Design for BIO4GS Module's Element Based on Experts' Consensus: Fuzzy Delphi Method Application

Wan Nasriha Wan Mohamed Salleh
Che Nidzam Che Ahmad

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Wan Nasriha Wan Mohamed Salleh, *Department of Biology, Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris, 35900 Tanjong Malim, Perak, Malaysia*

Che Nidzam Che Ahmad, *Department of Biology, Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris, 35900 Tanjong Malim, Perak, Malaysia*
Email: nidzam@fsmt.upsi.edu.my

Abstract

The BIO4GS Module is a teaching and learning module that applies gamification to enhance students' engagement and motivation towards learning Biology. This study aimed to analyse experts' opinions and consensus on the element of BIO4GS Module. This study employed the Fuzzy Delphi Method (FDM) by using a seven-point Likert scale to collect responses of 23 experts in various backgrounds and fields of education. The experts involved in this study were selected using the purposive sampling method. A Design Module Questionnaire was given to the experts for evaluation. Data were analysed using the triangular Fuzzy numbering (Triangular Fuzzy Number) and the Fuzzy evaluation process (defuzzification). The results showed that the experts' agreement exceeded 75%, the overall value of the threshold (d) ≤ 0.2, and an A_{max} value exceeds the value of α-cut = 0.5. This indicated that all items in the questionnaire met the requirements required in the Triangular Fuzzy Number and the Fuzzy evaluation process (defuzzification). The findings showed that experts reached a consensus with the elements of gamification and educational game components. Therefore, all these elements can be used not only to design and develop the BIO4GS Modules but also as a reference in the development of other modules.

Keywords: Fuzzy Delphi Method, element of module, gamification, educational games

Introduction

Biology is a field of science that systematically studies about living things, the environment, and the interaction between lives and its environment as well as things that are related to life[1]. Effective learning of biological concepts enables students to apply the learned knowledge in their daily life to solve problems and deal with future challenges[2]. However, Biology is perceived as a boring, complex, and an incomprehensible subject to many students. This is due to numerous abstract biological concepts[3] that are difficult for students to understand [4-6]. This is further proven by students' unsatisfactory academic achievement in Biology. Students' academic achievement in Biology is still low [7]. Although the annual percentage of students who pass the Malaysian Certificate of Education examination is good, many are still unable to achieve excellent grades in Biology. The percentage of students achieving an excellent grade in Biology subjects was at 22.5% in 2017, and 22.2% in 2018, and 22.6% in 2019 [8].

Many scholars argued that engagement in learning is an important element in successful and effective learning [9-11]. Engagement should be first priority to promote curiosity, activate students' prior knowledge, and initiate independent learning [12]. Students' engagement in learning directly influences their academic achievement [13]. However, students' engagement in learning Biology is presently a major issue faced by many schools [5, 14-17]. Students' engagement level in the learning process is less [5, 13, 18]. Lack of students' engagement in learning can have detrimental effects on their attitude toward learning and their academic achievement [15, 19].

Besides, students' motivation in learning is also a factor that needs to be given attention. Learning engagement is related to students' motivation [20-22]. Engagement ensures that students are able to pay attention and focus on learning which will in turn motivate them to actively seek knowledge [23]. Therefore, motivation is a prerequisite in the learning process [24]. High motivation is needed to ensure that students remain interested in continuing activities and mastering the knowledge learned [13, 25-30]. Also, motivation influences students' success in learning [31-33]. The motivation of students to learn science while in school is an important predictor to determine the field chosen at the tertiary level and in their future career [34]. However, the aspect of motivation is also a major issue in education whereby students are less motivated towards their learning process [18]. It was found that the level of students' motivation towards learning science is declining [35-39].

Thus, students should be encouraged to be more motivated towards learning Biology, especially for students who have a low level of motivation in learning Biology to achieve higher achievement [40, 41]. Strategies in teaching and learning that involve students' engagement and motivation towards learning Biology also need to be given focus and taken into account [34]. Thus, the selection of appropriate teaching approaches and learning materials is paramount in increasing learning motivation, engagement in learning, and students' achievement [19, 42].

Overview of Gamification

The term "gamification" started emerging a few years ago and it is mostly practiced in the fields of marketing, finance, health, and entertainment [43-45]. As gamification has the potential to have many positive effects, gamification has begun to gain more attention [46]. Gamification has also begun to be applied in the education sector [11, 16, 33, 47, 48]. Gamification involves the use of mechanics and the elements of gamification in the education environment [49] which have a positive impact on learning through fun learning activities [10].

In education, gamification can affect student's behaviour as well as increasing their interest, motivation, and engagement in learning [6, 7, 18, 49-54]. Gamification influences students' engagement in terms of their behavioural engagement, emotional engagement, and cognitive engagement [52]. Indirectly, gamification also has the potential to have positive effects on improving students' knowledge, skills, and their academic performances [18, 46, 55-57]. Apart from that, gamification is also capable of engaging students' learning process by utilising the higher levels of Bloom's taxonomy and improving their Higher Order Thinking Skills [10, 38].

Despite many studies pointing towards the benefits and positive effects of incorporating the use of gamification in teaching and learning, there are still limited empirical studies on the aforementioned subject matter [46]. The implementation of gamification in the field of education is also still not widespread and indirectly does not provide many empirical reports on its effectiveness on student learning [43, 44, 46, 58, 59]. Studies related to the effects of gamification in education on students' achievement, engagement, and motivation are still lacking and this method requires more in-depth research as previous studies have mostly obtained descriptive data from survey studies [1, 12, 60].

Gamification is a relatively new in Malaysia [61] and in the field of education, gamification is less discussed [11, 34, 62]. There are several studies related to gamification conducted by local researchers. Most gamification studies were found in the field of History subject [25, 33-35, 62-68], [23, 69] and Islamic education [70]. These studies mostly focused on gamification applications in the production of digital and non-digital games and not many studies were conducted in developing gamification module.

Therefore, there is a need to apply gamification in the biology subjects by developing a module. This gamification module can be used as a teaching material, guideline, and guidance for teachers to improve their teaching strategies creatively and innovatively. Guides in the form of efficient instructional programmes need to be developed as a guide for teachers to adapt teaching and learning approaches that are up to the standards to be achieved [21]. The development of the BIO4GS module applies gamification to improve students' engagement and motivation in learning Biology. Different gamification elements have different effects on students' engagement and motivation [33, 64, 65, 67]. This indicates that the selection of each gamification element must be appropriate and coincide with the purpose for which the gamification method and approach is constructed [5, 71-76].

Therefore, more empirical studies related to the determination of design elements and development of the BIO4GS Module should be done to identify the appropriate elements to be included that are agreed and verified by the experts. Experts' consensus in determining the design elements of the module, especially the gamification elements and educational games component, can affect the engagement and motivation of students in learning Biology. Module design elements that have been agreed upon by a group of experts can be used in the module development process to produce high-quality modules.

Fuzzy Delphi Method

The Fuzzy Delphi Method (FDM) was introduced over three decades ago by [71, 77] and it was later revised by [46, 78, 79]. This method is generated from the modified Delphi technique whereby the combination of the Fuzzy Set Numbering or Fuzzy Set Theory [42] is applied in the traditional Delphi technique [21, 71, 80-82] to reach consensus among the experts in the specific fields [26, 80-85]. FDM is an improved research method from the traditional Delphi method that is able to reach decisions and solve problems in a study [8, 20, 23, 83, 86]. Fuzzy Set Theory was applied to transform qualitative information from experts into quantitative data [87]. The Fuzzy Set Theory was adopted as an extension of the Classical Set Theory whereby each element in a set is evaluated based on a binary set which is (1) Yes or (2) No [42]. This FDM technique is widely used by many recent researchers in various fields of study to obtain experts' consensus in the guideline, product, and module development [3, 5, 6, 9, 19, 30, 35, 59, 67, 70, 88-90]. Thus, various disadvantages of the traditional Delphi technique can be overcome.

In Fuzzy Delphi method, the experts were chosen specifically for the research based on their knowledge, skills, and experience in the respective fields of study [50, 87, 91, 92]. The experts were concern in research problems, aside from being knowledgeable and informative in the related field of study, able to give a commitment to the study and not dominant in giving views and appreciate the views of other experts [62, 63, 93] is also a criterion in the selection of experts. Other than that, the criteria required in the selection of these experts are based on the willingness and availability to make valid contribution to the research at the time of the study [89, 94]. The selection of the right experts is claimed to affect the quality of the result of the study[27, 95-97].

A sampling group with people from various areas of expertise, backgrounds, personalities and perspectives on the subject matter researched lead to contribution of diverse opinions in reaching a consensus on matter researched better than a homogenous sampling group [4, 72, 77, 85, 93, 97-99], which stated that for the Fuzzy Delphi Method, the number of respondents should be between 10 and 50 experts. The numbers of experts selected should be between 15 and 35 experts in order ensure the findings are comprehensive [64, 65]. Group responses are more accurate than individual responses [100]. Variations in group size of experts can also affect the accuracy of the result. Increasing the number of experts in various areas of specialisation is pertinent to produce more accurate and reliable conclusions [53, 101, 102].

Objective

This study aims to identify components in the design of the Form 4 biology module that applies Gamification, Game-based learning via educational Games in the topic of Cell Division and Gametogenesis (BIO4GS Module) based on the experts' consensus in terms of the gamification elements and educational games components.

Research Question

Based on the objective of the study, the researcher would like to identify the answers to the following questions:

1. What is the consensus of experts on the elements of gamification?
2. What is the consensus of experts on educational games' components?

Methods/Methodology

In this quantitative study, the Fuzzy Delphi Method (FDM) was used as the analytical method to obtain experts' consensus on the elements of the BIO4GS Module.

Sampling

The experts involved in this study were selected through purposive sampling. Purposive sampling is the most suitable method used in FDM [26, 103, 104] Based on the views of previous researchers related to the expert selection criteria, the researcher determined the criteria for the selection of experts in this study based on their academic qualification, knowledge, experience, expertise, and contributions in the field of Biology or Science education, Biology or Science curriculum, gamification or games, module development, Higher Order Thinking Skills (HOTS) and psychology or motivation. In addition, the experts who were willing and available to provide a valid view in the context of the study were also chosen for this study. These experts are university lecturers, Malaysia Teacher Education Institute's lecturers, school teachers, curriculum officers in the Malaysia Ministry of Education (MOE). They have at least a Bachelor's degree and 5 years' experience in the respective fields. These experts are chosen based on one of the criteria which is they need to have at least 5 years' experience in teaching because a teacher or a lecturer who has served between five and ten years are considered as experts in their field [91].

A total of 23 experts were carefully selected to answer the Design Module Questionnaire. Table 1 illustrated the experts' background information selected for this study. The experts' background information collected by the researcher consist of their respective levels of education, positions, fields of work, institutions, working experiences and fields of expertise.

Table 1
Panel of Experts' Background Information

Experts' criteria			
Expertise	Biology/Science curriculum, Biology/Science education, gamification/games, module development, Higher Order thinking Skills (HOTS), Psychology/motivation		
Highest Qualification	Degree	4	23
	Master	8	
	PhD	11	
Institution	University	6	23
	IPG	4	
	Polytechnic	1	
	MOE	1	
	PPD	1	
	Matriculation	1	
	Secondary School	9	
Teaching/ Working Experience	6 - 10 years	1	23
	11 - 15 years	10	
	16 – 20 years	1	
	> 20 years	11	
Position	Professor	2	23
	Senior Lecturer/lecturer	10	
	Assistant Director	1	
	SISC + (Biology, Science & Mathematic)	1	
	Biology/science teacher	7	
	Counselling teacher	2	

Instrument

The experts' consensus was obtained through the Design Module Questionnaire. The questionnaire in Delphi method is an extremely effective instrument and it is claimed to be useful in the process of data collection when interviewing individuals cannot be done [12, 50, 51, 100]. The opinions of experts were gathered via questionnaires that were later analysed through statistical analysis by using the triangular Fuzzy numbering (Triangular Fuzzy Number) and the Fuzzy evaluation process (defuzzification). This questionnaire was formed based on the literature review and analysis that was later followed by mapping, analysing, and identifying the appropriate elements of the questionnaire. The idea to do the aforementioned practiced was inspired by previous researchers in which these studies mentioned that the formation of items in a questionnaire can be done through a comprehensive literature review and analysis of the scope of study researched [101, 105].

The formation of items in the questionnaire is also claimed to be form effectively based on literature, by using pilot studies and experience of experts [61], interviewing experts of the field of study researched and focus group techniques [20, 83].This questionnaire consisted of 15 items in the design and development of the BIO4GS Module which was divided into two constructs namely: (1) Gamification elements and (2) Educational games components. Table 2 illustrated the distribution of the questionnaire items in each dimension.

Table 2

The distribution of the Design Module Questionnaire item in each dimension.

Element of The BIO4GS Module	Total of items
Element of Gamification	8
Educational Games Component	7
Total of items	15

This questionnaire used a seven-point linguistic scale of 1 to 7 Likert scale is to replace the Fuzzy numbers [38, 103, 104] to make it easier for experts to answer the questionnaire and to address the issue of fuzziness among experts. The use of the Likert seven-point scale is better than Likert three-point or five-point scale [83]. A higher scale value would indicate that the response analysis is more accurate [3, 20, 39, 83, 102].

Accordingly, the Fuzzy Set Theory allows a gradual process of interpretation of each element in a set and these contained values range from 0 to 1 or within unit intervals (0, 1) [2, 36, 68, 90, 106]. By using the triangulated Fuzzy numbers, the issue of fuzziness in thoughts and inaccuracy among experts were able to be reduced [17, 38, 80, 81, 83].

Data collection process

The Fuzzy Delphi method contains some steps that were followed for the experts' approval. Figure 3 shows a flow chart summary of the procedure involved in the Fuzzy Delphi method as suggested by [83] to obtain the results of the study in terms of experts' consensus.

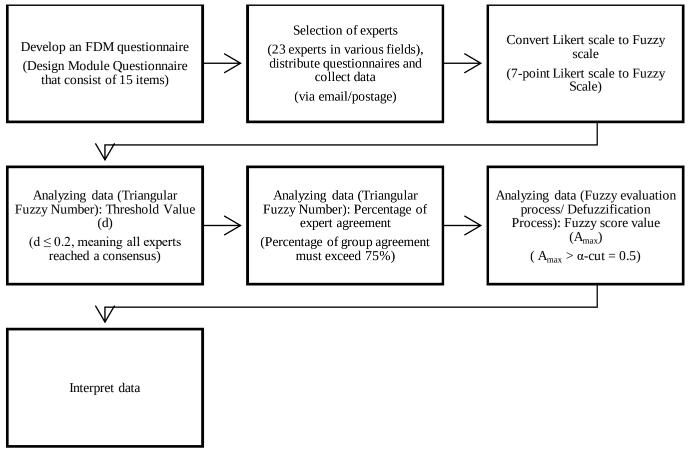

Figure 3. The flow chart of procedure in Fuzzy Delphi Method

Data Analyse

Results obtained from the Design Module Questionnaire were analysed by using the Fuzzy Delphi Method (FDM), specifically the 'TEMPLET ANALISIS FDMv2.0' via Microsoft Excel software [83]. All data obtained from the Likert scale were then converted to the Fuzzy scale by using Triangular Fuzzy Number. This Fuzzy numbering combination produced three Fuzzy values to form a Triangular Fuzzy Number. In the Triangular Fuzzy Number, three values namely minimum value (m1), median value (m2), and maximum value (m3) between the range of 0 and 1 are as shown in Figure 1.

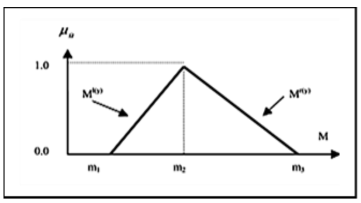

Figure 1. Triangular Fuzzy Number

The rationale for the use of these three numbers is to show that each scale in the Fuzzy scale is not at a fixed value like in the Likert scale [83]. The relationship between the 7-point Likert scale (linguistic scale) and Fuzzy scale is as shown in Figure 2.

Table 3

The seven-point Likert scale and Fuzzy scale Adaptation of [83]

Agreement level	Likert scale	Fuzzy scale		
		m1	m2	m3
Extremely Agree	7	0.9	1	1
Strongly Agree	6	0.7	0.9	1
Somewhat Agree	5	0.5	0.7	0.9
Moderately Agree	4	0.3	0.5	0.7
Somewhat Disagree	3	0.1	0.3	0.5
Strongly Disagree	2	0	0.1	0.3
Extremely Disagree	1	0	0	0.1

The data from the experts' questionnaire were analysed to obtain the Fuzzy value (n1, n2, n3), the average value of Fuzzy (m1, m2, m3), threshold value (d), percentage of experts' group consensus (%), and ranking of an item through the Fuzzy evaluation process (defuzzification) which is the Fuzzy score, A_{max}.

To obtain experts' agreement for each item, the distance between the average and the experts' evaluation data were less than or equal to the threshold value, (d) = 0.2 (d≤0.2) (Chen, 2000; Cheng & Lin, 2002). To obtain the threshold value, the distance between the two Fuzzy numbers which is n = (n_1, n_2, n_3) and m = (m_1, m_2, m_3) were determined by using the formula shown in Figure 4.

$$d(\bar{m},\bar{n}) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]}$$

Figure 4. The formula for determination of the distance between two Fuzzy numbers.

The percentage of experts group agreement for the whole construct or item should be greater than 75% [21, 31, 40, 59, 71, 98] or greater than 67.0% [25, 35, 67, 106]. The percentage of experts' agreement can be calculated by using the formula showed in Figure 5.

$$\text{Percentage of experts' agreement} = \frac{(\text{Numbers of item } d \leq 0.2) \times 100\%}{(\text{Total Items})}$$

Figure 5: The percentage of experts' agreement formula

The Fuzzy evaluation process (defuzzification) was also carried out to determine the Fuzzy score (A_{max}) and the position or priority for each item, variable, or sub variable. The highest value element is determined by the most important position [11, 34, 62]. This ranking process is effective to determine whether certain item should be retained in or discarded from the questionnaire. The Fuzzy scores, (A_{max}) for each questionnaire item can be calculated by using the formula namely: (1) $A_{max} = 1/3 * (m_1 + m_2 + m_3)$, (2) $A_{max} = 1/4 * (m_1 + m_2 + m_3)$ or (3) $A_{max} = 1/6 * (m_1 + m_2 + m_3)$. In this study, formula $A_{max} = 1/3 * (m_1 + m_2 + m_3)$ was used to calculate the Fuzzy scores, (A_{max}).

The Fuzzy score values are numbers that range from 0 to 1. Fuzzy score A_{max} for each item, should exceed α- cut = 0.5, whereby the value of α-cut = the median value for '0' and '1', where α- cut = (0 + 1) / 2 = 0.5. If the resulting value A_{max} exceeds the value of α-cut = 0.5, the item is accepted as it shows that all the experts unanimously agree with the item (Tang & Wu, 2010; Bodjanova, 2006). Otherwise, the item is rejected as it indicates that the experts unanimously agreed to reject the item. Figure 6 shows the position of the α-cut value in the Fuzzy numbering.

A-cut=0.5

0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

Figure 6. The position of the α-cut value in the Fuzzy numbering
Adaptation: [83]

A consensus among experts is considered to be achieved if the threshold value is less than or equal to 0.2 (d≤0.2) and the overall group agreement should be more than 75% (>75%) [107]. Otherwise, a second round of the FDM survey is made to verify whether the item is needed or not (Chen, 2000, Cheng & Lin, 2002) and the survey is repeated until a consensus is achieved.

Result and Discussion

There are two main things in FDM: (1) the Triangular Fuzzy Number and (2) the Fuzzy evaluation process (defuzzification). Table 4 tabulated the findings for analysis by using the Fuzzy triangular numbering that shows the average threshold of the (d) value and the experts' consensus' percentage, Fuzzy score (A_{max}), and ranking of all items in the element of gamification and educational games.

Table 4

The threshold of (d) value, expert consensus percentage, Fuzzy score (A) and ranking of gamification elements and educational games components

Items	Rules of Triangular Fuzzy Numbers		Requirement of Fuzzy Evaluation Process				Experts' Consensus	Ranking
	Threshold value, d	Percentages of experts' consensus, %	m1	m2	m3	Fuzzy Score (A)		
(A) Gamification elements								
Storytelling	0.142	95.7%	0.787	0.922	0.974	0.894	Accepted	5
Avatar	0.159	91.3%	0.787	0.917	0.965	0.890	Accepted	7
Leader-board	0.176	91.3%	0.752	0.896	0.957	0.868	Accepted	8
Progress bar	0.111	91.30%	0.813	0.943	0.983	0.913	Accepted	3
Badges	0.127	95.65%	0.778	0.922	0.978	0.893	Accepted	6
Points	0.069	100.00%	0.830	0.965	1.000	0.932	Accepted	2
Rewards	0.044	100.00%	0.865	0.983	1.000	0.949	Accepted	1
Feedback	0.098	91.30%	0.804	0.943	0.991	0.913	Accepted	3
(B) Educational games components								
Game components and equipment	0.111	100.0%	0.787	0.930	0.987	0.901	Accepted	3
Educational games	0.110	87.0%	0.804	0.939	0.987	0.910	Accepted	1
Game guide / manual	0.144	95.7%	0.770	0.913	0.970	0.884	Accepted	4
Number of players	0.170	95.65%	0.739	0.887	0.957	0.861	Accepted	6
How to play guide	0.190	91.30%	0.726	0.878	0.948	0.851	Accepted	7
How to give points, rewards, and badges guide	0.112	86.96%	0.796	0.935	0.987	0.906	Accepted	2
How to determine the winner guide	0.142	95.65%	0.761	0.909	0.970	0.880	Accepted	5

The results of the analysis on experts' consensus showed that the value of the agreement is at a good level. Based on Table 4, the average threshold values of all items ranged between 0.068 and 0.197 for the element of gamification and 0.105 to 0.190 for the educational game components. This indicates that the first requirement for the Fuzzy Delphi method is reached since the threshold value (d) for all items is less than 0.2 ($d \leq 0.2$). This means that the item in the questionnaire has reached a good experts' agreement [78, 79, 107].

In addition, the percentage of experts' agreement of all items ranged between 91.30% and 100% for the element of gamification and 86.96% to 100% for the educational game components is considered acceptable. This indicates that all items exceed the value of 75% and reach experts' agreement. The second rule of the Fuzzy Delphi Method is reached in which the percentage value of the items is more than 75% [107]. All the accepted items were then calculated based on their respective rankings and importance by defuzzification.

All A_{max} defuzzification values exceeded the a-cut = 0.5 for all items for the gamification element and the educational games components. This indicates that the items are accepted as they showed their agreement to accept the item and the consensus of experts has been reached. The third rule of the Fuzzy Delphi Method is reached. The experts' agreement was achieved when the defuzzification value (Fuzzy score, A_{max}) of all items exceeded the value of α-cut = 0.5. If the value is less than the value of α-cut = 0.5, the item is rejected as it indicates the experts' agreement in rejecting the item [53, 56]. The findings conclusively suggested that the experts have consensus agreed with and verified all the gamification elements and the educational game components. Hence, since consensus was able to achieve, there is unnecessary to repeat the Fuzzy Delphi Method.

Conclusion

Based on the result of the triangulated Fuzzy number and the Fuzzy evaluation process (defuzzification), all items in each dimension comply with all the requirements of the Fuzzy Delphi Method. This study has successfully answered the research questions whereby the results of these analysis show elements of gamification and educational games' components for the design and development of the BIO4GS Module are well conceded by the experts from various fields and backgrounds of education chosen for this study. Therefore, all the elements included have been consensus to be used in designing and developing the BIO4GS Module to encourage students' engagement and motivation towards learning Biology. All the elements included can also be used as a reference for the design and development of modules that apply gamification in the teaching and learning process especially in biology. This study is expected to provide useful information to the biology teachers and the researchers in designing other teaching and learning modules, not only for secondary schools, but also for matriculation colleges and universities.

As a recommendation, FDM should be widely used in education related studies to gather an experts' opinion and consensus, especially in the development of teaching and learning modules as teaching aids for students. Furthermore, it is hoped that this study can be beneficial as guidance for any future education related research especially for Biology education which intends to use FDM for their studies. As suggestion for subsequent studies, researchers can use the Fuzzy Delphi Method with the formation of more precise items in the design and development of modules as well as get more experts from various fields of expertise to ensure better quality results in this field of knowledge.

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