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FUZZY DELPHI METHOD FOR DESIGNING AND DEVELOPING ACID BASE Et-PBL MODULE TO IMPROVE PROBLEM-SOLVING SKILLS

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Abstract
Innovative and creative techniques and materials for teaching and learning are required to keep up with the advancements of globalization. This study aims to reach an expert consensus on the precise and relevant components used while designing and developing an acid-base Et-PBL (Ethics-Problem Based Learning) module to improve problem-solving skills. This study's design is quantitative and employs the Fuzzy Delphi method. Thirty-three items made up the questionnaire instrument used to gather research data. Twelve experts from 10 colleges specializing in chemistry and Islamic education participated in the study. Based on the expert consensus value over 75%, the fuzzy score (A) > α - cut value = 0.5, and the threshold value (d) < 0.2, the data analysis results indicated that the experts accepted all these items. Consequently, it demonstrates that these components have been agreed upon by experts and are required to design and develop the acid-based Et-PBL module.

Keywords: *Fuzzy Delphi Method; Problem-Based Learning; Ethics; Acid-Base*

INTRODUCTION

One of the main challenges in higher education today is developing and implementing teaching strategies that increase students' capacity to apply knowledge effectively. [1]. Higher education institutions must prepare graduates with the skills needed in today's world of work. Many high-performing institutions require decision-makers and solution-oriented employees to overcome complex workplace problems. [2]. One of the approaches that goals to improve such skills in learners is Problem-Based Learning (PBL) [3] .

PBL has been widely implemented in a variety of fields and educational contexts to foster critical thinking and problem-solving in real-world learning environments [4]. PBL is an active learning approach in which a problem triggers learning[5]. In PBL, learning is organized around problems. Students work collaboratively in groups that encourage them to share ideas in solving the given problems [6]. They engage in self-directed learning, apply what they know to the problem, and then evaluate the effectiveness of their selected strategies [3].

One of the essential promises of PBL is to improve problem-solving skills [7]. Problem-solving is a higher-order thinking process where students can analyze and evaluate the given problems using their prior experiences [8]. One measure of effective problem-solving skills is the ability to transfer reasoning strategies to new problems, identify the real issues and aspects of problem-solving that refer to recognizing the problems that need to be addressed [9].

In problem-solving, college students possess more agility and creativity to find answers to the issues given, and this allows them to propose problem-solving strategies and develop a plan for implementing problem-solving [10]. Chemistry learners must be good problem-solvers [11]. However, in reality, Alhayat et al. (2022) reported that the ability to solve contextual chemistry problems among college students is still relatively low, with an overall average percentage of 51.35% [12]. The study conducted by Hadi (2019) also found a low level of problem-solving skills in the chemistry course[13].

One of the subjects studied in basic chemistry courses in universities is acids and bases. This subject are commonly regarded as challenging due to its intricate concept [14], the need for higher-level thinking skills [15], and deep understanding [16]. Yet, this subject is also closely related and widely applied in everyday life [17], [18]. Real-life problems related to acids and bases can be designed in PBL to make it engaging for students to solve them.

PBL originated in the West and was first introduced in medicine by Barrows and colleagues [19]. Based on the philosophy of epistemology, the fundamental pillars of scientific knowledge in the Western tradition are rationalism, which prioritizes reason, and empiricism, which is based on human sensory experience [20] . In contrast to Islam, the main source of knowledge in science is the Quran, along with reason and sensory experience [21]. For Muslims, disregarding the importance of valuing the Quran while gaining knowledge may adversely affect Muslims and lead to a shift towards secular thinking [20].

The process of knowledge acquisition in the Indonesian system aims to develop persons who are comprehensive and harmonised in terms of their physical, emotional, spiritual, and intellectual dimensions, as stated in the goals of Indonesian National Education [22], [23]. Therefore, it is necessary to integrate ethics into chemistry learning. The ethics referred to in this study are theological ethics, specifically derived from Allah through the holy book of Islam, the Quran [24].

To implement PBL, which is stated to improve problem-solving skills and also integrate ethics, chemistry educators need guiding materials specifically and carefully designed to facilitate its execution. One of them is a module that is known for self-instructional characteristics [25]. This aligns with the demands of college students, who must learn more independently without relying heavily on their lecturers. The module that will be developed is named Ethics-Problem Based Learning, abbreviated as Et-PBL.

An appropriate method is needed to design and develop an Et-PBL module. Various studies on Design and Development Research (DDR) initiated by Richey and Klein (2007) have been carried out in developing modules. One of the methods widely used in several DDR studies is Fuzzy Delphi Method (FDM), including in designing and developing modules [26], [27], [28], [29]. The method is considered effective because it can gather various views of experts and their agreement to achieve the desired goal [30]. Through the use of FDM in the learning module design and development process, researchers will get answers and views of experts based on their thoughts and research without any pressure or coercion from any parties. [31].

This study aims to reach a consensus among experts regarding the precise and relevant elements for designing and developing an Et-PBL module on the topic of acid based on a basic chemistry course related to (i) learning objectives, (ii) learning content, and (iii) learning assessment.

METHOD

This study applies the Fuzzy Delphi Method (FDM) to identify, assess, and confirm all the important components and contents of the acid-base Et-PBL module. The fuzzy Delphi Method is a refinement of the Delphi method, which requires the fulfillment of 3 values: the threshold (d) value, percentage expert agreement, and fuzzy score. An item can be accepted based on expert consensus if the threshold (d) value is less than 0.2, the percentage of expert agreement exceeds 75%, and the defuzzification value is above of α - cut = 0.5.

The process of data collection and analysis for this research follows the steps of implementing FDM. There are selection of experts, making questionnaires, distributing questionnaires, changing linguistic variables and finally analysing data based on the 3 value requirements previously described [32].

FDM regulates the number of experts involved in its review to a minimum of 10 experts to achieve high uniformity [33], [34]. Therefore, by using purposive sampling technique, 12 experts were selected to participate in the study. They consist of doctoral degrees in the fields of chemistry education and Islamic education and have at least ten years of teaching experience. Expert selection criteria follows Berliner (2004), who stated that a person who has more than 5 years of experience in a field is considered an expert in that field [35]. In addition, high academic qualifications are also required to become an expert [36].

The experts involved in this study are lecturers who came from various universities in Indonesia, such as Universitas Negeri Surabaya, Universitas Negeri Yogyakarta, Universitas Lambung Makurat Banjarmasin, Universitas Islam Negeri Ar-Raniry Banda Aceh, Universitas Islam Negeri Sultan Syarif Kasim Riau, Universitas Islam Negeri Sunan Kalijaga Yogyakarta, Universitas Islam Negeri Mahmud Yunus Batusangkar, Universitas Negeri Padang, Universitas Adzkia Padang, and Sekolah Tinggi Agama Islam Darul Quran Payakumbuh. Demographics and the number of experts involved in this study can be seen in Table 1.

Table 1. Experts Demographics Information

Experts Demographics		Frequency	Total
Level of Education	Doctor	12	12
Teaching Experience	More than 25 years	6	12
	16 to 25 years	2	
	10 to 15 years	4	
Academic Position	Professor	3	12
	Associate Professor	6	
	Assistant Professor	3	
Field of Expertise	Chemistry Education	8	12
	Islamic Education	4	

Subsequently, the research instrument in the form of a set of questionnaires was developed based on literature analysis. Several ways that can be used to develop questionnaire items include studying the literature, pilot studies, and one's own experience [37]. Elements developed based on literature studies must be in accordance with the research scope[38]. The questionnaire consists of four parts: part A, which is expert demographics; part B, which states the learning objective design; part C, which states the learning content design; and part D, which states the assessment. The total number is 33 items. Excerpt of the questionnaire used is as shown in Figure 1.

After customizing the questionnaire, it was given to three validators to get their views and comments. After being upgraded based on their feedback, the questionnaire was distributed to 12 selected FDM experts either face-to-face or via electronic mail.

Part A: Expert Demographics

Part B : Learning Objective Design

Learning objectives used in the Et-PBL module		Scale							Comments
		1	2	3	4	5	6	7	
1.	Enhance devotion to God								
2.	Exhibit a religious attitude								
3.	Etc								

Part C: Learning Content Design

1. Acids and bases learning material used in the Et-PBL module		Scale							Comments
		1	2	3	4	5	6	7	
1.	Acids and bases theory								
2.	Nomenclature of acids and bases								
3.	Etc								
2. Learning approach used in the Et-PBL module		**Scale**							**Comments**
		1	2	3	4	5	6	7	
1.	Provides active learning activities								
2.	Provides problem-solving activities (scenarios) resembling								
3.	Etc								
3. Ethical elements used in the Et-PBL module		**Scale**							**Comments**
		1	2	3	4	5	6	7	
1.	Provides activities that lead to the cultivation of noble morals,								
2.	Provides values that are sourced from the Al-Qur'an								
3.	Etc								

Part D: Assessment

The assessment used in Et-PBL module		Scale							Comments
		1	2	3	4	5	6	7	
1.	Formative assessment: quizzes. question and answer, written test								
2.	Summative assessment: written test, Essay								
3.	Etc								

Figure 1. Excerpt of the questionnaire used

Data analysis was carried out by converting the Likert Scale to fuzzy numerical data. Triangular Fuzzy Numbers consist of the average values of fuzzy numbers, namely m1, m2, and m_3, calculated for each item. The notation m_1 represents the smallest value, m2 represents the most plausible value, and m3 represents the maximum value. The three values in this Triangular Fuzzy Number can be represented as shown in Figure 2.

All items marked by 12 experts on the questionnaire using a Likert scale were converted to a fuzzy scale. The fuzzy scale with 7 points is used in this study because it can reduce the gap of ambiguity for each value of acceptance and expert approval [39]. The use of a higher scale can also provide precise and accurate answers. Table 2 shows a fuzzy rating score on a seven-point Likert Scale.

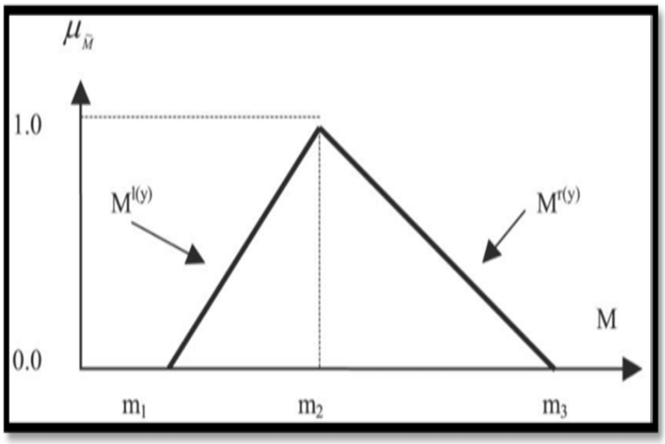

Figure 2. Triangular Fuzzy number diagram

The triangular fuzzy membership function defines the degree of membership μ of a variable M in a fuzzy set, ranging from 0 (no membership) to 1 (full membership). It is characterized by three key points: m_1 (where membership starts to rise), m_2 (where membership is maximum), and m_3 (where membership drops back to 0). The function increases linearly from m_1 to m_2 and decreases linearly from m_2 to m_3. This model is commonly used in fuzzy logic systems to handle uncertainty and approximate reasoning by defining ranges for qualitative variables such as "medium" or "high."

Table 2. Fuzzy rating score on seven-point Likert Scale

Level of agreement	Likert scale	Fuzzy scale
Extremely disagree	1	(0.0,0.0,0.1)
Strongly disagree	2	(0.0,0.1,0.3)
Disagree	3	(0.1,0.3,0.5)
Somewhat disagree	4	(0.3,0.5,0.7)
Agree	5	(0.5,0.7,0.9)
Strongly agree	6	(0.7,0.9,1.0)
Extremely agree	7	(0.9,1.0,1.0)

Furthermore, the threshold value (d) is calculated based on the distance between two fuzzy numbers, m (m_1, m_2, m_3) and n (n_1, n_2, n_3, will be calculated using the following formula:

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

The first requirement that must be adhered in the use of the Fuzzy Delphi study is that if the distance between the average and the expert assessment data is less than or equal to the threshold value (d) ≤ 0.2, then all experts are considered to have reached and established a consensus. [40]. For the second requirement, the percentage value achieving group consensus must be greater than or equal to 75%[41] .

The final requirement is through the fuzzy evaluation process, which determines the priority or ranking for each item or element, also known as fuzzy scores. The symbol for the fuzzy evaluation process is A, which can be calculated using the following equation:

$A = 1/3 * (m_1 + m_2 + m_3)$, or
$A = 1/4 * (m_1 + 2m_2 + m_3)$, or
$A = 1/6 * (m_1 + 4m_2 + m_3)$

Fuzzy score range from 0 to 1, so the midpoint (α-cut) = 0.5. The measured item is accepted if score A exceeds the value of α-cut = 0.5 [14].

RESULTS AND DISCUSSION

The design elements of learning objectives

Learning objectives are important elements to include in a learning module. The learning objectives that will be developed are adjusted to the graduate competency standards, which consist of three competencies: attitude, skills, and knowledge. [43]. Attitude competency is related to increasing faith in Allah and religious attitudes. Skill competency relates to problem-solving skills and logical and systematic thinking skills. Knowledge competency is related to increasing knowledge about acids and bases and integrating it with Islamic values. Theological ethics are Islamic values that originate from God and are revealed through the Qur'an. [24] Therefore, the module that integrates ethics in this research is theological ethics, which is named the ethics module abbreviated as Et. Next, the module's approach uses PBL, which is named the Et-PBL module.

Table 3 reveals the expert assessment results of the learning objective elements that need to be included in the design and development of the acid-base Et-PBL module. The table presents the threshold values (d), expert consensus percentage, Fuzzy scores (A), assessment status, and rank of each item.

Table 3 depicts seven items for the Et-PBL module's learning objectives. All items had threshold value, d ≤ 0.2, expert agreement more than 75%, and the A value is above the α - cut 0.5. This result indicates that all these items Enhance devotion to God Almighty, exhibit a religious attitude, internalize values and norms, improve the ability to think logically and systematically, enhance problem-solving skills, increase knowledge about acids and bases, integrate knowledge about acids and bases with Islamic, have reached expert consensus. The learning objectives are divided into 3 aspects: attitudes (items 1, 2, and 3), knowledge (items 6 and 7), and skills (items 4 and 5), In compliance with the Indonesian Regulation of the Minister of Education and Culture number 53 of 2023 about National Higher Education Standards, which states that graduate learning outcomes are formulated with attitudes, knowledge, and skills. [43]All learning objectives in the Et-PBL will be developed based on the graduate learning outcomes 2024 (revised) for the undergraduate chemistry education curriculum document established by the HKI Chemistry Education Division Forum at Universitas Muhammadiyah Malang on 29 June 2024, and therefore, they have been approved by all experts.

The highest Fuzzy score in Table 1 is 0.942, and it became ranked 1. Items with the same Fuzzy score will get the same ranking (items 1 and 4). The learning objective that received top priority based on expert consensus was item no. 5, enhancing problem-solving skills. The consensus among experts on this matter is closely tied to the numerous research findings that prove that PBL has enhanced problem-solving skills [44], [45], developed problem-solving skills [46], possibly affected problem-solving skills [47], and made students problem-solving skills better [48]. The elements of learning content are classified into three categories: (i) Learning topics, (ii) Learning approaches, and (iii) Ethical elements.

Table 3. The threshold value, expert consensus, Fuzzy score, assessment status, and item rank for each item of learning objectives

No	Items	*Triangular Fuzzy Numbers*		*Fuzzy Evaluation Process*				Experts Consensus	Rank
		Threshold Value, d	Experts Consensus (%)	m1	m2	m3	Fuzzy Score (A)		
1	Enhance devotion to God Almighty	0.068	100.0	0.833	0.967	1.000	0.933	Accepted	2
2	Exhibit a religious attitude	0.097	100.0	0.783	0.933	0.992	0.903	Accepted	5
3	Internalizing values and norms	0.119	100.0	0.767	0.917	0.983	0.889	Accepted	6
4	Improve the ability to think logically and systematically	0.068	100.0	0.833	0.967	1.000	0.933	Accepted	2
5	Enhance problem solving skills	0.057	100.0	0.850	0.975	1.000	0.942	Accepted	1
6	Increase knowledge about acids and bases (Knowledge)	0.087	91.7	0.833	0.958	0.992	0.928	Accepted	3
7	Integrate knowledge about acids and bases with Islamic values	0.098	91.7	0.800	0.942	0.992	0.911	Accepted	4

Design elements of the learning topic

The learning topic in this research is acids and bases. Acids and bases are topics that are close to students' real lives [17] Terms such as stomach acid, alkaline water, neutral, and pH are commonly heard daily. However, this topic is quite challenging because it has an abstract and intricate concept [49], and the need for high-level thinking skills [15]

Table 4 reveals the expert assessment results of the learning topic elements that need to be included in the design and development of the acid-base Et-PBL module. The table presents the threshold values (d), expert consensus percentage, Fuzzy scores (A), assessment status, and rank of each item.

Table 4. The threshold value, expert consensus, Fuzzy score, assessment status, and item rank for each item of learning topic

No	Items	*Triangular Fuzzy Numbers*		*Fuzzy Evaluation Process*				Experts Consensus	Rank
		Threshold value, d	Expert Consensus (%)	m1	m2	m3	Fuzzy score (A)		
1	Acids and bases theory	0.075	91.7	0.850	0.967	0.992	0.936	Accepted	2
2	Nomenclature of acids and bases	0.057	100.0	0.850	0.975	1.000	0.942	Accepted	1
3	Ionization of water	0.075	91.7	0.850	0.967	0.992	0.936	Accepted	2
4	pH	0.075	91.7	0.850	0.967	0.992	0.936	Accepted	2
5	Classification of acid and bases	0.117	83.3	0.817	0.942	0.983	0.914	Accepted	3

Acids and bases are topics studied in the basic chemistry course. [50], [51] As shown in Table 4, there are 5 items for acids and bases topic: acids and bases theory, Nomenclature of acids and bases, ionization of water, pH, and classification of acids and bases. All items meet the requirements because the threshold value, d ≤ 0.2, expert agreement is more than 75%, and the A value is above the α - cut 0.5. Experts agreed on this topic.

Nomenclature of acids and bases is a top priority because it has the highest fuzzy score (0.942). It means, most experts gave it high approval ratings. Learning the nomenclature of compounds, including acids and bases, will simplify understanding the names of chemical compounds. Mastering the names of compounds systematically following IUPAC rules is undoubtedly important to make communication in chemistry more precise and clear. Meanwhile, for acids and bases theory, ionization of water and pH have the same Fuzzy score (0.936) and are second priority. Last, the classification of acids and bases is in the end priority because it has the lowest fuzzy score (0.914).

Design elements of the learning approaches

The results of the expert assessment of the learning approach elements that need to be included in designing and developing the acid-base Et-PBL module. The expert consensus is revealed in Table 5. The table presents the threshold values (d), expert consensus percentage, Fuzzy scores (A), the assessment status, and the rank of each item.

Table 5 shows that there are 9 items offered to design a learning approach in the Et-PBL module: learning through activities, learning through contextualized problem solving, providing problem-solving activities (scenarios) that challenge thinking, provides easy information organization tools that can structure ideas in solving problems, give opportunities for self-assessment regarding the learning process experienced, provides activities for self-information gathering, organizing discussion activities with friends, provides activities that allow for collaboration with peers in the group, provides activities that allow determining the best solution. All items meet the expert's agreement because the threshold value, d ≤

Table 5. The threshold value, expert consensus, Fuzzy score, assessment status, and item rank for each item of learning approaches

No	Items	*Triangular Fuzzy Numbers*		*Fuzzy Evaluation Process*				Experts Consensus	Rank
		Threshold (d)	Experts Consensus (%)	m1	m2	m3	Fuzzy score (A)		
1	Provides active learning activities	0.098	91.7	0.800	0.942	0.992	0.911	Accepted	4
2	Provides problem-solving activities (scenarios) resembling real life	0.068	100.0	0.833	0.967	1.000	0.933	Accepted	1
3	Provides problem-solving activities (scenarios) that challenge thinking	0.095	91.7	0.817	0.950	0.992	0.919	Accepted	3
4	Provides easy information organization tools that can structure ideas in solving problems	0.074	100.0	0.817	0.958	1.000	0.925	Accepted	2
5	Give opportunities for self-assessment regarding the learning process experienced	0.095	91.7	0.817	0.950	0.992	0.919	Accepted	3
6	Provides activities for self-information gathering	0.074	100.0%	0.817	0.958	1.000	0.925	Accepted	2
7	Organizing discussion activities with friends	0.068	100.0	0.833	0.967	1.000	0.933	Accepted	1
8	Provides activities that allow for collaboration with peers in the group	0.074	100.0	0.817	0.958	1.000	0.925	Accepted	2
9	Provides activities that allow to determine the best solution	0.068	100.0	0.833	0.967	1.000	0.933	Accepted	1

0.2, the expert agreement is more than 75%, and the A value is above the α - cut 0.5

The learning approach that will be applied in developing the Et-PBL module is a problem-based learning (PBL) approach. Various models have been introduced to explain in detail the PBL approach by several researchers, including Schmidt (1983) [52], Barrows (1988) [53] and Hmelo-Silver & Ferrari (1997) [54]. This study chose the Hmelo-Silver & Ferrari PBL model because it is more detailed than the two previous models. [55]This model consists of five stages: starting a new group, starting a new problem, problem follow-up, performance presentation, and post-problem reflection. [54]. In addition, this model distinguishes itself by using an information organization tool known as the FILA Chart. [56]. The FILA Chart is a template that stimulates thinking and structures students' ideas in systematically solving problems. [54], and it is in line with expert consensus for item 4.

The problem is the most important component in PBL, and the problem must be contextual [57]. For this reason, problem scenarios on the acids and bases topic in the Et-PBL module must be designed close to real life. Therefore, this item ranks first among the experts' agreements. Some topics and contextual issues in acids and bases such as pH balance in the body, soil acidity for agriculture, rainwater and acid rain, acid-base properties in food, household products for hygiene and daily life, and also natural pH indicators, will can attract students' attention in solving the problems given.

Another elements such as activities that facilitate cooperation and discussion among group members, figuring out the finest answer, and self-information seeking are also the priorities for experts. Those are compatible with Hmelo-Silver (2004), which states that PBL is a problem-solving process, a collaborative learning process, and a self-directed learning process [9]. In the collaborative learning process, students will have discussions, express ideas from different perspectives, and share knowledge and views [58]. This can stimulate the development of ideas to provide detailed justification for the solutions found at the end of the learning session. [9].

The self-directed learning process refers to the freedom given to students to determine the direction of the learning process. At the same time, the teacher acts as a facilitator in helping to achieve the learning objectives that have been set. [9]This also includes students choosing their learning resources, such as books, articles, or the Internet, to gather information.

One other component of PBL is reflection at the end of the learning process. Reflection is important for evaluating students' learning experiences and suggesting improvements to enhance future learning. [53], and therefore, experts have agreed upon it.

The design elements of the ethics

The results of the expert assessment of the ethics elements that need to be included in designing and developing the acid-base Et-PBL module. The expert consensus is revealed in Table 6. The table presents the threshold values (d), expert consensus percentage, Fuzzy scores (A), the assessment status, and the rank of each item.

As presented in Table 6, there are six items for the ethics element. All items had threshold value, d ≤ 0.2, expert agreement more than 75%, and the A value is above the α - cut 0.5. This means that experts approve all of the ethical elements.

Table 6. The threshold value, expert consensus, Fuzzy score, assessment status, and item rank for each item of the ethics

No	Items	*Triangular Fuzzy Numbers*		*Fuzzy Evaluation Process*				Experts Consensus	Rank
		Threshold value, d	Experts Consensus (%)	m1	m2	m3	Fuzzy score (A)		
1	Provides activities that lead to the cultivation of noble morals, faith, and syaria	0.057	100.0	0.850	0.975	1.000	0.942	Accepted	1
2	Provides values that are sourced from the Al-Qur'an	0.087	91.7	0.833	0.958	0.992	0.928	Accepted	2
3	Provides values of "tawheed" and divinity	0.095	91.7	0.817	0.950	0.992	0.919	Accepted	4
4	Provide nuances of Islam in examples. pictures and illustrations	0.098	91.7	0.800	0.942	0.992	0.911	Accepted	5
5	Provide problem scenarios that lead to the cultivation of noble morals, "tawheed" and sharia	0.074	100.0	0.817	0.958	1.000	0.925	Accepted	3
6	Provides activities to read the Quran / translation / tafsir	0.122	100.0	0.783	0.925	0.983	0.897	Accepted	6

Based on these results, experts recommend integrating ethics in the Et-PBL module; it should provide activities that cultivate noble morals, tawhid, and sharia. Cultivating tawhid helps individuals possess noble character and increase their faith in Allah. [59], and this is in line with the learning objectives of the Et-PBL module. Another element of ethics is that the module is designed to provide values derived from the Quran, such as monotheism and divinity. Studies conducted by Ramadayanti et al. (2020) prove that the presence of Islamic values derived from the Quran and Hadith can enhance the religious character of students. [60]According to Muspiroh (2016), integrating Islamic values into learning natural sciences strengthens the values of tawhid, stimulates the continuous search for knowledge, and pays attention to students' moral aspects and noble character. [61] . Islamic values integrated with science are believed to influence students' thinking patterns. [62].

The problem as a key component of PBL is also emphasized to instil morals and tawhid. In addition, the integration of ethics into the module can be done by providing nuances of Islam in examples, pictures, and illustrations. The Islamic nuances in the module can provide new insights to students both in terms of the material and the relationship between the material and Islamic values[63]. Further, the Et-PBL module provides activities for reading the Quran, translating it, and tafsir. This is intended to bring individuals closer to the Quran. According to Sari et al. (2023), strengthening one's faith can be achieved by getting close to the Holy Quran. [64].

The design elements of learning assessment

The results of the expert evaluation of the ethics elements that need to be included in designing and developing the acid-base Et-PBL module. The expert consensus is revealed in Table 7. The table presents the threshold values (d), expert consensus percentage, Fuzzy scores (A), the assessment status, and the rank of each item.

outcomes. [43]. This can be used to determine whether the learning objectives have been achieved. Other aspects of the assessment are adapted to the characteristics and steps of the Hmelo-Silver PBL. As previously stated, the Hmelo-Silver & Ferrari PBL model consists of five steps. The third step is problem follow-up. In this step, each student will present individually regarding the sources and methods they use to solve the problem presented. Therefore, individual presentations can constitute one assessment point. In the fourth step, namely problem presentation, each group will also present the resolution of the problem based on the results of their group discussion. Again, group presentations are also an aspect of assessment. In the fifth step, namely reflection, each student will answer several questions related to their learning experiences in the reflection journal. This will also be an assessment that allows educators to provide constructive feedback on the learning process.

One of the core characteristics of PBL is that learning should be realized with a small group of students [65], PBL is a collaborative learning [9], where students complete together the tasks given in their group [66]So, through these activities, an assessment of group activities can be carried out. By providing various types of assessment, such as formative, summative, presentations, reflection journals, or group activities, modules can be more accommodating to different students' learning styles and needs. This ensures that each student gets the opportunity to demonstrate their understanding and skills in a way that is appropriate for them.

Table 7. The threshold value, expert consensus, Fuzzy score, assessment status, and item rank for each item of learning assesment

No	Items	*Triangular Fuzzy Numbers*		*Fuzzy Evaluation Process*				Experts Consensus	Rank
		Threshold value, d	Experts Consensus (%)	m1	m2	m3	Fuzzy score (A)		
1	Formative assessment: quizzes. question and answer, written test	0.057	100.0	0.850	0.975	1.000	0.942	Accepted	1
2	Summative assessment: written test, Essay	0.057	100.0	0.850	0.975	1.000	0.942	Accepted	1
3	Group activities	0.068	100.0	0.833	0.967	1.000	0.933	Accepted	2
4	Individual presentation	0.074	100.0	0.817	0.958	1.000	0.925	Accepted	3
5	Group presentation	0.098	91.67	0.800	0.942	0.992	0.911	Accepted	4
6	Reflection Journal	0.098	91.67	0.800	0.942	0.992	0.911	Accepted	4

Based on Table 7, there are six items for the assessment: formative assessment (quizzes. question and answer, written test), summative assessment (written test, essay), Group activities, individual presentation, group presentation, and reflection journal. All items had threshold values, d ≤ 0.2, expert agreement more than 75%, and the A value was above the α - cut 0.5. This means that experts approve all of the ethical elements.

One of the components that must be included in the module is the assessment component. [25]Assessment has an important role in learning as it can measure the success of implementing the learning that has been done. Formative and summative assessments can be used to assess student learning

CONCLUSION

Design and Development Research using the Fuzzy Delphi method can be conducted objectively to develop the acid-base Et-PBL module. The consensus results obtained from the views and agreements of experts in determining learning objectives serve as the foundation and principles for the development of the module. Similarly, the selection of appropriate topics, the content of the module consisting of acid and base topics, the PBL approach, and ethical aspects are essential. The assessment methods agreed upon by the experts will also serve as input for educators and all students in utilizing the learning module. Overall, this study has produced an overview of the design and development of the Et-PBL module for the topic of acids and bases. The success was primarily due to applying the fuzzy Delphi method, which involved the perspectives of 12 experts in chemistry education and Islamic education. This study can also serve as input for other researchers interested in integrating ethics or Islamic values in the development of modules for chemistry education.

REFERENCES

[1] F. Dochy, M. Segers, P. V Bossche, and D. Gijbels, "Effects of problem-based learning: A meta-analysis," Learn Instr, vol. 13, no. 5, pp. 533–568, 2003, doi: 10.1016/S0959-4752(02)00025-7.

[2] W. A. B. W. Mohamed, B. Omar, and M. F. R. Romli, "Developing Problem Solving Skills for Long Live Learning Through Work Based Learning Among College Community Student," Journal of Technical Education and Training, Johor: Universiti Tun Hussein Onn, 2011.

[3] C. E. Hmelo-Silver and C. Eberbach, "Learning theories and problem-based learning," in Problem-Based Learning in Clinical Education: The Next Generation, 2012, pp. 3–17. doi: 10.1007/978-94-007-2515-7_1.

[4] E. H. J. Yew and K. Goh, "Problem-based learning: An overview of its process and impact on learning," Health professions education, vol. 2, no. 2, pp. 75–79, 2016.

[5] Y. Ayyildiz and L. Tarhan, "Problem-based learning in teaching chemistry: enthalpy changes in systems," Research in Science & Technological Education, vol. 36, no. 1, pp. 35–54, 2018.

[6] H. G. Schmidt and J. H. C. Moust, "Factors affecting small-group tutorial learning: A review of research," Problem-based learning, pp. 19–51, 2000.

[7] W. Hung, D. H. Jonassen, and R. Liu, "Problem-based learning," in Handbook of research on educational communications and technology, Routledge, 2008, pp. 485–506.

[8] I. Anugraheni, "The influence of polya model problem solving learning on students' mathematical problem solving abilities," Jurnal Pendidikan (Teori Dan Praktik), vol. 4, no. 1, p. 1, 2019.

[9] C. E. Hmelo-Silver, "Problem-based learning: what and how do students learn?," Educ Psychol Rev, vol. 16, no. 3, pp. 235–266, 2004, doi: 10.1023/B:EDPR.0000034022.16470.f3.

[10]C. R. Aldous, "Creativity in Problem Solving: Uncovering the origin of new ideas.," International Education Journal, vol. 5, no. 5, pp. 43–56, 2005.

[11] J. Valdez and M. Bungihan, "Problem-based learning approach enhances the problem solving skills in Chemistry of high school students," J Technol Sci Educ, vol. 9, no. 3, pp. 282–294, May 2019, doi: 10.3926/jotse.631.

[12] A. Alhayat, M. Masriani, R. Rasmawan, H. Hairida, and E. Erlina, "Profile of chemistry education students' abilities in solving chemical contextual problems," Edukatif : Jurnal ilmu pendidikan , vol. 4, no. 3, pp. 4694–4705, 2022.

[13] W. P. Hadi, "Identifying the problem solving abilities of prospective science teacher students in solving titration problems," J-PEK (Jurnal Pembelajaran Kimia), vol. 4, no. 2, pp. 100–105, 2019.

[14] N. Peni, L. Carvallo, and M. Priska, "Problem Solving Learning Model By Integrating ARCS Motivation Strategies On Acid-Base Subjects," Pedagogia : Jurnal Pendidikan, vol. 9, no. 2, Aug. 2020, doi: 10.21070/pedagogia.v9i2.641.

[15] H. Herunata, N. Hidayaturrahman, O. Sulistina, and M. Su'aidy, "Acid-base topic materials oriented towards higher-order thinking skills/HOTs based instruments," in AIP Conference Proceedings, 2021. doi: 10.1063/5.0043117.

[16] F. R. Amalia, S. Ibnu, H. R. Widarti, and H. Wuni, "Students' mental models of acid and base concepts taught using the cognitive apprenticeship learning model," Jurnal Pendidikan IPA Indonesia, vol. 7, no. 2, pp. 187–192, Jun. 2018, doi: 10.15294/jpii.v7i2.14264.

[17] M. Paristiowati, T. Hadinugrahaningsih, A. Purwanto, and P. A. Karyadi, "Analysis of students' scientific literacy in contextual-flipped classroom learning on acid-base topic," J Phys Conf Ser, vol. 1156, pp. 1–6, 2019, doi: 10.1088/1742-6596/1156/1/012026.

[18] D. Salirawati, E. Priyambodo, A. R. E. Nugraheni, and R. Basuki, "Critical thinking ability of high school students in daily life acid-base concept," Jurnal Pendidikan Sains (JPS), vol. 9, no. 1, pp. 1–13, Apr. 2021, doi: 10.26714/jps.9.1.2021.1-13.

[19] A. J. Neville, "The problem-based learning tutor: Teacher? Facilitator? Evaluator?," Med Teach, vol. 21, no. 4, pp. 393–401, 1999.

[20] M. Ulum and L. K. Utami, "Science in Islamic and Western Perspectives: A Review of Ontology and Epistemology," MA'ALIM: Jurnal Pendidikan Islam, vol. 4, no. 1, pp. 84–100, 2023, doi: 10.21154/maalim.v4i1.7030.

[21] D. Fatchuroji, "Sources of Islamic and Western Knowledge," Maslahah, vol. 1, no. 1, pp. 53–64, 2022.

[22] Law of the Republic of Indonesia No. 20 of 2003 concerning the National Education System. 2003.

[23] Direktorat Jenderal Pendidikan Islam Kementerian Agama RI, "Improving the Quality of PAI, Creating a Young Generation of High Quality and Nationality."

[24] Y. F. Annur, R. Yuriska, and S. T. Arditasari, "Character education and ethics in education," in

Prosiding Seminar Nasional Program Pascasarjana Universitas PGRI Palembang, 2021.
[25] A. Prawoto, Creative Guide to Creating Innovative Teaching Materials. Yogyakarta: Diva Press, 2012.
[26] N. Yusof, H. Baharudin, M. I. Hamzah, and N. I. A. Malek, "Fuzzy Delphi method application in the development of i-aqran module for Arabic vocabulary consolidation," Ijaz Arabi Journal of Arabic Learning, vol. 4, no. 2, 2021.
[27] N. M. Rusdin, "Fuzzy Delphi technique in designing an Active Learning Pedagogical Module based on 4k skills for round numbers and basic Mathematical operations," Jurnal Pendidikan Sains Dan Matematik Malaysia, vol. 11, no. 2, pp. 67–80, 2021.
[28] W. N. Ab Kadir, N. S. Abdullah, and I. R. Mustapha, "The Application Of The Fuzzy Delphi Technique On A Component Of Development Of Form Four STEM-Based Physics Interactive Laboratory (ILab)," International journal of scientific & technology research, vol. 8, p. 12, 2019.
[29] F. B. A. Rahman, Z. Mustafa, and A. F. Kharuddin, "Employing fuzzy delphi technique to validate multiple intelligence based instructional teaching module for preschool children," Southeast Asia Early Childhood Journal, vol. 10, no. 1, pp. 62–71, 2021.
[30] M. R. Mohd Jamil and N. Mat Noh, Methodological Diversity in Design and Development Research. Bangi: Qaisar Prestige Resources, 2020.
[31] S. Siraj, Design and Developmental Research, Emergent Trends in Educational Research. Kuala Lumpur: Pearson Malaysia Sdn Bhd, 2013.
[32] Z. Eshak and A. Zain, "Fuzzy Delphi Method: Design of self defense training module for preschool sex education," Jurnal Pendidikan Awal Kanak-Kanak Kebangsaan, vol. 9, no. 2, pp. 12–22, 2020.
[33] M. Adler and E. Ziglio, Gazing into the oracle: the delphi method and its application to social policy and public health. London: Jessica Kingsley Publishers, 1996.
[34] H. Jones and B. L. Twiss, Forecasting technology for planning decisions . New York: Macmillan, 1978.
[35] D. C. Berliner, "Describing the Behavior and Documenting the Accomplishments of Expert Teachers," Bull Sci Technol Soc, vol. 24, no. 3, pp. 200–212, Jun. 2004, doi: 10.1177/0270467604265535.
[36] J. A. Gambatese, M. Behm, and S. Rajendran, "Design's role in construction accident causality and prevention: Perspectives from an expert panel," Saf Sci, vol. 46, no. 4, pp. 675–691, 2008, doi: https://doi.org/10.1016/j.ssci.2007.06.010.
[37] G. J. Skulmoski, F. T. Hartman, and J. Krahn, "The Delphi method for graduate research," Journal of Information Technology Education: Research, vol. 6, no. 1, pp. 1–21, 2007.
[38] C. Okoli and S. D. Pawlowski, "The Delphi method as a research tool: an example, design considerations and applications," Information & management, vol. 42, no. 1, pp. 15–29, 2004.
[39] M. J. Mohd Ridhuan and M. N. Nurulrabihah, Methodological Diversity in Design and Development Research. Selangor D E: Qaisar Prestige Resources, 2021.
[40] C.-H. Cheng and Y. Lin, "Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation," Eur J Oper Res, vol. 142, no. 1, pp. 174–186, 2002.
[41] H.-C. Chu and G.-J. Hwang, "A Delphi-based approach to developing expert systems with the cooperation of multiple experts," Expert Syst Appl, vol. 34, no. 4, pp. 2826–2840, 2008.
[42] S. Bodjanova, "Median alpha-levels of a fuzzy number," Fuzzy Sets Syst, vol. 157, no. 7, pp. 879–891, 2006.
[43] Regulation of the Minister of Education, Culture, Research and Technology of the Republic of Indonesia Number 53 of 2023 concerning Quality Assurance in Higher Education.
[44] Y. Kang and I. Lee, "The Effect of Mixed Reality-based HoloPatient in Problem-based Learning Contexts," Clin Simul Nurs, vol. 82, no. 101438, Sep. 2023, doi: 10.1016/j.ecns.2023.101438.
[45] F. Z. Kök and B. Duman, "The effect of problem-based learning on problem-solving skills in English language teaching," Journal of Pedagogical Research, vol. 7, no. 1, pp. 154–173, Feb. 2023, doi: 10.33902/JPR.202318642.
[46] F. F. Amanda, S. B. Sumitro, S. R. Lestari, and I. Ibrohim, "The Correlation of Critical Thinking and Concept Mastery to Problem-solving Skills: The Role of Complexity Science-Problem Based Learning Model," Pedagogika, vol. 146, no. 2, pp. 80–94, Sep. 2022, doi: 10.15823/p.2022.146.4.
[47] D. D. Tanrikulu and Z. N. Baysal, "The Effect of Cartoon-Supported Problem-Based Learning Method in Primary School, Fourth-Grade Social Studies Course on Students' Perceptions of Their Problem-Solving Skills and Their Level of Achievement.," International Journal of Curriculum and Instruction, vol. 15, no. 1, pp. 599–619, 2023.
[48] B. K. Prahani, I. A. Rizki, K. Nisa', N. F. Citra, H. Z. Alhusni, and F. C. Wibowo, "Implementation of online problem-based learning assisted by digital book with 3D animations to improve student's physics problem-solving skills in magnetic field subject," J Technol Sci Educ, vol. 12, no. 2, p. 379, Jun. 2022, doi: 10.3926/jotse.1590.
[49] I. W. Redhana, I. B. Sudria, I. N. Suardana, V. D. Putriani, and ..., "Students' mental models in acid-base topic," J Phys Conf Ser, vol. 1521, pp. 1–8, 2020, doi: 10.1088/1742-6596/1521/4/042092.

[50] I. N. Suardana and P. P. Juniartina, "Analysis of Needs for Development of Inquiry-Based Basic Chemistry Learning Tools," Jurnal Pendidikan Matematika Dan IPA, vol. 11, no. 1, pp. 62–73, 2020.
[51] E. S. Bahriah and A. R. Nugroho, "Intermediate semester program: its effectiveness on students' mastery of concepts in basic chemistry courses," JIPVA (Jurnal Pendidikan IPA Veteran), vol. 3, no. 2, pp. 192–203, 2019.
[52] H. G. Schmidt, "Problem-based learning: Rationale and description," Med Educ, vol. 17, no. 1, pp. 11–16, 1983, doi: 10.1111/j.1365-2923.1983.tb01086.x.
[53] H. S. Barrows, The Tutorial Process. Springfield, Ilinois: Southern Illinois University School of Medicine, 1988.
[54] C. E. Hmelo and M. Ferrari, "The problem-based learning Tutorial: cultivating higher order thinking skills," Journal for the Education of the Gifted, vol. 20, no. 4, pp. 401–422, Jun. 1997, doi: 10.1177/016235329702000405.
[55] M. Ibrahim and K. Jamaludin, "The Roles of Teacher and Students via Blended Problem-Based Learning: Improving Students' Mastery of Three Representation Levels of Chemistry," Jan. 2020.
[56] M. M. Ibrahim and K. A. Jamaludin, Mixed Mode Problem-Based Learning Strategies: An Educational Innovation. Tanjong Malim: Universiti Pendidikan Sultan Idris, 2021.
[57] W. Hung, "The 9-step problem design process for problem-based learning: Application of the 3C3R model," Educ Res Rev, vol. 4, no. 2, pp. 118–141, 2009.
[58] T. Y. Peen and M. Y. Arshad, "FILA-MMS Chart in Chemistry PBL Lesson: A Case Study of Its Implementation During Problem Analysis," PBL Across Cultures, p. 154, 2013.
[59] N. D. Feba, N. S. Susila, and N. Azzahra, "The Importance of Instilling Tawheed Education in Early Childhood," in Gunung Djati Conference Series, 2023, pp. 222–233.
[60] D. Ramadayanti, I. Syaputra, and N. Anas, "Pengembangan Modul Berbasis Nilai-nilai Islam pada Materi Sistem Reproduksi Manusia untuk Meningkatkan Nilai Karakter Religius Siswa," JURNAL PEMIKIRAN DAN PENGEMBANGAN PEMBELAJARAN, vol. 4, no. 3, pp. 1–13, 2022.
[61] N. Muspiroh, "Integration of Islamic values in science learning (Islamic education perspective)," Jurnal Pendidikan Islam, vol. 28, no. 3, pp. 484–498, 2013.
[62] M. Idris, S. Mokodenseho, E. Willya, and Y. A. Otta, "Integrating education, environment and values Islamic value as an effort to improve ethics and Environmental literacy," Journal of Islamic Education Policy, vol. 7, no. 2, 2022.
[63] U. Usmadi, I. Iftitahurrahmah, and E. Ergusni, "Development of an Islamic Nuance Module in Mathematics Learning on Statistics Material for Class XI Science High School Students," INSPIRAMATIKA, vol. 8, no. 1, pp. 1–12, 2022.
[64] S. P. Sari, S. A. Nurfadhillah, T. S. S. Wibowo, and Y. N. Syifa, "Strengthening Faith in Allah," in Gunung Djati Conference Series, 2023, pp. 439–449.
[65] H. S. Barrows, "Problem-based learning in medicine and beyond: A brief overview," Bringing Problem-Based Higher Education: Theory and Practice: New directions for Teaching and Learning, vol. 8, no. 5–6, 1996.
[66] P. Dillenbourg, "What do you mean by collaborative learning?," Collaborative-learning: Cognitive and computational approaches., pp. 1–19, 1999.