

REIMAGINING CHEMISTRY LESSONS THROUGH THE BRAINSTEMTA MODULE FOR TEACHING THE ACID-BASE TOPIC

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Abstract: *The topic of acid-base is one of the most challenging topics in chemistry that contains many abstract and complex concepts. To address the persistent challenge, the Whole Brain STEM Teaching Approach (BRAINSTEMTA) Module is systematically developed using the ADDIE instructional design model and incorporates seven Whole Brain Teaching (WBT) strategies: Class-Yes, Five Classroom Rules, Teach-Okay, The Scoreboard, Hand and Eyes, Switch, and Mirror. The STEM-based approach is embedded in alignment with the STEM Teaching and Learning (T&L) Framework introduced by the Ministry of Education Malaysia. BRAINSTEMTA Module is evaluated and validated by 12 experts based on five criteria: (1) effectiveness of WBT strategies, (2) quality of STEM integration, (3) suitability for students, (4) potential to enhance achievement in the acid-base topic, and (5) potential to enhance scientific creativity in the acid-base topic. The quantitative data are analysed using the Content Validity Index (CVI). The results indicated that the value of CVI for the scale (S-CVI/Ave) is 1.00 and is within the accepted range. The scores highlighted BRAINSTEMTA Module strengths in enhancing achievement and scientific creativity in the acid-base topic. These findings also advocated the module's quality and potential for classroom implementation and future empirical testing.*

Keywords: *Whole Brain Teaching (WBT), STEM, acid-base topic, ADDIE Model, achievement, scientific creativity*

Introduction

Chemistry is a core subject at the secondary school level globally. It's an essential subject for strengthening students' scientific thinking and problem-solving skills, as well as for getting them ready for STEM careers. Based on the national curriculum in Malaysia, the introduction of the chemistry subject in schools aims to nurture innovative and scientifically literate students (KPM, 2018). However, it is found that this subject is one of the most challenging subjects for students to learn since it involves a lot of abstract concepts and uses various symbols. Among the numerous chemistry topics that highlight how challenging chemistry is, the acid-base topic is one. Students face a lot of challenges in grasping the concepts, especially when dealing with submicroscopic concepts and symbolic representations, such as ionisation reactions and particle interactions (Krebs et al., 2023). These situations can make it tougher for students to learn and for them to see how theory relates to their lives.

The difficulties in learning the acid-base topic have been widely reported in the literature. The difficulties are often linked to misconceptions that lead to low achievement levels among students (Khaira & Ibrahim, 2024; Salleh et al., 2023). To comprehend this topic, students need to conceptualise abstract concepts and many invisible processes. The difficulties in grasping the concept lead to resorting to memorisation and an algorithmic approach, instead of developing a full comprehension of the fundamental ideas (Naz & Mushtaq, 2022). Among the difficulties faced by students in learning the topic are chemical properties, strength of acid and alkali, and concentration (Naz & Mushtaq, 2022). The students also have difficulties in explaining the difference between the strength of an acid and its concentration, as well as correctly interpreting pH scales (Krebs et al., 2023; Khaira & Ibrahim, 2024). In Malaysia, analysis of average performance achievers in the public examination of Sijil Pelajaran Malaysia (SPM) in this topic revealed that among the problems faced by the students are being unable to provide correct answers to represent monoprotic and diprotic acids, the difference between base and alkali, and writing the correct chemical equation (KPM, 2025).

Achievement is a common indicator used to assess students' performance in the acid-base topic. The teacher's role in improving students' achievement is critical, as lower conceptual understanding frequently leads to issues in problem solving related to the acid-base topic. Students who portray a high level of achievement can effectively engage in advanced competencies such as analytical thinking and higher-order thinking skills. Beyond aspects of achievement, scientific creativity is emerging as a significant construct that is garnering increased focus in chemistry education research. As the global trend shifts toward fostering 21st-century skills, this trait is increasingly recognised for developing innovative and scientifically literate individuals (Krebs et al., 2023). Chemistry student that portrayed this trait are able to generate the original ideas, manage to design of experiments, and capable to apply the knowledge in novel circumstances (Hu & Adey, 2002). This trait is important for chemistry students as they need to visualise ionisation, pH changes, and proton transfer, which are classified as invisible processes in the acid-base topic.

Despite the importance of the scientific creativity aspect, it is found that students lack exposure to enhance this trait due to teacher-centred and exam-oriented approaches (Zainuddin et al., 2020). These conditions serve as evidence for teachers to shift toward practical and student-centred approaches during chemistry lessons, as it has the potential to promote scientific creativity alongside achievement in the acid-base topic. The implementation of a STEM-based approach in teaching the acid-base topic has the potential to help students build connections between what they learnt in school and problems that they encountered in their lives, which

makes it simpler for them to comprehend the concepts. Recent technological development enhances more sophisticated study in the field of STEM to become more relevant in education fields (Shahari, 2020; Padzil et al., 2021). This approach enables students to explore the related concepts of pH and the concentration of hydrogen ions through the use of technology such as digital pH meters, visual simulations, and measurements involving technology.

Whole Brain Teaching (WBT) is one of the brain-based instructional strategies that are used to stimulate whole-brain engagement in learning. It provides strategies that integrate kinesthetic, verbal, and social components to actively stimulate various parts of the brain during the learning process (Biffle, 2013). The strategies transform how students' brains deal with information and skills in learning, which indirectly improves their learning (Fourie & Schlebusch, 2022). The approach emphasised in WBT parallels neuroscience principles, in which learning is more efficient when various brain systems are simultaneously involved during learning. Simultaneous activation of brain areas includes the prefrontal cortex, motor cortex, visual cortex, Broca's area, Wernicke's area, the limbic system, and the hippocampus, supporting focus, movement, emotion, language processing and the formation of memories (Jensen, 2008; Sousa, 2017). The activation of these areas within WBT focuses on seven strategies explained by Biffle (2013). The strategies include Class-Yes, Five Classroom Rules, Teach-Okay, The Scoreboard, Hand and Eyes, Switch, and Mirror.

As the potential integration of a STEM-based approach in teaching the acid-base topic has been illustrated by previous scholars, there is a need for clear instructions on how chemistry teachers can effectively implement it during real lessons. However, instructional modules based on such integration remain limited, particularly in the Malaysian context and within the area of the acid-base topic. There is a lack of structured, validated modules for targeting the development of students' achievement and scientific creativity, particularly in the acid-base topic. The integration of the WBT strategy with a STEM-based approach provides an innovative way of instruction during the lesson. The advancement of today's technology seeks innovative instruction in teaching chemistry. Chemistry teachers need to cater for the challenges of students' requirements in learning through differentiated instruction (Furkan et al., 2022). The WBT strategy is recognised as one of the effective 21st-century teaching models (Rizki Mulyani & Mahaputra, 2023). Therefore, there is a need to validate a developed module that incorporates this potential pedagogical innovation. Thus, the objectives of this study are:

- 1) To evaluate the content validity of the BRAINSTEMTA module by using expert judgment based on five criteria:
 - a) The effectiveness of the Whole Brain Teaching (WBT) strategies.
 - b) The quality of STEM integration.
 - c) The suitability for chemistry students.
 - d) The potential to enhance achievement in the acid-base topic.
 - e) The potential to enhance scientific creativity in the acid-base topic.

Methodology

This study employed a quantitative expert survey design to validate the content validity of the BRAINSTEMTA module, developed for teaching the acid-base topic to Form Four Chemistry students. The module is developed in alignment with the STEM Teaching and Learning (T&L) Framework introduced by the Ministry of Education Malaysia (KPM, 2016). BRAINSTEMTA emphasises the integration of three key elements: knowledge, skills, and values, as shown in Figure 1.

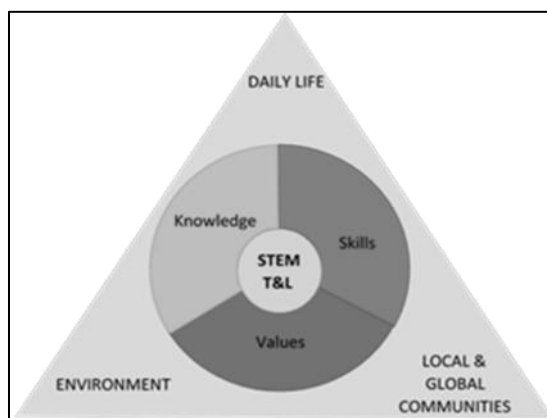


Figure 1: The STEM Teaching and Learning (T&L) Framework

The STEM elements, as in Fig. 1, are applied within real-world contexts, represented by the triangle surrounding the core of daily life, the environment, and local & global communities. The module was developed based on the integration of a STEM-based approach with Whole Brain Teaching (WBT). The development of the module followed the ADDIE Model, comprising five systematic phases: Analysis, Design, Development, Implementation, and Evaluation. The purposive sampling technique was used to select a panel of 12 experts comprising university and matriculation chemistry education lecturers, excellent secondary school chemistry teachers, and STEM education and WBT specialists in Malaysia. Selection criteria included at least ten years of experience in teaching or curriculum development and familiarity with either WBT, STEM, or chemistry education pedagogy. Table 1 shows the details of the experts involved in BRAINSTEMTA module validation.

Table 1: The profiles of the experts

Expert Code	Profile	Expertise
E1	University Lecturer	Chemistry
E2	University Lecturer	Chemistry
E3	University Lecturer	Chemistry
E4	Matriculation Lecturer	Chemistry
E5	University Lecturer	STEM
E6	School Inspector	STEM
E7	IPG Lecturer	Module
E8	Excellence Teacher	WBT
E9	Excellence Teacher	Chemistry
E10	Excellence Teacher	Chemistry
E11	Excellence Teacher	Chemistry
E12	Excellence Teacher	Chemistry

The development of the BRAINSTEMTA module requires systematic validation to ensure accuracy of the content, pedagogical effectiveness, and alignment with students' cognitive level. The Content Validity Index (CVI) is a widely used metric for validating modules by quantifying expert consensus regarding a module's appropriateness. It is a multi-criteria evaluation approach which ensures that the module is not only theoretically sound but also practically applicable. In this study, an expert validation checklist was developed to assess the BRAINSTEMTA module, based on five main aspects. Experts rated each criterion using a 4-point Likert scale (1 = Not Relevant, 2 = Somewhat Relevant, 3 = Quite Relevant, 4 = Highly

Relevant) and provided qualitative feedback for BRAINSTEMTA module improvement. The collection of data was conducted through distributed and email forms, with correspondence over a three-week period. Quantitative data were analysed using the CVI to determine the level of expert agreement on the BRAINSTEMTA module content. The formula to calculate I-CVI and S-CVI is as follows:

$$\text{I-CVI} = \frac{\text{Number of agree items}}{\text{Number of experts}}$$

$$\text{S-CVI/ Ave} = \frac{\text{Total I-CVI}}{\text{Number of items}}$$

The Item-CVI (I-CVI) was calculated for each item, and the Scale-CVI/Average (S-CVI/Ave) was computed to represent overall content validity. The experts' judgement was analysed by using Microsoft Excel. The accepted S-CVI value is ≥ 0.80 (Davis, 1992), while the accepted I-CVI value is ≥ 0.78 (Lynn, 1986). Qualitative comments were systematically analysed to identify suggestions and recurring feedback for module refinement.

Findings

The results were presented in accordance with the objectives of the study. The BRAINSTEMTA module content validity was evaluated by 12 panel of experts based on five specific criteria represented by the items:

- 1) The effectiveness of the Whole Brain Teaching (WBT) strategies.
- 2) The quality of STEM integration.
- 3) The suitability for chemistry students.
- 4) The potential to enhance achievement in the acid-base topic.
- 5) The potential to enhance scientific creativity in the acid-base topic.

The findings from the expert validation are summarised in Table 2. The data represent the responses from twelve subject matter experts involved in the content validation process. For clarity and confidentiality, each expert is represented using coded labels (E1 to E12).

Table 2: The Findings from The Expert Validation

No. Item	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	No. of Expert Agreement	I-CVI	UA	A/R
1	4	4	4	3	4	3	4	4	4	4	4	4	12	1.00	1	A
2	4	4	4	4	4	3	4	4	4	4	4	4	12	1.00	1	A
3	4	3	3	4	4	4	4	4	4	4	4	4	12	1.00	1	A
4	4	3	4	3	4	3	4	4	4	4	4	4	12	1.00	1	A
5	4	3	4	3	3	3	4	4	4	4	4	4	12	1.00	1	A

(*A = Accept)

Based on Table 2, the ratings provided by the experts show a generally consistent pattern across all five items. Analysis of the data indicated that all the items are in the accepted range of values for item (I-CVI). Besides, the value of CVI for the scale (S-CVI/Ave) is 1.00 and is found to be in the accepted range. Most items received favourable judgments from a majority of the panel members, suggesting a strong alignment between the module's content and the educational objectives outlined in the national curriculum. The consistency of these expert evaluations served as the foundation for the calculation of the item-level and scale-level Content

Validity Index (CVI). The expert reviews were also analysed to assess various aspects of the developed module. The summary of these reviews is presented in Table 3, highlighting key feedback and suggestions provided by the reviewers.

Table 3: The Summary of Experts' Review

Expert Code	Profile
E1	The module can be described as user-friendly.
E2	The lessons are well-sequenced, progressing logically from fundamental concepts to more advanced concepts.
E3	The concept and overall idea of the module are excellent.
E4	The module is good and can be implemented for research.
E5	A graphic designer can be hired for the final version of the module.
E6	The module is an excellent and innovative approach to improve achievement and scientific creativity.
E7	This module has been developed based on theoretical references and the standard curriculum (DSKP) in achieving the study objectives.
E8	This module has excellent presentation with clear instructions and is well-designed in terms of activities.
E9	This module is very interactive and helps improve understanding of scientific concepts as well as practical applications in everyday life.
E10	Very good module with an extremely attractive approach, clear instructions, and interesting activities.
E11	This module relates to the standard curriculum (DSKP) and the KSSM textbook; it is more enjoyable and fun. Students understand the impact of STEM principles included in this module better.
E12	This module can be used well to develop the achievement and scientific creativity of students and also novice teachers.

Discussion

The results from experts' validation provide strong agreement for the pedagogical relevance and content quality of the developed BRAINSTEMTA module. The analysis of the Content Validity Index (CVI) showed strong agreement among 12 experts across five evaluation criteria, including: (1) the effectiveness of the Whole Brain Teaching (WBT) strategies, (2) the quality of STEM integration, (3) the suitability for chemistry students, (4) the potential to enhance achievement in the acid-base topic, and (5) the potential to enhance scientific creativity in the acid-base topic. The Scale-Level CVI (S-CVI) value obtained from experts, which is 1.00, indicated excellent content validity as a whole for the BRAINSTEMTA module (Polit et al., 2007). The first criterion, which is the WBT strategies in the BRAINSTEMTA module, showed that the high ratings given by the experts suggested that the instructional strategies embedded in this module, such as Class-Yes, Mirror, Teach-Okay, and The Scoreboard, were perceived as effective in enhancing achievement and scientific creativity in the acid-base topic. This finding was consistent with previous scholars who have highlighted WBT's potential to enhance students' learning performance (Biffle, 2013; Abrenica & Casuncad, 2022).

The positive evaluation criteria for the STEM-based instructional approach in the BRAINSTEMTA module reflected the module's potential in connecting acid-base concepts to real-world applications. This result of evaluation among experts showed that this integration is potentially capable of enhancing achievement and scientific creativity in learning the acid-base topic. Next, the experts also reviewed that the learning activities and designed experiments

within the module encouraged students' inquiry and problem-solving skills, which are in line with the principles of integrated STEM education (Kurup et al., 2021; Ginting & Amdayani, 2024). STEM integration is highly significant for teaching this topic because students often face problems relating abstract acid-base concepts to everyday life (Khaira & Ibrahim, 2024). The high rating of the third criterion, which is the suitability of the BRAINSTEMTA module for Form Four students, showed that the module content is well-aligned with students' cognitive level and learning needs. This suitability is represented by the well-structured content, use of visual aids, and inquiry-based activities embedded within a STEM setting that can enhance meaningful and deeper learning in the abstract acid-base topic.

Besides, the experts' positive judgments regarding the potential of the BRAINSTEMTA module in enhancing student achievement and scientific creativity are particularly noteworthy. It is suggested that the focused aspects of verbal, visual, kinesthetic, and engagement in WBT create a cognitively enriched classroom environment that is conducive to deeper acid-base conceptual mastery. The BRAINSTEMTA module demonstrated a pathway to guide teaching in enhancing students' achievement and scientific creativity. The integration of WBT strategy and STEM approach in the development of the BRAINSTEMTA module not only encourages retention of core content of the acid-base topic, but also the ability to apply the concepts in novel contexts. The integration of STEM to create an innovative teaching and learning process enhanced achievement among students and helped develop essential future career skills (Rahmawati et al., 2020). This is congruent with the constructivist viewpoint that students actively construct knowledge through experience, particularly when they are given autonomy to investigate and communicate their ideas using various ways of learning (Mishra, 2023).

The experts' views on the potential of the BRAINSTEMTA module in enhancing achievement and scientific creativity are also consistent with previous studies in the brain-based domain that emphasise the benefits of engaging both hemispheres of the brain. For example, previous studies demonstrated that WBT enhanced students' conceptual understanding and creative thinking (Resti Ayuni Suri et al., 2025), as well as the effectiveness of STEM-integrated teaching that enhanced students' achievement and scientific creativity (Bostan Sarioglan & Senturk Ozkaya, 2023). This is also supported by previous studies that STEM instructional designs not only enhanced students' conceptual understanding but also enhanced critical thinking and engagement (Khaira & Ibrahim, 2024). The high score for both criteria indicates that the learning activity design in the BRAINSTEMTA module emphasises active interaction and relation with real-world context, with the potential to reduce misconceptions and enhance conceptual understanding in the acid-base topic. From the perspective of scientific creativity, the experts agree that the module is able to guide the teacher in implementing activities that can enhance traits of creativity suggested by Hu and Adey (2002), including fluency, flexibility, and originality.

Conclusion

According to the findings, the development of the BRAINSTEMTA module, which resulted from the integration of the Whole Brain Teaching (WBT) Model and the STEM elements for teaching the acid-base topic, was effectively developed and validated. The ADDIE instructional design model served as the framework in developing the module. The data based on the findings of the expert's validation indicated that the module is pedagogically aligned with the curriculum and appropriate for targeted chemistry students. Taken together, the expert validation results illustrated that the BRAINSTEMTA module has high instructional value to be implemented in classroom during chemistry lesson. Strong content validity provides a solid foundation for

additional testing throughout the experimental phase of the study, given the significance of the module's content validity. Importantly, the alignment of expert feedback with previous literature reinforces the theoretical and practical grounding of the BRAINSTEMTA module design.

High levels of agreement were obtained across five key criteria of the BRAINSTEMTA module: (1) the effectiveness of the Whole Brain Teaching (WBT) strategies, (2) the quality of STEM integration, (3) the suitability for chemistry students, (4) the potential to enhance achievement in the acid-base topic, and (5) the potential to enhance scientific creativity in the acid-base topic. These findings show that the module not only addresses frequent challenges in teaching abstract acid-base concepts, but it also encourages active participation and interdisciplinary learning. The inclusion of creativity-focused elements reflects current educational priorities aimed at nurturing 21st-century skills such as critical thinking and innovation. Although the module has demonstrated strong content validity, future study should focus on classroom implementation to evaluate its practical effect on student outcomes. Overall, the developed module shows a promising instructional tool to enhance the instruction of the acid-base topic in Malaysian secondary schools.

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