Automatic Question Generation With Classification Based On Mind Map

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***Abstract*— In Indonesia's national education system, a question within a national standardized school examination (Ujian Sekolah Berstandar Nasional, USBN) is generated based on a predetermined grid. A predetermined grid is a matrix that contains a set of criteria that all question should abide. Students who would like to take the final school exam usually prepare themselves by learning through the existing predetermined grid then extend their knowledge around the predetermined grid. But extending knowledge around the predetermined grid is not easy because it depends on the student's creativity to associate the material that exists. The contribution of this research is to generate various types of questions that have relevance to the predetermined grid. The dataset that used is learning the material of all grade in 4, 5, and 6 of elementary school science subjects. The question generation process is done by the rule which generated from the mind map. The mind map will help to determine the interrelationship between the learning material. This study uses 50 competencies from the predetermined grid as input to generate questions. The results of question generation are then validated by an expert. Expert state that all inputs used can generate questions according to competence. The experiment result shows that the proposed method can be used to generate questions that are related to the predetermined grid.**

Keywords—Question Generation, Rule-Based, Mind Map, Question Classification

I. INTRODUCTION

In Indonesia, the questions for the final exam are developed through a predetermined grid [1]. A predetermined grid is a matrix that contains a set of criteria that all question should abide. The purpose of making a predetermined grid is to determine the scope and as instructions for writing questions [2]. The predetermined grid consists of competency, material scope, material, cognitive level, question indicator, the form of a question, and a number of the question [3]. Formal education in Indonesia consists of elementary school, junior high school, senior high school, and university. An elementary school has six levels. Start from grade 1 until grade 6. Students in the sixth grade of elementary school should pass a national standardized school examination (Ujian Sekolah Berstandar Nasional, USBN) to be able to continue to the junior high school level. Questions of USBN for elementary schools in Indonesia are a combination of learning material in grades 4, 5, and 6. Therefore, to passed USBN, students are required to remember and also linking their knowledge from learning the material in grades 4, 5, and 6. Students who will face USBN usually learn through the predetermined grid provided by their teacher. Then they extend the predetermined grid to predict other questions that might come out on USBN. But, to predict other questions is not easy. Students must understand the learning material then they can make questions about that.

Currently, the questions in USBN have several difficulty levels. Questions with varying difficulty level can be used to assess students' abilities more precisely [4]. The varying difficulty level is divided into three levels, namely Lower Order Thinking Skill (LOTS), Medium Order Thinking Skill (MOTS), and High Order Thinking Skill (HOTS). The first level is LOTS. LOTS means the students can remember and understand a learning material. For example, a LOTS question is "What is perfect metamorphosis?". This question is considered as having LOTS level because to answer it, a student needs to understand the learning material about perfect metamorphosis. The second level is MOTS. MOTS means the students can applicate a learning material. For example, a MOTS question is "Animals classified as perfect metamorphosis are…". This question is considered as having the MOTS level because to answer it, a student needs to apply their knowledge to classify animals that carry out perfect metamorphosis. The third level is the HOTS. HOTS mean students have reasoning abilities for learning material. For example, a HOTS question is, "Are there factors that influence perfect metamorphosis? Try to explain your opinion!". This question is considered as having the HOTS level because to answer it, a student needs to provide an analysis of what factors will affect the perfect metamorphosis process [5]. HOTS questions are usually made from a combination of previous learning material. Therefore students are also required to understand the interrelationships between learning material.

Latipah and Adman [6] using a mind map to improve learning outcomes. Mind map could help students to find out the important points of discussion in the learning material [7]. There has been no other study where mind map combines similar materials from different levels of grades. Recently, mind maps are only made for each chapter or subchapter. It will only help students to understand the points one by one, but not the interrelationship, and the question that may arise from the learning material. Currently, mind maps are just learning media. Although there is a possibility that mind maps can also be used to help make learning evaluation questions automatically.

Recently, there have been several studies using both Indonesian and English that try to generate questions automatically. The research included the question generation of 5W 1H for the domain of Indonesian using syntactical templated-based features from academic textbooks [8], generating automatic type questions for Indonesian texts that use compound sentences [9], and generating questions in Indonesian based on Bloom's Taxonomy using template-based methods [10]. There are also three studies related to the question generation that use English, namely automatic/smart question generation system for the academic purpose [11], automatic question generation from paragraph [12], and automatic generation-based questions on analysis of sentence structure [13]. The majority of research that has been carried out only focuses on generating questions according to the sentences or paragraphs that are used as input. The question raised is dependent on the input sentence. There is still rarely research that can generate questions outside the input sentence but still have relevance to the sentence used as input.

The variety of types of questions commonly used for evaluating learning outcomes requires that automation of question generation in the field of education can generate questions with the varying difficulty level. To generate questions with varying difficulty level cannot only depend on input sentences but also must understand the relevance of the input sentences with the other topics. Therefore this study focuses on generating questions outside of input sentences but having relevance to sentences that are used as input. This study uses a mind map to see the interrelationships between topics. The existence of a mind map helped to increase the variety of questions.

This paper is organized as follows. In section 2, we have described the previous work. In section 3, we have introduced the implementation of our approach. In section 4, we have evaluated the result. In section 5, we have described the conclusions of this method and future work.

II. Previous Work

Setio & Kusuma [8] made the generation of questions for the academic field. Four processes are carried out to generate these questions including the identification of declarative sentences for eight co-classes and 19 fine-class sentences, the classification of rules for fine-class sentences, the identification of question patterns and the extraction of sentence components as well as the rule generation of questions. This research resulted in an accuracy of 83% for coarse class and 92% for fine class.

Ginanjar and Purnamasari [9] make automatic question generation for Indonesian Texts containing compound sentences. The method consists of two stages, namely pre-processing and main processing. Pre-processing is the initial stage for getting word types and entities named for each word in the sentence, while the main process is a syntactic analysis process which consists of identifying phrases with pattern matching methods, the process of determining grammatical functions with rule-based methods and the question generation process with the template-based method. The results of the problem generation accuracy are 71.06%.

Kusuma and Alhamri [10] make the question generation classified according to the taxonomy of bloom. The method used is template based. This research does not only generate questions but also classifies the level of difficulty. The classification process is based on the keywords that appear on the question. In addition to questions, this study also predicts answers based on the template that has been made. But the question generation in this study is very dependent on the sentence inputted. This study cannot generate questions outside the inputted sentence.

Vibahndik and Samant [11] made the generation of questions in the field of Education. There are seven stages used to generate a question. The seven stages are Key Phrase Extraction, Key Phrase Classification Conceptual Graph Construction and Conceptual Question Generation, Abbreviation Extraction, Possible Option Extraction, and MCQ generation. This research only focuses on five categories of education, namely Research Field, Technology, System, Term, and others.

Swali, Palan, and Shah [12] do the generation of questions from a paragraph using a semantic approach and a syntactic approach. Each sentence will be selected first, whether it can be a question or not. The selection process is done by identifying the features of each sentence. The features used are the first sentence, last sentence, frequently appearing words, sentence length, number of nouns, adverbs, and conjunctions. This study has not been able to make questions from sentences that have pronouns.

Blstak & Viera [13] performs the question generation through the template-based method obtained from sentence structure analysis. This study produces a more effective pattern than previous studies because it has fewer patterns but has better results in generating problems. The pattern in this study was made through a combination of POS Tags, Named Entity Relations (NER), and Super Sense Tags (SST). Although it has good accuracy, the use of combining patterns makes the computing process more complex.

III. Research Methodology

In this section, we have described our approach in detail. There are three processes in this study, namely dataset collection, mind map building, and question generation and classification.

A. Dataset Collection

The dataset used is elementary schools science learning materials of class 4, 5, and 6. The material is obtained from the Buku Sekolah Elektronik (BSE) of the Indonesian Ministry of Education. The material has been used as a material for making mind maps.

B. Mind Map Building

Mind maps are built based on discussion points in a material. Figure 1 shows an example of a mind map of the animal life cycle.

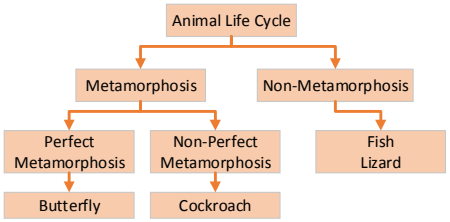

Figure 1. Mind Map of Animal Life Cycle

From the main discussion point, the mind map of the animal life cycle will branch out into smaller sub-discussions. There are no specific rules or limitations in making mind maps. Therefore, one mind map can have various versions. The majority of mind maps do not bring up issues that can be used as questions from the material. Therefore, the mind map used in this study was modified. It focuses on generating mind maps to generate a question based on the material. The mind map in this study would also be modified so that it has material relevance in the previous class. An example of an extended mind map used as a dataset is shown in Figure 2.

Mind maps are formed from a collection of discussion points, grade, sub-discussion points, and issues. Fourth components come from learning material at BSE. Discussion point comes from the material in BSE. The grade comes from the level in elementary school. The sub-point discussion comes from the sub-material discussed, while the issue is formed from the questions that appear in the final evaluation section in the material/discussion point. Each discussion point is related to sub-discussion points. Linkages can occur between sub-discussion point in one class or different classes (4.5, or 6). The sub-discussion point grouping is important because sometimes there is a connection between sub-discussion point that we must know, for example before understanding breeding in animals, students should know about the theory of animal life cycle processes, animal classification and other theories related to animal life. Experts will validate the truth of the formation of discussion points, sub-discussion points, issues, and grouping of discussion points. Examples of discussion point are "2. Hewan" (2. Animal). Example of grades is 4,5 or 6. Example for the sub-discussion is "2.1Penggolongan hewan" (2.1 Animal Classification). The example for the issue of the sub-discussion is in point "2.1.1Terdiri dari" (2.1.1 consists of). The issue was formed because, at the end of the evaluation, there was a question "Classification of animals consisting of ...".

The extended mind map concept in Figure 2 looks almost the same as ontology-based knowledge modeling as in the research of Le Thanh, Matokhina, and Kizim [14] who use ontology to model knowledge in the domain of "Electrical Engineering." But actually, ontology is not suitable if applied in this study. The concept of ontology is to provide relationships between each class using the property. In this study, knowledge is divided into four parts, namely discussion points, grades, discussion sub-points, and issues. Sub-discussion points always have issues that represent questions that can be raised from the sub-discussion. The issue does not explain the relationship between sub-discussions. So, the concept cannot be equated with ontology

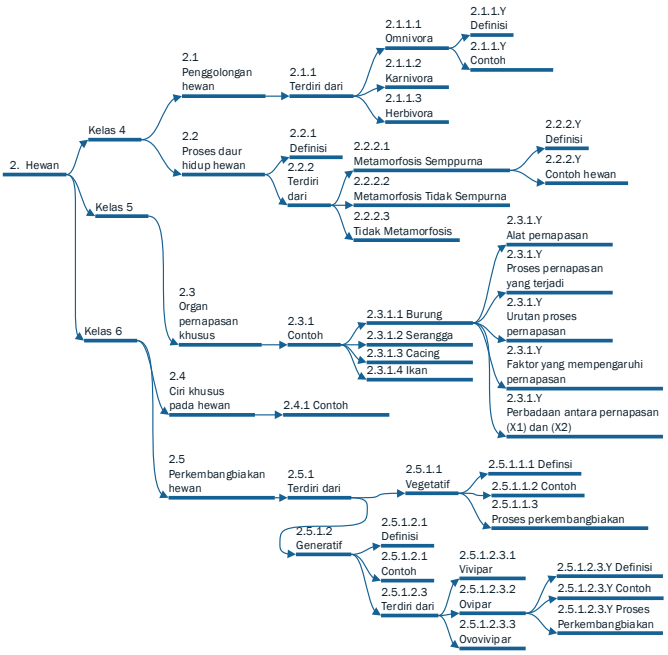

Figure 2. Extended Mind Map of Animal (Hewan)

After there are sub-points of discussion there will be an issue related to the sub-points of the discussion and so on. The issue "2.1.1Terdiri dari" (consisting of) will produce the next sub-discussion point, which is divided into omnivores, carnivores, herbivores. From the second sub-discussion point, new issues will arise regarding "2.1.1.1Y Definisi" (2.1.1.Y Definitions) and "2.1.1.Y Contoh hewan" (2.1.1.Y An example of an animal).

The process of making mind maps is shown in Figure 3. The process is done manually by an expert in the field of education. The expert will collect material along with supporting questions from each material for grades 4, 5, and 6. Then the expert will raise the issue of each material based on the questions that are often raised from the material. The issues that arise will be formed like a mind map. Rule generation questions will be developed based on the mind map that is formed. Examples of rule from mind maps in Figure 2 are shown in Table 1. Rules that are made are general, which means they can be applied to any material. For example, for the issue of "2.3.1.Y Proses yang terjadi pada (X)" (The process that occurs in (X)), the issue can be used to generate questions from material about "2.3.1.1 Burung" (Bird) and "2.3.1.3 Ikan" (Fish). The example of the question is, "How do the process that occurs in Bird breathing?" And "How to do the processes that occur in Fish breathing?". The symbol (X) is the sub-discussion point from the previous branch. The symbol (Y) in each issue means that the issue can be used to generate questions from sub-discussion points in the previous branch. Besides generating rules, experts will also determine the difficulty level of the questions in every rule. Classification on the difficulty level is based on Bloom's Taxonomy. Capability for remembering (C1) and understanding (C2) are classified into LOTS level. Capability for applying (C3) is classified into MOTS level. While Capability for analyzing (C4), evaluating

TABLE I. RULE IDENTIFICATION

No	Level	Issues	Rule	Generated Questions
1	L	2.1.1 Terdiri dari.. (Consist of)	(X) terdiri dari... ((X) Consist of..)	Questions 1:**Penggolongan hewan** terdiri dari… **(Animal classification** consists of…) Questions 2:**Perkembangbiakan hewan** terdiri dari…(**Animal breeding** consists of…)
2	H	2.3.1.Y Proses yang terjadi (Processed Occurred)	Bagaimana proses yang terjadi pada (X)? (How is the process that occurs at (X)?)	Question 1: Bagaimana proses yang terjadi pada pernapasan burung? (How is the process that occurs at **bird breathing?)** Question 2: Bagaimana proses yang terjadi pada pernapasan ikan?(How is the process that occurs at **Fish breathing?)**
3	H	Hubungan antar materi pelajaran. (Linkages between materials)	Apakah ada hubungan antara (X) dan (W)? (Is there a link between (X) and (W)?)	Question 1: Apakah ada hubungan proses daur hidup hewan dan perkembangbiakan hewan? (Is there a link between **animal life cycle** and **breeding of animals**?) Question 2: Apakah ada hubungan antara organ pernapasan dan ciri khusus pada hewan? (Is there a link between **respiratory organs** and **special characteristics in animals?)**

(C5), and creating (C6) are classified into the HOTS level [2]. The difficulty level for each rule will be shown in the level column. L means LOTS, M means MOTS, and H means HOTS. There is an issue that is not directly reflected as a branch of sub-discussion point, for example, in table 1 no 3. The issue of the relationship between materials appears not yet reflected as a branch because this issue will always be generated automatically from 2 sub-discussion point.

C. *Question Generation and Classification*

The concept of the question generation process from beginning to end is shown in Figure 3. The generation of questions begins by entering the competency as input. Then the competency is entered into the preprocessing, which consists of tokenizing process, stop word removal, and lemmatization. The term from preprocessing result will be compared with the words in the mind map. When there are the same words, mark the sub-discussion points. Then find the suitability of the issue based on the selected sub-discussion points. Use the rule in each issue that is selected to generate questions. The results of this method are questions that have different difficulty level but still have a relationship of discussion with the competency used as input.

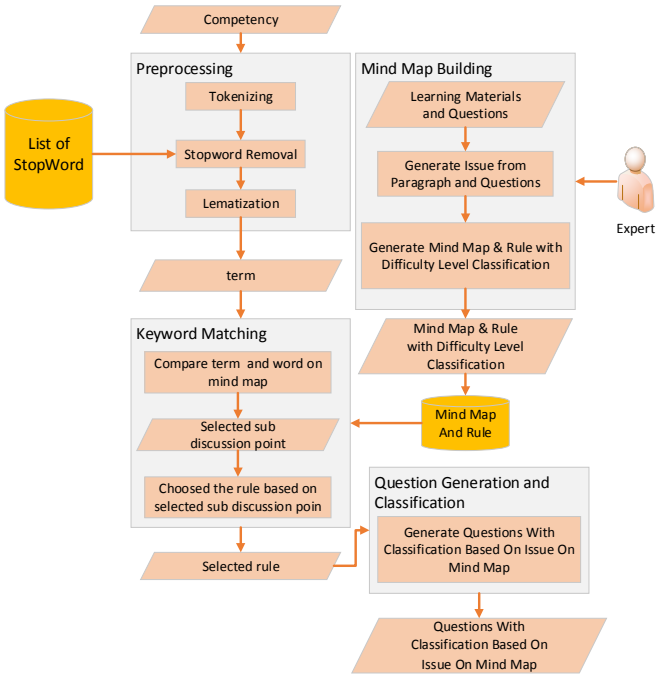

Figure 3. Question Generation Process

The difficulty level for each question raised has been determined during the process of making mind maps and rules for each issue on the mind map. Details of each process shown in Figure 3 will be explained in the following sections.

1. Preprocessing

The input in this study is a competency. Competency is one part of the predetermined grid. An example of competency is "Siswa dapat menjelaskan tentang proses pernapasan pada burung" (Students can explain the breathing process in a bird). In accordance with the steps in Figure 3, the input then goes to the preprocessing stage. Preprocessing begins with tokenization, stop word removal, and stemming. Tokenization is the separation of sentences into word to word. The results of the tokenizing process are "Siswa-dapat-menjelaskan-tentang-proses-pernapasan-pada-burung." After tokenizing then going to the stop word removal process. Stop word removal is used to remove non-essential words. The non-essential words referred to in this study are words that do not represent related topics in this discussion point. The result after the stop word removal is "proses-pernapasan-burung." The word "siswa" (student) is not included in the stop word, but the words are added to the stop word because the word is considered meaningless in this study. The next step is the lemmatization process. Lemmatization means getting the basic word from a word. The result of lemmatization process is "proses-napas-burung." The results of the lemmatization process are the terms that will be used as input in the process of keywords matching.

2. Keyword Matching

Keyword matching is done to find the appropriate discussion points and rules on the mind map. Two processes occur at the keyword matching stage. First is comparing the terms and words in the mind map to determine sub-discussion points, and the second is rule selection based on the selected sub-discussion points. These rules will be used as a benchmark for generating questions. In the first process, each input in the keyword matching process will be matched with a discussion point from the leftmost mind map. When the word is not found in each discussion point, then searches for the second branch of each sub-discussion point (marked with 2-digit number code) and so on. But if the word is found, it will focus only on the appropriate sub-discussion point. For example, the keywords used are "proses-napas-burung" (process-breath-bird). The words are found in code 2.3 for "breath", 2.3.1.1 for "bird" and 2.3.1.Y, 2.5.1.1.3, 2.5.1.2.3.Y for "process".

TABLE II. RULE OF QUESTION GENERATION

No	Level	Issues (2.3.1.Y)	Rule
1	L	Alat pernapasan (Respiratory)	(X) bernapas dengan… ((X) breathe with…)
2	L	Proses pernapasan yang terjadi (The breathing process that occurs)	Proses yang terjadi pada pernapasan (X) adalah… (Process which is happened (X) is…)
3	M	Urutan proses pernapasan (Sequence of breathing process)	Urutan proses penapasan (X) adalah… (Sequence of breathing process on (X) is...)
4	H	Faktor yang mempengaruhi proses pernapasan (Factor that effects on breathing process)	Faktor yang mempengaruhi proses pernapasan (X) adalah… (Factor that effect on breathing process (X) is…)
5	H	Perbedaan antara dua proses pernapasan (The difference between 2 breathing process)	Perbedaan antara pernapasan (X1) dan (X2) adalah… (The difference between the breathing of (X1) and (X2) is ...)

The word "process" is located in more than 1 sub-discussion point. If there are words detected in some sub-discussion point, the word will be ignored. That makes the focus of the sub-discussion point for generating questions, not false. After getting the sub-discussion points then proceed to the second process, namely rule selection based on the selected sub-discussion points. Every sub discussion point always has an issue. The issue is always after the sub discussion point. Every issue has a rule, so the rule will be found if an issue has been found — the example rule used in this study, as shown in table 2. The (X) represents a sub-discussion point in the previous branch. If there are two sub-discussion point compared, then codes X1 to Xn will be used.

3. Question Generation and Classification Process

The generation of questions is based on the rule that appears. Examples of questions that can be generated from the rule in Table 2 are shown in Figure 4. If the rule "(X) breathe with... " then the symbol (X) will be replaced with the previous sub-discussion point. In this case, the sub-discussion point is a bird. So the question that will be formed is "Bird breathes with… ". From point 2.3 about respiratory organs, it is known that respiratory organs material in animals not only discusses the respiratory of bird but also discusses the respiratory of insect, worms, and fish. So, the rules that were used to generate questions related to respiratory of bird can also be used to raise questions regarding the respiratory of insect, worms, and fish. The results of the generation of questions for respiratory of bird in animals are shown in Figure 4. Sub-discussion about the respiratory organ of animal has produced 20 questions. But the example in Figure 4 only produces five questions because it only raises questions for 1 type of animals, namely bird. The same rule can be used to generate questions for similar sub-discussion point at the same level.

Question in Indonesian
Soal untuk materi pernapasan burung:
1. Pernapasan Burung **menggunakan**…
2. **Faktor yang mempengaruhi proses** pernapasan Burung adalah…
3. **Proses yang terjadi** pada pernapasan Burung adalah…
4. **Urutan proses** pada pernapasan Burung adalah....
5. **Perbedaan antara** pernapasan Burung dan Serangga adalah…

Question In English
Questions for discussion point of bird breathing:
1. Bird breathe **with**…
2. **Factors that affect the process of** bird breathing is…
3. **A process which is happened** on bird breathing is…
4. **The sequence process** of bird breathing is**…**
5. **The difference between** bird breathing and the insect is…

Figure 4. Result of Question Generation and Classification

The generated rule is equipped with the difficulty level. So that when using the rule, it will be known what level the question is. Question number 1 in Figure 4 is the question of remember level (LOTS) because to answer it, students have to remember the material that has been studied. Question number 4 is a question of apply level (MOTS) because to answer it, the student has applied theory about respiratory of a bird. Number 3 is the question of understanding level (LOTS) because to answer questions, students only should explain the understanding. Whereas questions number 2 and 5 are a question of analyzing level (HOTS) because the answers to these questions are not in the material being studied. So, the student must analyze by their self. The division of the difficulty level of this question is based on Bloom's Taxonomy.

IV. RESULT AND DISCUSSION

From this study, it is known that to be able to generate a question at the HOTS level, it cannot be made simply by using descriptive sentences from a material. But also need to use the linkages of the information that is available to form HOTS questions. Therefore, to find out the interrelationship between learning materials, a mind map is needed. The mind map will help to see the relationship between words and learning materials. There are eight discussion points in the mind map that are used as datasets. There are human, animal, environment, objects, universe, energy, and force (Manusia, hewan, lingkungan, benda, alam semesta, energy, dan gaya). The eight discussion points produced 412 issues. Completeness of mind map will affect the number of issues. The more issue of the mind map, the more questions that can be generated. Figure 5 shows a comparison chart between the number of discussion sub-points and the number of issue of questions that can be raised. The majority of data shows that the generation of the issue is twice as large as the discussion point. The X axis on the chart represents the discussion point while the Y axis represents the number of issues from each discussion point.

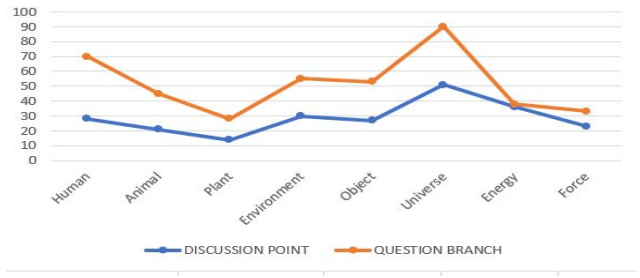

Figure 5. Comparison Between Discussion Points And Number of Issue

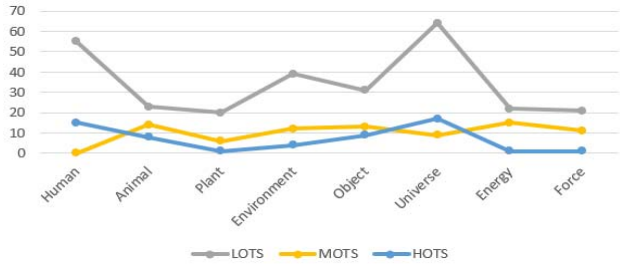

Figure 6. Comparison of The Number of Questions For Each Difficulty Level

Figure 6 shows a comparison chart between the number of questions that can be raised at each level. The X-axis on the chart shows the discussion point while the Y-axis represents the number of questions at each difficulty level from each discussion points.

From these data, it can be seen that LOTS level produces the highest questions, and HOTS level produces the fewest questions compared to other levels. These happened because the rule of generating questions at HOTS level that has been successfully modeled is still limited. There must be another method used to generate questions at the HOTS level. The experiment in this study uses 50 competencies from the predetermined grid as input. And then competency produced questions similar to the competency. The result of question generation validated by an expert. Experts validate by comparing questions generated by experts with questions generated by this method. If it is the same, it will be marked "yes," but if not, it will be marked "no." The number of "yes" answers will be divided by the total number of questions raised. The calculation will represent the accuracy of the success of the proposed method. An expert who carries out validation of generated questions suggests that all of the questions are related to the competency used as input.

V. CONCLUSION

Mind maps will help determine the interrelationship between the learning material. Mind maps can be used to help generate questions automatically and with the various difficulty level. The more branch the mind map has the more questions that can be generated. There are 412 issues that can be used as material for generating questions. But from the 412 issues, only 56 issues were categorized at the HOTS level. From this study, it is known that the rules that have been modeled to generate HOTS level questions are still limited. Therefore, there must be another method used to generate questions at the HOTS level. Besides that, the next research will also focus on developing a more varied and dynamic generate question method.

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