The generated template cannot be used to generate questions in other domains. The results of the question generation were then classified into 3 difficulty levels, which are easy, medium, and high. The classification is based on the calculation of the difficulty level of the sentence, the options used, and the set of options available. However, the evaluation method used was not verified.

Kusuma, Siahaan, Fatichah, & Naufal [16] used a mind map to generate Indonesian questions automatically. However, the mind map does not relate information but relates questions that have similarities in one discussion. The purpose of generating this mind map question is to be able to bring up variations of the questions from one input sentence. The weakness of this research is that the relations that are formed are only question relations, not information relations so that it is impossible to bring up information relations from some information.

III. Research Methodology

This study has 4 sequential stages, which are collecting the dataset, determining the question model, generating questions, then experimenting and evaluating the research results. The details of each process are described in chapter A to chapter D.

A. *Dataset Collection*

The data used in this study is ontology from the subject of Natural Sciences in grades 4, and 5 of Elementary School. This study uses 2 ontologies that discuss the material of the five senses of the human from grade 4 and material on human organs from grade 5. The dataset was created manually by experts in the field of informatics and teachers in the field of Natural Sciences. An example of the resulting piece of ontology is shown in Figure 1. This research use protégé for generate ontology. However, this paper is redrawn in order to clarify the relationship between instances. A box is a class, a box with a dotted line is a subclass, a circle is a instance and a circle that has a dotted line is a data property of an instance. Relationship arrows with dashed lines mean the relationship between subclasses and classes, arrows in the form of lines mean the relationship between instances and classes. Meanwhile, a straight line without arrows means that it describes the relationship between instances. The number of components that each ontology has is shown in Table I.

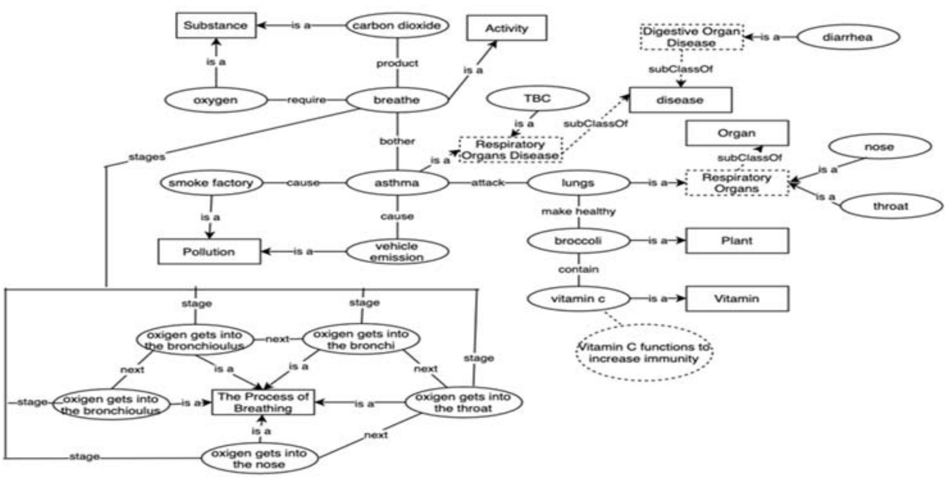

Figure 1. Human Organ Ontology

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TABLE I. DETAIL ONTOLOGY COMPONENT

Num	Learning Material	Explanation
1	Indra Manusia	Axiom : 487 Class : 18 Object Property: 10 Data Property : 5 Individual : 108
2	Human Organs	Axiom : 622 Class : 29 Object Property: 21 Data Property : 4 Individual : 144

B. Determination of Question Model

Questions in education have various categories difficulty level. The categories of questions used in this study were obtained from research [17] and from categories that have been determined by the expert based on existing question models. Questions in the education domain also consider a variety of question types, therefore some categories have more than 1 type of question. Each category of questions in this study has a difficulty level. The difficulty level is given based on the category of questions that are adjusted to the characteristics of each type of difficulty level that has also been used in research [18] [19]. Symbol L in table 2 means LOTS, M means MOTS and H means HOTS. The categories of questions used in this study are shown in Table 2.

TABLE II. QUESTION CHATEGORIES

Num	Level	Category	Questions
1	L	Definition	1. Definisi asma adalah... (*The definition of asthma is..*) 2. Penyakit yang menyerang organ pernapasan adalah… (*Disease that attack the respiratory organs is…)*
2	L	Concept Completion	Jelaskan hubungan paru-paru dan asap pabrik ... (*Explain the relationship of oxygen to breathing!*)
3	H	Verification	TBC adalah penyakit pernapasan. Benar atau salah? Jelaskan pendapat anda! (*TBC is a respiratory disease. True or False? Explain your opinion!*)
4	L	Relation with 2 node	1. Asma menyerang organ pernapasan… (*Asthma attacks the respiratory organs..)* 2. Paru-paru diserang oleh penyakit…(*The lungs are attacked by …. Disease*)
5	H	Relation with more than 2 node	Penyakit yang mengganggu kegiatan bernapas, menyerang paru-paru dan disebabkan oleh asap kendaraan adalah.. (*Disease that infere with breathing activities, attack the lungs and are caused by vehicle fumes is..)*
6	H	Comparison	Apa perbedaan dan persamaan asma dan TBC? (*What the differences and similarities between asthma and tuberculosis?)*
7	L	Feature Selection	1. Sebutkan cara menjaga kesehatan organ pernapasan!(*Mention how to maintain healthy respiratory organs!)* 2. Rajin olahraga dan tidak merokok merupakan…(*Always exercising and not smoking is..)*
8	M	Instantiation	Contoh dari organ pernapasan adalah…(*Example of respiratory organs are..)*
9	H	Classification	Klasifikasikan organ pernapasan berdasarkan jenisnya! (*Classify the respiratory organs according to type!)*
10	L	Function	1. Fungsi dari vitamin C adalah… (*The function of vitamin C is…)* 2. Vitamin yang memiliki fungsi meningkatkan daya tahan tubuh adalah.. (*Vitamins that have the function of increasing endurance are..*)
11	L	Step of the process	1. Bagaimana tahapan proses bernapas? (*What are stages of the breathing process?)* 2. Proses apa yang terjadi setelah oksigen masuk tenggorokan pada proses pernapasan manusia? (*What processes occur after oxygen enters the throat in the human respiratory process?*) 3. Proses apa yang terjadi sebelum oksigen masuk tenggorokan pada proses pernapasan manusia? (*What processes occur before oxygen enters the throat in the human respiratory process?)*

C. Question Generation

The question generation is based on the predetermined question categories. The flow of the question generation process is shown in Figure 2. The input used in the question generation process is ontology. Then information extraction from the ontology by using SPARQL queries. SPARQL is a query language for getting information from an RDF Graph. SPARQL allows data development by querying an unknown relation. Therefore, SPARQL is suitable for information retrieval as a material for generating questions. The result of information extraction is a triplet of information from each category. The triplet is then used as input for the question generation process. The process of converting triplets into questions is carried out based on an algorithm that has been determined in the program. The results of the question generation process are questions in various categories with predetermined difficulty levels. The SPARQL query that is used to extract information is shown in Table 3. There are several categories of questions that use the same query because from this one information, questions with different categories can be generated. For example, category selection and instantiation feature questions can be generated from a query that raises information about the class in the ontology.

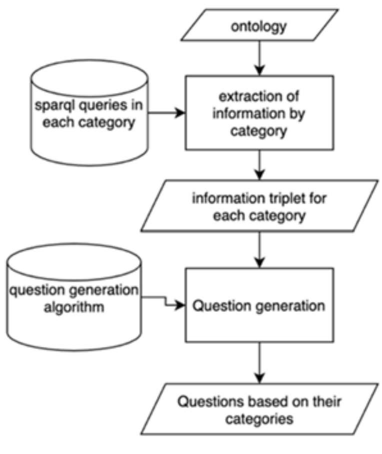

Figure 2. Question Generation Process

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TABLE III. QUERY SPARQL

Num	Category	Query SPARQL

1	Definition	SELECT ?subject ?predicate ?object
		WHERE
		{
		values ?a {:definisi}
		?predicate rdfs:subPropertyOf* ?a.
		?subject ?predicate ?object.
		}

2	Concept Completion	SELECT ?subject ?predicate ?object WHERE { ?p rdf:type owl:ObjectProperty. ?predicate rdfs:subPropertyOf* ?p. ?subject ?predicate ?object . FILTER (?predicate != :selanjutnya && ?predicate !=:sebelumnya && ?predicate !=:tahapan_dari && ?predicate !=:memiliki_tahapan) . }GROUP BY ?subject ?predicate ?object ORDER BY (?subject)
3	Verification	
4	Relation with 2 node	
5	Relation with more than 2 node	SELECT ?class ?subject ?predicate ?object WHERE { ?p rdf:type owl:ObjectProperty. ?predicate rdfs:subPropertyOf* ?p. ?subject rdf:type ?class . ?subject ?predicate ?object . FILTER (?class != owl:NamedIndividual &&?predicate != :selanjutnya && ?predicate !=:sebelumnya && ?predicate !=:tahapan_dari && ?predicate !=:memiliki_tahapan) . }GROUP BY ?class ?subject ?predicate ?object ORDER BY (?subject)
6	Comparison	SELECT ?subject ?predicate ?object WHERE { values ?p {rdf:type} ?predicate rdfs:PropertyOf* ?p . FILTER (?object != :Proses_Bernapas) . FILTER (?object != :Proses_Mencerna_Makanan) . FILTER (?object != owl:Class) . FILTER (?object != owl:ObjectProperty) . FILTER (?object != rdfs:Datatype). FILTER (?object != owl:AnnotationProperty) . FILTER (?object != owl:NamedIndividual) . FILTER (?object != owl:InverseFunctionalProperty) . FILTER (?object != owl:DatatypeProperty) ?subject ?predicate ?object }ORDER BY ASC(?object)
7	Feature Selection	
8	Instantiation	
9	Classification	SELECT ?subject ?predicate ?object WHERE { values ?p {rdfs:subClassOf} ?predicate rdfs:PropertyOf* ?p . ?subject ?predicate ?object . }ORDER BY (?subject)
10	Function	SELECT ?subject ?predicate ?object WHERE { values ?p {:fungsi} ?predicate rdfs:subPropertyOf* ?p . ?subject ?predicate ?object . }

11	Step of the process	SELECT ?subject ?predicate ?object
		WHERE
		{
		values ?p {rdf:type}
		?predicate rdfs:PropertyOf* ?p .
		?object rdfs:subClassOf :Proses.
		?subject ?predicate ?object
		}

```
Input: Ontology triplet (SUBJECT, PREDICATE, OBJECT) and QuestionCategory from 1 to 11
Output: Generated question

Proses:
If QuestionCategory == 1 then
        Question is Definisi SUBJECT adalah ...
        OR
        Question is OBJECT adalah ...
Else If QuestionCategory == 2 then
        Question is Jelaskan hubungan OBJECT 1 and OBJECT2 in
         same SUBJECT
Else If QuestionCategory == 3 then
        Question is SUBJECT PREDICATE OBJECT.
        Benar atau salah? Jelaskan pendapat Anda!
        OR
        Question is SUBJECT not PREDICATE OBJECT.
        Benar atau salah? Jelaskan pendapat Anda!

Else If QuestionCategory == 4 then
        Question is SUBJECT PREDICATE ...
Else If QuestionCategory == 5 then
        c is GroupBy(SUBJECT)
        for i in c then
            Question is class of i
            for j in PREDICATE of i and k in OBJECT of i
            Question += ,j k
       Question += adalah ...
Else If QuestionCategory == 6 then
        for S, T, U, V in SUBJECT
        if S and T has same OBJECT and U and V has same OBJECT
        and S is not equal with T and U not equal with V then
         Question is Apa perbedaan S dan T
         OR
         Question is Apa persamaan S dan T
         OR
         Question is Jika S dan T adalah OBJECT maka U dan V
         Adalah
Else If QuestionCategory == 7 then
        N  is the number of instance in OBJECT
        Question is Sebutkan N OBJECT
Else If QuestionCategory == 8 then
        Question is Contoh dari OBJECT adalah
Else If QuestionCategory == 9 then
        Question is Klasifikasikan OBJECT berdasarkan jenisnya
Else If QuestionCategory == 10 then
        Question is Fungsi dari SUBJECT adalah
        OR
        Question is OBJECT adalah fungsi dari
Else If QuestionCategory == 11 then
        Question is Bagaimana proses SUBJECT pada
        OBJECT
        OR
        Question is Proses apa yang terjadi setelah
        SUBJECT pada OBJECT
        OR
        Question is Proses apa yang terjadi sebelum
        SUBJECT pada OBJECT
```

Figure 3. Question Generation Pseudocode

The pseudocode used to generate questions in each category is shown in Figure 3.

D. *Experiment and Evaluation*

The evaluation used in this study is almost the same as the study [20]. The experiment carried out in this study was to generate questions from various categories and then evaluate the results by 3 experts. Experts are teachers in the field of Natural Sciences at the Elementary School level who have more than 10 years of teaching experience and have been on the team for generate examining questions. Evaluation is needed to test the reliability of the proposed method in

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solving problems. The evaluation that is carried out is to assess the results of generating questions from the methods that have been built. Evaluation is done by taking 100 questions randomly from the entire category. The results of question generation will be assessed by experts by assessing whether the question is true or false. The expert's answer will be correct if the question can be understood and false if the question cannot be understood. The level of understanding on the results of the assessment between experts will then be calculated using Kappa calculations. The Kappa calculation formula is shown in equation 1.

$$K = \frac{P(a)-P(c)}{1-P(c)} \quad (1)$$

where, K refers to value, P(a) refers to the observed interassessor agreement and P(c) is the probability of a chance agreement. If the K value is close to 1, it can be concluded that all the experts have a similar agreement.

IV. Result and Discussion

Based on the experiments that have been carried out, the proposed method produces 1711 questions with details as in table 4. In table 4 there are details of the number of questions from 11 question categories based on 2 types of data. Data 1 is an ontology about the five human senses and data 2 is an ontology about human organs. If it is related to table 1 about the components that each data has, it is known that the data that has the most ontology components will generate many questions. Each question category has a dependency on the ontology component.

The category definition will depend on the existence of the label definition on each instance. The categories of concept completion, verification, and relations with 2 nodes will depend on the triplet relations that the ontology has. The relation category with more than 2 nodes will also depend on the triplet relations that the ontology has, but focuses on nodes that have triplet relations with more than 1 node. Category comparison, feature selection, instantiation will depend on the number of classes and the number of instances of the ontology. Classification categories will depend on the existence of sub-classes on the ontology because this question model will classify instances in a class based on their sub-classes. The function category will depend on the existence of the data property "function" on each instance. The step of the process category depends on the existence of a stage / process in the ontology component. The validation results from the experts showed that 86% of the questions that were successfully generated could be understood. However, the expert suggests that in future research, questions should be more attractive by adding a stimulus sentence at the beginning of the question. The expert stated that this method can generate a lot of questions that can be used to provide a variety of questions when generating exam questions, so that even though the questions are different, the level of difficulty of the questions is still the same.

TABLE IV. Details Of The Number Of Questions Generated

Num	Category	Data		Total Questions
		1	2	
1	Definition	14	38	52
2	Concept Completion	36	149	185
3	Verification	36	149	185
4	Relation with 2 node	36	149	185
5	Relation with more than 2 node	6	26	32
6	Comparison	277	610	887
7	Feature Selection	24	34	58
8	Instantiation	12	17	29
9	Classification	3	5	8
10	Function	22	26	48
11	Step of the process	25	17	42
Total		491	1220	1711

V. Conclusion

Ontology is a part of information technology that represents relationship between concepts. Ontology can be implemented in solving various case studies. In this study, the ontology was successfully used for automatically generating 11 categories of questions. The study deals with education domain. The relationship between concepts helps generate complex questions. The weakness of this ontology-based question generation method is that it relies on the completeness of ontology information. The more related concepts, the more various questions can be raised. Future research that would be developing methods to allow self-expansion of existing ontologies with updated information. It models the grow of knowledge when dealing with incremental grades in formal education.

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