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Quantitative Assessment of Concept Maps for Conceptualizing Domain Ontologies: A Case of Quran

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ABSTRACT

The use of graphical knowledge representation formalisms with a representational vocabulary agreement of terms of conceptualization of the universe of discourse is a new high potential approach in the ontology engineering and knowledge management context. Initially, concept maps were used in the fields of education and learning. After that, it became popular in other areas due to its flexible and intuitive nature. It was also proven as a useful tool to improve communication in corporate environment. In the field of ontologies, concept maps were explored to be used to facilitate different aspects of ontology development. An essential reason behind this motivation is the structural resemblance of concept maps with the hierarchical structure of ontologies. This research aims to demonstrate quantitative evaluation of 4 different hypotheses related to the effectiveness of using concept maps for ontology conceptualization. The domain of Quran was selected for the purpose of this study and it was conducted in collaboration with the experts from the Centre of Quranic Research, Universiti Malaya, Kuala Lumpur, Malaysia. The results of the hypotheses demonstrated that concept mapping was easy to learn and implement for the majority of the participants. Most of them experienced improvement in domain knowledge regarding the vocabularies used to refer to the structure of organization of the Quran, namely Juz, Surah, Ayats, tafsir,

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Malay translation, English translation, and relationships among these entities. Therefore, concept maps instilled the element of learning through the conceptualization process and provided a platform for participants to resolve conflicting opinions and ambiguities of terms used immediately.

Keywords: Binomial test, concept maps, domain conceptualization, ontology

INTRODUCTION

Ontologies have been discussed for centuries in philosophy. It describes ontology as "the study of being or existence" (Cahn, 2012; Simperl, 2009). In computer science, ontologies are extensively used in the fields of knowledge management, information retrieval, natural language processing, e-Commerce, information integration, e-learning, database design, geographical information systems and many other areas. They are the essential parts of intelligent information systems where they are utilized by knowledge engineers to come up with problem-solving and reasoning mechanisms.

According to Lassila & McGuinness (2001), "An explicit specification of a conceptualization or ontology has the following properties: (1) a finite controlled vocabulary, (2) an unambiguous interpretation of classes and term relationships and, (3) strict hierarchical subclass relationships between classes". There may be many definitions for ontology depending on the purpose of creation and utilization. Therefore, there is no one definite definition of ontology. It depends on the context that it is being referred to.

Similarly, there is no one definite methodology for engineering ontologies. There have been several feasible solutions and methodologies for engineering ontologies proposed to date. Instead of using a particular methodology, the notion of merging different methodologies and techniques is supported by the practitioners from the field of ontology engineering (Brusa et al., 2008; Spyns et al., 2008).

CONCEPT MAPS FOR ONTOLOGY DEVELOPMENT

There have been different techniques for conceptualizing ontologies presented over the years. Conceptualization comprises a simplified version of objects, concepts and other entities that are assumed to exist in some area of interest and the relationships among them. The use of graphical knowledge representation formalisms with a representational vocabulary agreement of terms of conceptualization of the universe of discourse is a new high potential approach in the ontology engineering and knowledge management context (Soares & Sousa, 2008).

A concept map is a kind of graphical knowledge representation formalisms that can be used for the purpose of ontology development. Concept maps present meaningful relationships between concepts linked by words from a semantic unit (Novak & Cañas, 2008). The concepts are included in circles or boxes while the links that connect the boxes represent relations among the concepts.

In the field of ontologies, concept maps were explored to use to facilitate different aspects of ontology development. Concept maps are effective, intuitive and adaptive in nature. They can be used to visualize any domain and can serve as a mechanism for domain experts to present the primary elements of their knowledge (Castro et al., 2006).

Tools were also proposed to convert concept maps into OWL ontologies. The tool proposed by Brilhante et al. (2006) which converted concept maps into OWL ontologies. The experts created the concept maps and a knowledge engineer used the tool to perform the conversion of maps into ontologies. Similarly, Dimitrova et al. (2008) came up with the notion of using controlled natural language to guide experts for ontology development. The system facilitated the users to develop ontologies by different ways. For instance, prompts errors when using controlled language and allows tracking classes that have been mentioned. There was another method proposed by Starr and De Oliveira (2013) to cater the need of a knowledge engineer to perform the conversion of concept maps into ontologies by using concept maps as a mean of defining domain knowledge by the experts followed by an application to analyze the concept maps using a set of questions.

Over the years, concept maps have been applied to develop ontologies for many different domains using different methods and techniques due to the structural resemblance of concept maps with the hierarchal structure of ontologies which makes them desirable to be used as a knowledge acquisition tool, and also as an intermediate representation to visualize any domain of knowledge. Some of the recent works on developing and conceptualizing ontologies using concept maps in different domains are discussed below.

The study conducted by Qi and Sugumaran (2018) semi-automatically created detailed level of concepts as a keyword list by applying natural language processing techniques. The list was then used to extract concepts for the domain of automotive safety. The study reported that this method helped to enrich the existing ontology and at the same time closed the gap between ontology and real-world organization ontology-based knowledge management systems.

The study conducted by Hedayati et al. (2017) explored to enhance curriculum development in the domain of ICT vocational education by using concept maps for collaborative ontology maintenance. The results of the study reported that the proposed method enabled to evaluate the external validity of the ontology developed for the domain of ICT vocational education effectively.

Similarly, study conducted by Verbeek and Bothma (2019) reported that the use of concept maps and ontologies were used in the field of civil engineering design in order to analyze and record specific experience by the engineers. The study discussed on how knowledge theories could be coupled with knowledge acquisition techniques to come up with solutions by creating new knowledge that can be linked to both existing and new ontologies. This will facilitate the thinking process and systematic organization of knowledge.

Another study conducted by Rousseau et al. (2018) placed the foundation to develop an ontology for the domain of Systemology. The study argued that by drawing (concept maps) system thinking principles improvement could be made in the standard methods for ontology development. The study reported four examples of how these could be applied for both domain-specific and upper ontologies. Therefore, the study came up with a systematic framework for selecting and organizing knowledge in order to develop an ontology for Systemology.

CONCEPTS IN QURAN

The conceptualization emphasizes on the structure of organization of the Quran. The concepts in the Quran include Juz, Surah, Ayats, tafsir, translations and relationships among these concepts. The key concepts are explained as follows:

A Juz is one of thirty parts of which the Quran is divided. Of note, the division of the Quran into Juz has no relevance to the meaning of the Quran and anyone can start reading from anywhere in the Quran. The most commonly memorized juz is JuzAmma, which is the 30th juz and contains chapters (Surah) 78 through 114.

A Surah is a chapter of the Quran. There are 114 chapters of the Quran and each chapter is divided into verses. The chapters or Surahs are of unequal length where the shortest chapter (Al- Kawthar) has only three ayat (verses) while the longest chapter (Al-Baqara) contains 286 verses. Out of 114 chapters in the Quran, 86 of them are classified as Meccan while 28 of them are classified as Medinan. This classification is based on the locations of revelation.

Ayat means “evidence” or “sign”. In the context of Quran, ayat means “verse”, namely each statement or paragraph marked by a number. Sometimes an ayat contains more than one sentence or may even have many sentences within it. A sentence may also be divided by a break in the ayat and one would have to read from the next ayat to complete the subject or topic. Tafsir is a body of commentary to explain the meaning of verses (Ayats) in the Quran. It is a lengthy explanation which spans over a few sentences to explain a particular ayat.

ONTOLOGY CONCEPTUALIZATION IN A COLLABORATIVE ENVIRONMENT

This research presents an experiment of ontology conceptualization in a collaborative environment using concept maps. There were a total of 30 participants and it was in line with the size of samples used in the similar studies exploiting concept maps (Dimitrova et al., 2008; Milton et al., 2006; Starr & De Oliveira, 2013). All the participants engaged in the study were split into groups and domain experts were invited to facilitate the discussion among the participants. The domain experts were from the Centre of Quranic Research, Universiti Malaya, Kuala Lumpur, Malaysia who specialized in the areas of Quran, hadith and Fiqh (Islamic jurisprudence). On the other hand, the participants (non-domain experts) engaged in the study were between the ages of 25 to 45. The minimum qualification of the participants in the study was Bachelor's Degree. In respect of knowledge of the Quran, majority of the participants were having little knowledge about the domain of Quran and its concepts. The experiment was to perform ontology conceptualization for the domain of Quran. The conceptualization emphasis on the structure of organization of the Quran, namely, Juz, Surah, Ayats, tafsir, Malay translation, English translation and relationships among these entities. A sample concept map for the domain of Quran is shown in Figure 1. It shows that Quran is divided into Juz and each Juz has its given name which comprises different Surahs. Furthermore, each Surah has its given name which has its revelation place and there are a number of verses associated with each of the Suarah. Each verse has its translation and there is tafsir associated with it. The following sets of instructions were given to the participants:

1. Every two members should construct one concept map and share it with others in the team.
2. Participants should not hesitate to share any thoughts regarding any term used in the concept maps. Participants are encouraged to interact actively with each other as well as with the domain experts. They should feel free to suggest exclusion of any existing terms or inclusion of any new terms. The reason should be taken down for every suggestion.
3. Whenever the domain knowledge of the participants increases as a result of interaction and discussion, the participants are advised to make changes to their maps. They are advised to keep all copies of their maps from the beginning till the end.
4. A detailed discussion should be carried out until a consensus is reached on the agreed terms used in the map at the intra-team level.
5. After this, every team should share the final agreed maps with the other teams and send a representative from their team for inter-team interaction. In the event there is any conflicting opinion among the teams, instruction 3 and 4 should be followed but it is at inter-team level for this round.

The interactive nature of such an activity reduced the ambiguity level of terms used and enhanced the understanding of the design and scope of ontology of the team members. Furthermore, it assured homogeneity and coherence in the way the team members perceived of how the domain was being modeled.

The reduction of ambiguities and growth or change of knowledge of participants was tracked and incorporated into subsequent versions of their maps over the time as highlighted by (Novak, 2003). The output of this activity is that the team develops a shared, homogeneous, coherent and unambiguous understanding of the ontology design through the concept mapping platform. All the participants engaged in the experiment were required to fill up the questionnaire after the completion of the experiment.

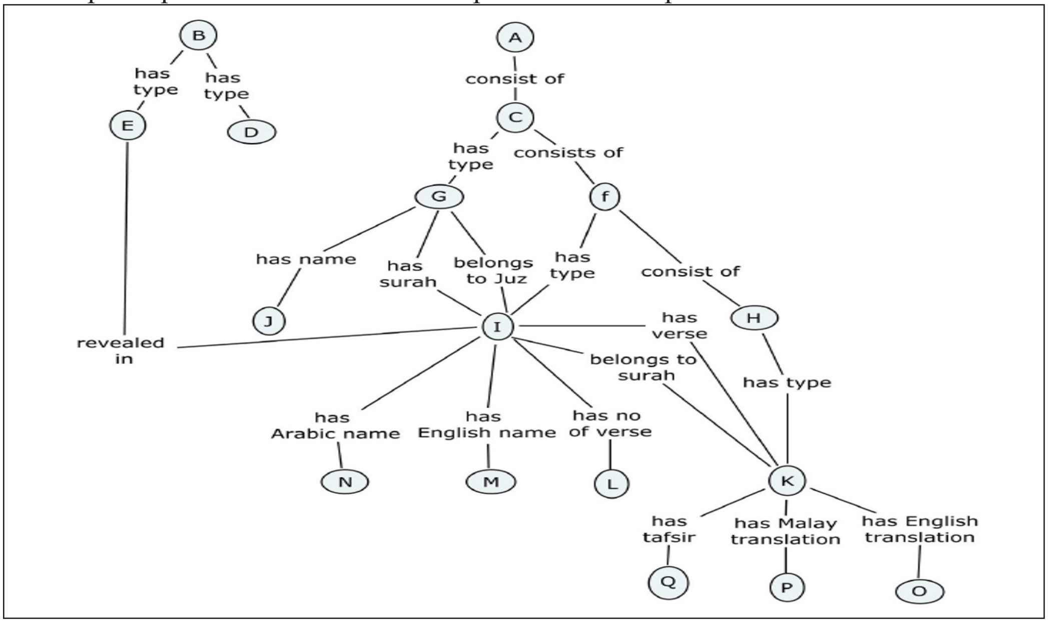

Figure 1. Concept map for the domain of Quran

QUANTITATIVE EVALUATION

The details of the quantitative evaluation of the effectiveness of using concept maps for ontology conceptualization are covered in this section.

Questionnaire

The questionnaire used in this research consisted of 21 closed-ended questions including the demographic questions. The questions of the questionnaire are shown in Table 1. The reason of using questionnaire of close-ended questions is because it provides faster response. Besides that, it provides the respondents a set of answers (explaining their response) for them to select of which is more reliable and consistent as compared to open-ended questions. There were some important factors being considered when formulating the questionnaire (Kumar, 2011):

(a) Using simple and everyday language

(b) Avoid asking ambiguous questions

(c) Avoid asking double-barreled questions
(d) Avoid asking leading questions
(e) Avoid asking questions based on presumptions

Table 1
Questions in the questionnaire

1.	**Age**
2.	**Gender**
3.	**Highest Qualification**
4.	**Years of working experience**
5.	**Are you a domain expert**
6.	**If yes, which category describes you best**
7.	**Do you understand the term “ontology”?**
8.	**Was it easy to learn concept mapping?**
9.	**Did you feel comfortable creating the maps?**
10.	**Were motivation scenarios and competency questions are effective way to represent ontology requirements & scope?**
11.	**Was the term extraction engine (TEE) effective in reducing development time & efforts?**
12.	**Was conceptualization process useful in resolving conflict in opinions & ambiguities related to terms used in the ontology on immediate basis?**
13.	**Do you think that participants experience any improvement or enhancement in their knowledge while performing concept mapping activities?**
14.	**Did you get a chance to input your feedback during the evolution of ontology design?**
15.	**Was the expert map a true and clear representation of the domain?**
16.	**Did the “correct-incorrect discrimination task” provide you an opportunity to test your knowledge about the ontology design?**
17.	**Was the understanding about the ontology design clear before it was implemented?**
18.	**Were the tabular outputs and the expert map helpful in getting a quick insight about the ontology design details?**
19.	**Was the ontology evaluation process effective in assessing compliance of the implemented ontology with its requirements specification?**
20.	**Do you think that all the participants experience homogeneity & coherence in the way each one of them perceives the domain being modeled?**
21.	**Do you feel confident in recommending the developed ontology for reuse?**

The questions in the questionnaire are based on the Likert scale as it provides a reliable and direct mechanism for assessing any phenomenon when a definite answer is required. The answers in the questionnaire are based on 4 levels of Likert scale, denoted by L(4). The scale ranges from “strongly agree” to “strongly disagree.” An even number of options is chosen for the Likert scale in order to ensure that the respondents take a side where the middle option of “Neither agree nor disagree” is not available. The respondents have to either agree or disagree. It is sometimes called the “forced choice” method since the neutral option is removed (Allen & Seaman, 2007). The neutral option can be an easy option for a respondent who is unsure, and as such it is questionable whether it is a true neutral option (Armstrong, 1987). It was also taken into account that the sequence of the questions appearing in the questionnaire should follow a logical progression based on the objectives of the study. This is to help to retain the interest of the respondents and keep them motivated to answer the questions.

Method of Analysis: Non-parametric Statistics

In this research, each individual participant of the study is deemed as a unit of analysis. This research employed nonparametric statistics which was not based on parameterized families of probability distributions. They included both descriptive and inferential statistics. The typical parameters included mean and variance. Unlike parametric statistics, nonparametric statistics do not make any assumptions on the probability distributions of the variables being assessed. Non-parametric models differ from parametric models in that the model structure is not specified a priori but is instead determined from data (Wasserman, 2006). The term nonparametric is not meant to imply that such models are completely lack of parameters but that the number and nature of the parameters are flexible and not fixed in advance. Therefore, nonparametric models are also known as distribution-free (Wasserman, 2006). Non-parametric (or distribution-free) inferential statistical methods are analytical procedures for statistical hypothesis testing which, unlike parametric statistics, do not make any assumptions on the frequency distributions of the variables being assessed (Gibbons & Chakraborti, 2003; Hollander et al., 2013). In this research, statistical hypothesis testing was performed, which is a method of inferential statistics. The binomial test was used, which is a non-parametric test of statistical significance and is an integral part of confirmatory data analysis (Wagner-Menghin, 2005). This binomial test was selected due to the dichotomous nature of the data where all the answers of the participants based on the questionnaire can be grouped into two categories: positive (agree) and negative (disagree) (Wagner-Menghin, 2005). The standard binomial test was applied to the data considering the p-value to be always less than 5% ($p < 0.05$). All the hypotheses referred to a proportion of the population. In the given scenario, the test was used to investigate the minimum population's proportion with respect to the p-value due to the fact that there was no prior expected value for the population's proportion. The following formula was used to calculate inference of the proportion of the population which at least agreed with the hypothesis (Fields, 2005). In the formula, $\hat{p}$ in Equation (1) presents the success proportion of a sample size where $positive\ responses$ refer to those responses which are categorized as positive and $total\ response\ (n)$ refer to the total number of responses. Similarly, $\hat{q}$ in Equation (2) presents the failure proportion of a sample size of which is calculated by subtracting $\hat{p}$ (success proportion in the sample) by 1, considering p-value to be $p < 0.05$. A small p-value indicates strong evidence which is against the null hypothesis. The margin of error is presented as $\hat{p} \pm 1.96\ (se)$. As such, 1.96 is the z-score for 95% confidence that is commonly used in statistics.

$$\hat{p} = \frac{positive\ responses}{total\ response\ (n)} \qquad (1)$$

$$\hat{q} = 1 - \hat{p} \qquad (2)$$

$$se = \sqrt{\frac{\hat{p}\hat{q}}{total\ responses\ (n)}}$$

$$\hat{p} \pm 1.96\ (se)$$

Hypotheses to be Tested

This research intended to investigate 4 hypotheses that were related to the effectiveness of employing concept maps for ontology conceptualization in a collaborative environment. The hypotheses are as follows:

Hypothesis 1. Concept mapping is easy to learn.

Hypothesis 2. Concept maps are comfortable to create.

Hypothesis 3. During conceptualization, learning is experienced by the participants.

Hypothesis 4. During conceptualization conflict of opinions are resolved on an immediate basis.

The quantitative hypothesis testing results for questions 8, 9, 12, and 13 of the questionnaire are reported in order to test the above hypotheses.

RESULTS AND DISCUSSION

Hypothesis 1 which is related with the ease of learning of concept maps is tested by the quantitative hypothesis testing result of question 8 of the questionnaire. The answers "Agree" and "Strongly Agree" were considered as the positive answer where 27 out of 30 participants were on the positive side with a $p < 0.05$. This infers that at least 79% of the population agreed that concept mapping was easy to learn. The statistical output of the binomial test is shown in Table 2.

Table 2
Binomial Output for Hypothesis 1

	Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Group 1	***Positive***	***27***	***0.90***	***0.50***	***0.00***
Group 2	***Negative***	***3***	***0.10***		
Total		***30***	***1.00***		

Hypothesis 2 which is related with the comfort in developing concept maps is tested by the quantitative hypothesis testing result of question 9 of the questionnaire. The answers "Agree" and "Strongly Agree" were considered as the positive answer where 26 out of 30 participants were on the positive side with a $p < 0.05$. This infers that at least 74% of the population agreed that concept maps were comfortable to develop. The statistical output of the binomial test is shown in Table 3.

Table 3
Binomial Output for Hypothesis 2

	Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Group 1	***Positive***	***26***	***0.87***	***0.50***	***0.00***
Group 2	***Negative***	***4***	***0.13***		
Total		***30***	***1.00***		

The quantitative results of hypotheses 1 and 2 are in line with the recommendation found in the existing literature that a down to earth method must be devised for conceptualization because the domain experts (as well as other participants including project stakeholders and users) have primarily practical skills with no experience whatsoever in modeling (Spyns et al., 2008). Some of the interviewees manifested their thoughts on the concept mapping as follows:

- "Concept mapping was easy to understand and implement."
- "Concept mapping provided an easy way for us to model the concepts and relationships together in a way which enable us to visualize how will the final ontology design look like."
- "It helped us to see how the structure of the final ontology will look."

In addition, some critical characteristics of the concept mapping were identified through the responses of the interviewees during the interview sessions. These characteristics are the potential reason for the participants to agree on the fact that concept mapping was easy to learn and implement. These characteristics are as follows:

- Easy for the brain to comprehend and straight forward.
- It aligns with the daily categorization of entities, how things are related in the physical world.
- It enables the ideas to flow freely and enables to link up things in a natural order.
- It is simple, intuitive and expressive.
- It is self-explanatory, and all the elements in it are logically connected.
- It enables to sort vast and complex information and see connections in between different elements.
- It is an effective way to visualize data and its connections.
- It enables to understand the key terms in a domain quickly.

- The users do not face any difficulty in learning it.
- It is close to the way how the human mind thinks and perceives any phenomena.
- It had a learning element in itself. It increased knowledge and understanding gradually.
- It does not require any prior technical knowledge or expertise for learning and implementing it.
- Provides smooth transition of ontology design to its implementation.

Hypothesis 3 which is related to the existence of learning element during the experiment is tested by the quantitative hypothesis testing result of question 12 of the questionnaire. The answers “Agree” and “Strongly Agree” were considered as the positive answer where 28 out of 30 participants were on the positive side with a $p < 0.05$. This infers that at least 84% of the population agreed that they were learning through the process. The statistical output of the binomial test is shown in Table 4.

Table 4
Binomial Output for Hypothesis 3

	Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Group 1	***Positive***	***28***	***0.93***	***0.50***	***0.00***
Group 2	***Negative***	***2***	***0.07***		
Total		***30***	***1.00***		

The above result is also found to be consistent with the existing literature on concept maps which emphasize on their usage in different ways to enhance learning process where they can be exploited as a teaching, learning and assessment tool (Darmofal et al., 2002).

Hypothesis 4 which is related with the resolution of conflict of opinions on immediate basis during the experiment is tested by the quantitative hypothesis testing result of question 13 of the questionnaire The answers “Agree” and “Strongly Agree” were considered as the positive answer where 27 out of 30 participants were on the positive side with value of $p < 0.05$. This infers that at least 79% of the population agreed that the decisive mechanism enables to resolve the conflict of opinions experienced during conceptualization on an immediate basis. For instance, in the domain of Quran, different participants know of the other name of the same concept (i.e., Juz and Para refer to the same concept in the domain of Quran). The statistical output of the binomial test is shown in Table 5.

Table 5
Binomial Output for Hypothesis 4

	Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Group 1	***Positive***	***27***	***0.90***	***0.50***	***0.00***
Group 2	***Negative***	***3***	***0.10***		
Total		***30***	***1.00***		

Some of the participants also expressed their views during the interview sessions conducted after the experiment. Some statements of the interviewees supporting hypothesis 4 are as follows:

- "We had differences in opinions in a few matters, but we were able to resolve it via group interaction, we knew that we have limited time and have to reach a consensus within the given time frame."
- "We got the opportunity to give our idea and suggestions supported with reasons. However, the final decisions were made based on the strength of the reason supporting the argument."
- "The agreement of users based on two-step decision-making mechanism helped to foster communication amongst all the people in an organized and timely manner."

Furthermore, some observations of the participants which signifies the effectiveness of concept maps while conceptualization are as follows:

(a) The team members openly discussed their opinions, conflicts, and suggestions with each other and settled them on an immediate basis.
(b) The team members continuously revised their concept maps.
(c) The participants experienced improvement and enhancement in their domain knowledge.
(d) All the participant groups actively contributed during the sessions.

As highlighted above, the domain knowledge of the participants was improved and they were able to clear ambiguities and resolve conflicting opinions immediately. It differs from most of the existing approaches which result in delayed argumentation and decisive mechanisms.

CONCLUSIONS

The results of hypotheses 1 and 2 show that 79% of the participants at least found that concept maps were easy to learn and 74% of the participants at least agreed that concept maps were comfortable to develop. The results of hypothesis 3 show that majority of the participants who participated the experiment of ontology conceptualization in a collaborative environment for the domain of Quran were learning through the experiment. Statistical inference shows that at least 84% of the population agreed that they were learning through the experiment and it is in line with the findings of an earlier study (Borgo et al., 2012). Moreover, it was shown that there was continuous enhancement in the domain knowledge of most of the participants evidenced by the series of artifacts (concept maps) drawn by the participants especially in the last maps drawn by them. As for hypothesis 4, the results manifest that participants who participated the experiment of ontology conceptualization had the opportunity to resolve conflicts and ambiguities. Statistical inference manifests that at least 79% of the population agreed that the decisive mechanism enables to resolve the conflicts of opinions and ambiguities related to the terms used during conceptualization on an immediate basis.

Therefore, the overall results and observations from the experiment strongly support the existence of discourse and learning through ontology conceptualization process. Moreover, it also provides a platform for the participants to resolve conflicting opinions and ambiguities of terms used immediately.

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