International Journal of Modern Education
EISSN: 2637-0905
IJMOE

Volume: 8 Issue: 31 (September 2026) PP. 132-148

INTERNATIONAL JOURNAL OF MODERN EDUCATION (IJMOE)
www.gaexcellence.com/ijmoe

GLOBAL ACADEMIC EXCELLENCE

DEVELOPMENT AND DELPHI-BASED CONTENT VALIDATION OF A CHEMISTRY LEARNING QUESTIONNAIRE: EVIDENCE FROM STEM FOUNDATION STUDENTS' PERCEPTIONS, ATTITUDES, INTEREST, AND LEARNING CHALLENGES

Mohamad Hussin Zain[1], Mimi Syazwani Suhaimi[2]*, Nurfarah Aini Mocktar[3], Rosmalini Razali[4], Nur Aliesya Sofea Azlan[5], Muhammad Marwazi Muhammad Zaki[6]

[1]STEM Foundation Centre, Universiti Malaysia Terengganu, Malaysia
mhuzain@umt.edu.my https://orcid.org/0000-0002-0538-8038
[2]STEM Foundation Centre, Universiti Malaysia Terengganu, Malaysia
mimi.suhaimi@umt.edu.my https://orcid.org/0000-0003-4406-6194
[3]STEM Foundation Centre, Universiti Malaysia Terengganu, Malaysia
mocktarfarah@gmail.com https://orcid.org/0000-0002-3765-1582
[4]STEM Foundation Centre, Universiti Malaysia Terengganu, Malaysia
a6722@ocean.umt.edu.my https://orcid.org/0009-0007-9572-2004
[5]STEM Foundation Centre, Universiti Malaysia Terengganu, Malaysia
a6567@ocean.umt.edu.my https://orcid.org/0009-0004-8155-8096
[6]STEM Foundation Centre, Universiti Malaysia Terengganu, Malaysia
a5447@ocean.umt.edu.my https://orcid.org/0009-0006-4204-9277
*Corresponding Author

Article Info:

Article history:
Received date: 21.07.2026
Revised date: 30.07.2026
Accepted date: 23.08.2026
Published date: 07.09.2026

Abstract:

Chemistry is often perceived as a complex subject requiring conceptual understanding and analytical skills, which may affect students' engagement and performance. This study developed and validated a questionnaire to assess the chemistry learning experiences of STEM Foundation students at Universiti Malaysia Terengganu (UMT). The questionnaire covered five domains: attitudes and interest towards chemistry, teaching methods and learning resources, conceptual understanding, laboratory practices and learning challenges, and students' perceptions of chemistry. A two-round Delphi method

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume: 8 Issue: 31 (September 2026) PP. 132-148

To cite this document:

Zain, M. H., Suhaimi, M. S., Mocktar, N. A., Razali, R., Azlan, N. A. S., & Zaki, M. M. M. (2026). Development And Delphi-Based Content Validation Of A Chemistry Learning Questionnaire: Evidence from Stem Foundation Students' Perceptions, Attitudes, Interest, And Learning Challenges. *International Journal of Modern Education, 8*(31), 132-148.

DOI: 10.35631/IJMOE.831008

involving five experts was used to establish content validity and refine the questionnaire items. Content validity was assessed using the Item Content Validity Index (I-CVI) and Scale Content Validity Index (S-CVI/Ave). In the second round, all items achieved acceptable I-CVI values of 0.80–1.00, while S-CVI/Ave values ranged from 0.97 to 1.00, indicating excellent content validity. The validated questionnaire was administered to 142 STEM Foundation students, and the data were analysed descriptively. Students reported generally positive chemistry learning experiences, with mean scores ranging from 3.84 to 4.11 across the five domains. However, the comparatively lower score for attitudes and interest suggests that greater attention should be given to student motivation and active engagement.

Keyword:

Chemistry Learning; Delphi Method; Learning Challenges; Questionnaire Validation; Student Perceptions; STEM Foundation Students

Introduction

Chemistry is a fundamental discipline within Science, Technology, Engineering, and Mathematics (STEM) education and provides essential knowledge for students pursuing further studies in science-related fields (Grancharova, 2024). Often described as the central science, chemistry connects the physical, biological, and applied sciences through the study of the composition, properties, and transformations of matter. However, some students perceive chemistry as difficult, abstract, or challenging to understand, which may influence their engagement with chemistry learning and their interest in pursuing science-related studies or careers. This concern is also relevant in the Malaysian context. In the Programme for International Student Assessment (PISA) 2022, Malaysian students achieved a science score of 416, compared with the OECD average of 485 (OECD, 2023). These results give broader evidence of science knowledge among Malaysian students and how they are going to apply the scientific concepts in real-world contexts (OECD, 2023).

Students' perceptions, attitudes, interests, and learning challenges should be considered as important factors that may influence the way students engage with the chemistry subject. Students who recognise the relevance of chemistry and feel confident with their capability will be more willing to participate in learning activities and persist when they encounter difficult

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume: 8 Issue: 31 (September 2026) PP. 132-148
concepts. Their experiences are also shaped by the way their chemistry is taught, the learning resources, and the ability to apply their chemistry concepts with laboratory work. One factor may affect the others. For example, difficulties in understanding the conceptual understanding may reduce students' confidence and interest, while supportive teaching practices may help them to work through such difficulties.

Differences in prior knowledge and learning experiences may contribute to difficulties in understanding chemistry concepts and performing calculations (Leong et al., 2021). Chemistry learning also requires students to connect theoretical knowledge with experimental skills and practical laboratory experiences (Agustian et al., 2022). Previous research has examined students' attitudes, perceptions, and learning difficulties in chemistry. However, less attention has been given to examining these dimensions collectively among STEM Foundation students in Malaysian higher education. Therefore, a broader understanding of students' chemistry learning experiences is needed, including the factors that may support or hinder their learning and engagement.

This study addresses this gap by developing and content-validating a questionnaire to assess STEM Foundation students' attitudes and interest toward chemistry, teaching methods and learning resources, conceptual understanding, laboratory practices and learning challenges, and perceptions of chemistry at Universiti Malaysia Terengganu (UMT). The questionnaire items were evaluated through a two-round Delphi process involving experts in chemistry education and STEM-related fields to provide evidence supporting their content validity before administration to the target students. The students' responses provide a structured description of their chemistry learning experiences and identify areas that may require further attention in chemistry teaching and learning.

Literature Review

Chemistry is an important component of STEM education because it provides fundamental knowledge for fields such as science, engineering, health sciences, environmental studies, and technology. Its applications extend to areas including pharmaceuticals, materials, energy, environmental protection, manufacturing, and water treatment (Ndiaye & Diop, 2026). For students in foundation programmes, chemistry also serves as preparation for further study, especially for those who plan to continue in STEM-related programmes in higher education (Vuorio et al., 2024). Mathematical reasoning is also embedded in many areas of chemistry, including stoichiometry, concentration, reaction rates, energy changes, and experimental data. In this sense, learning chemistry brings together knowledge and skills from different areas of STEM (Reyes, 2025).

Despite its importance, chemistry is often perceived as a difficult subject because students need to understand abstract concepts and move between different forms of chemical representation (Moju et al., 2025). For example, students need to connect the macroscopic world that can be observed with the submicroscopic world of particles, atoms, molecules, and ions that cannot be seen directly. These ideas must then be connected to symbolic forms such as chemical formulae, equations, and mathematical representations (Talanquer, 2011). When these connections are not well developed, students may struggle to build a strong conceptual chemistry understanding (Laohapornchaiphan & Chenprakhon, 2024; Rahmawati et al., 2022).

Besides, students' readiness for these demands may vary as they enter the foundation programmes with different levels of prior knowledge, laboratory experience, and confidence (Leong et al., 2021). Abidin (2025), for example, found that STEM Foundation students were having difficulties in applying chemistry knowledge in calculations. The same group of students also preferred to have an active and visual learning approach. These findings suggest that chemistry learning at the foundation level involves both conceptual and application-related challenges.

Students' chemistry learning experiences are also shaped by what happens around the learning itself. Teaching approaches, learning environments, prior knowledge, academic confidence, laboratory experiences, and the perceived relevance of chemistry can all influence how students respond to the subject (Chestnut & Johnson, 2025; Ramirez & Paderna, 2025). Meaningful learning activities and real-world contexts can help students recognise the relevance of chemistry and may support their interest and engagement (Reyes, 2025). Similarly, recent research has shown that students' engagement in chemistry learning can be influenced by the nature of learning tasks, instructional approaches, and interactions within the learning environment (Pontigon & Talanquer, 2025). These findings indicate that students' responses to chemistry are shaped by a combination of cognitive, affective, instructional, and contextual factors rather than by conceptual difficulty alone.

Overall, the literature indicates that students' experiences in chemistry are influenced by multiple interconnected factors, including teaching approaches, learning environments, prior knowledge, attitudes, confidence, laboratory experiences, and perceived relevance (Chestnut & Johnson, 2025; Pontigon & Talanquer, 2025; Ramirez & Paderna, 2025). Previous studies have also highlighted the importance of students' attitudes and perceptions in their engagement and learning experiences in chemistry (Montes et al., 2025; James et al., 2025). However, research focusing specifically on STEM Foundation students remains comparatively limited. Recent Malaysian research has provided useful evidence on foundation students' attitudes, learning difficulties, and learning preferences in chemistry (Abidin, 2025), but further research is needed to examine several related dimensions of chemistry learning within this specific educational context.

Given this gap, there is a need for an instrument that can examine multiple dimensions of chemistry learning among STEM Foundation students. A questionnaire can provide a systematic way of examining students' perceptions, attitudes, interests, learning experiences, conceptual understanding, laboratory experiences, and learning challenges within a single study. However, the content of such an instrument needs to be carefully evaluated to determine whether its items adequately represent the intended areas of assessment. Expert review through a Delphi process can provide structured evidence to support the content validity of questionnaire items before they are used with targets population (Dragostinov et al., 2022; Montes et al., 2023). Accordingly, the present study developed and content-validated a questionnaire through a two-round Delphi process before examining STEM Foundation students' chemistry learning experiences.

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EISSN: 2637-0905
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Methodology

Figure 1 illustrates the methodological flow of the study, which was conducted through ten sequential stages. These stages covered the questionnaire development, Delphi content validation, administration of the questionnaire and analysis of the collected data.

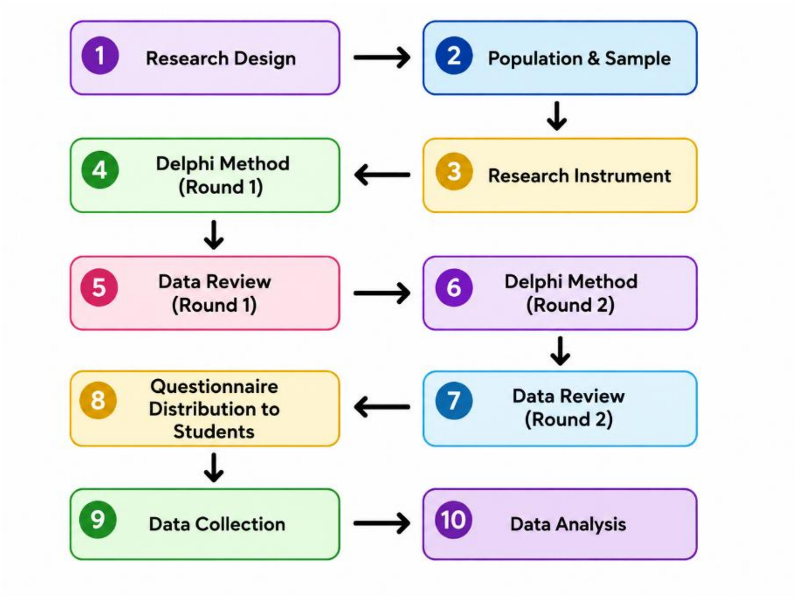

Figure 1: Flowchart of Methodology

Research Design

This study adopted a two-stage research design consisting of questionnaire development and content validation using the Delphi method, followed by the administration of the validated questionnaire to STEM Foundation students. In the first stage, the questionnaire items were developed based on the five identified domains of chemistry learning and subsequently evaluated through a two-round Delphi process. The experts assessed the relevance and suitability of the items and provided comments for further refinement. Content validity was evaluated using the Item Content Validity Index (I-CVI) and Scale Content Validity Index using the average approach (S-CVI/Ave). The iterative Delphi method allowed the questionnaire items to be systematically reviewed and refined based on expert evaluation before being administered to the target population.

In the second stage, the content-validated questionnaire was administered to STEM Foundation students at UMT to examine their learning experiences. Students' responses were then analysed using descriptive statistics to identify patterns across the five domains and provide an overall understanding of their chemistry experiences.

Population and Sampling

The target population comprised STEM Foundation students at UMT who were enrolled in chemistry as part of their academic programme. The questionnaire was distributed to all 440 eligible students using a total population sampling approach, with participation being

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EISSN: 2637-0905
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voluntary. A total of 142 students completed the questionnaire, resulting in a response rate of 32.3%. All 142 completed responses were included in the final analysis.

Research Instrument

The primary instrument used to collect data from the students was a structured questionnaire developed and content-validated through the Delphi method before being administered using Google Forms. The questionnaire assessed five domains: attitudes and interest toward chemistry, teaching methods and learning resources, conceptual understanding, laboratory practices and learning challenges, and students' perceptions of chemistry. Students responded to the questionnaire items using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), to indicate their level of agreement with each statement. The responses were coded numerically and analysed using descriptive statistics.

Delphi Method for Questionnaire Content Validation

The Delphi method was used to establish the content validity of the questionnaire. Content validity indicates how well the items in a measurement instrument represent the construct that the instrument is intended to assess (Polit & Beck, 2006; Lynn, 1986; Rubio et al., 2003). In this study, the content validity of the instrument was assessed using the I-CVI and S-CVI/Ave. The I-CVI evaluates the content validity of each individual item based on expert agreement, whereas the S-CVI/Ave represents the overall content validity of each domain by averaging the I-CVI values of all items within that domain. The formulas used to calculate the I-CVI and S-CVI/Ave values are shown below:

$$\text{I-CVI} = \frac{\text{Number of experts rating 3 or 4}}{\text{Total number of experts}}$$

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

This study employed a two-round Delphi method involving five experts with expertise in chemistry education and STEM-related fields. The use of a small, specialised expert panel is consistent with Delphi studies, in which panel size may vary depending on the purpose of the study and the expertise of the participants (Hsu & Sandford, 2007).

In the first round of the Delphi method, experts evaluated the relevance of each questionnaire item using a four-point scale (1 [not relevant], 2 [somewhat relevant], 3 [quite relevant], and 4 [highly relevant]). Ratings of 3 or 4 were considered relevant for the calculation of the Item Content Validity Index (I-CVI), which was determined as the proportion of experts who rated each item as relevant. Following Polit et al. (2007), an I-CVI of 0.78 or higher is generally considered acceptable. Given the panel of five experts, an I-CVI of ≥ 0.80 was adopted as the criterion for item-level content validity, corresponding to agreement among at least four of the five experts. Items with an I-CVI of ≥ 0.80 were retained, whereas items below this criterion were reviewed and refined based on the experts' ratings and qualitative comments. In addition, the S-CVI/Ave was calculated for each domain by averaging the I-CVI values of the items within that domain. An S-CVI/Ave of ≥ 0.90 was considered to represent excellent content validity (Polit & Beck, 2006). In the second round of the Delphi method, the same five experts re-evaluated the revised items and provided further feedback on their relevance, clarity, and suitability. The I-CVI and S-CVI/Ave were then recalculated to assess the content validity of the revised questionnaire.

Questionnaire Distribution to Students and Data Analysis

The validated questionnaire that has been reviewed and evaluated by the experts via the two rounds of the Delphi method was distributed to the eligible STEM Foundation students through Google Forms. The data collected from the student questionnaire were analysed using descriptive statistics. The mean values were calculated to describe the overall level of agreement with the questionnaire statements across the five domains.

Results And Discussion

The results are presented in two main components: the findings from the Delphi method and the findings from the student questionnaire. The discussion then integrates both sets of findings with previous literature to provide a comprehensive interpretation of students' experiences in learning chemistry.

Content Validation of the Questionnaire

The questionnaire was reviewed by experts through two Delphi rounds. Feedback from the first round was used to improve the wording, clarity, relevance, and suitability of the items before they were reviewed again in the second round. In the second round, all retained items achieved I-CVI values ranging from 0.80 to 1.00 (Tables 1–5), meeting the predetermined criterion of ≥ 0.80. Therefore, all items were retained in the final questionnaire. These results show a high level of agreement among the experts regarding the relevance of the questionnaire items and support the content validity of the final instrument.

The S-CVI/Ave values across the five domains ranged from 0.97 to 1.00 (Figure 2), with all domains exceeding the recommended value of 0.90 for excellent content validity (Polit & Beck, 2006). Overall, these findings suggest that the items within each domain were relevant to the intended areas of students' chemistry learning experiences and provide strong evidence for the content validity of the questionnaire. The findings from the second round support the relevance and suitability of the refined items across all five questionnaire domains.

Table 1: Content Validity Results for Students' Interest and Attitude Items

No.	Questionnaire Item	I-CVI	Decision
1	I find learning new concepts and topics in chemistry interesting and enjoyable.	1.00	Retained
2	Chemistry is one of my favourite subjects.	1.00	Retained
3	I feel motivated to study chemistry regularly.	1.00	Retained
4	I look forward to attending chemistry classes.	1.00	Retained

5	I am curious to know how chemistry is applied in real life.	1.00	Retaine d
6	I feel confident in my ability to learn chemistry.	1.00	Retaine d
7	I believe chemistry is useful for my future career opportunities.	1.00	Retaine d
8	I like solving chemistry-related problems.	1.00	Retaine d
9	I am willing to spend extra time studying chemistry.	1.00	Retaine d
10	Chemistry lessons stimulate my interest in science.	1.00	Retaine d
11	I feel proud when I perform well in chemistry.	1.00	Retaine d
12	I enjoy discussing chemistry topics with my classmates.	1.00	Retaine d
13	I actively participate during chemistry lessons.	1.00	Retaine d
14	I find chemistry more interesting than other science subjects.	1.00	Retaine d
15	I feel chemistry helps me understand the world better.	1.00	Retaine d
16	I would choose chemistry-related subjects if given a choice.	1.00	Retaine d
17	Overall, I have a positive attitude towards chemistry.	1.00	Retaine d

Table 2: Content Validity Results for Teaching and Learning Items

No.	Questionnaire Item	I-CVI	Decision
1	The chemistry lecturer explains concepts clearly.	1.00	Retained
2	Teaching methods used in chemistry class help me understand the subject.	1.00	Retained
3	Lessons are well-organised and easy to follow.	1.00	Retained
4	The lecturer uses a variety of engaging teaching strategies.	1.00	Retained
5	Classroom discussions help me understand chemistry better.	1.00	Retained
6	The lecturer encourages students to ask questions.	1.00	Retained
7	The lecturer relates chemistry concepts to real-life situations.	1.00	Retained
8	Learning resources such as articles and YouTube videos are helpful.	1.00	Retained
9	The use of technology and visual aids effectively supports my learning.	1.00	Retained
10	The pace of teaching is suitable for my learning.	1.00	Retained
11	The lecturer provides helpful feedback on my work.	0.80	Retained
12	Chemistry lessons encourage active student participation in class.	1.00	Retained
13	I find the online learning platform used by my lecturer helpful.	1.00	Retained

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14	The lecturer supports students who have difficulties in chemistry.	1.00	Retained
15	The teaching methods increase my interest in chemistry.	0.80	Retained
16	Learning materials are sufficient and accessible.	1.00	Retained
17	Revision and practice are emphasised during lessons.	1.00	Retained
18	Overall, the teaching methods and learning resources are effective for learning chemistry.	1.00	Retained

Table 3: Content Validity Results for Chemistry Conceptual Understanding Items

No.	Questionnaire Item	I-CVI	Decision
1	I understand most of the chemistry concepts taught in class.	1.00	Retained
2	I can relate chemistry theories to practical examinations.	0.80	Retained
3	I understand basic chemistry terms, symbols, and equations.	1.00	Retained
4	I can explain chemistry concepts in my own words.	1.00	Retained
5	I am able to apply chemistry concepts to solve problems.	1.00	Retained
6	I find certain chemistry concepts difficult or confusing to understand.	1.00	Retained
7	I understand the relationship between different chemistry topics.	1.00	Retained
8	I can remember chemistry concepts for a long time.	1.00	Retained
9	I understand numerical problems in chemistry.	1.00	Retained
10	I need extra help to understand chemistry lessons.	0.80	Retained
11	I understand chemistry better when examples are given.	1.00	Retained
12	I can answer examination questions based on my understanding.	1.00	Retained
13	I find chemistry concepts logical and systematic.	1.00	Retained
14	I understand chemistry concepts taught during practical lessons.	1.00	Retained
15	I can identify my weaknesses in chemistry concepts.	1.00	Retained
16	I feel confident about my conceptual understanding of chemistry.	1.00	Retained
17	Overall, I have a good understanding of chemistry concepts.	1.00	Retained

Table 4: Content Validity Results for Laboratory Learning Items

No.	Questionnaire Item	I-CVI	Decision
1	I find performing chemistry experiments in the laboratory interesting and enjoyable.	1.00	Retained
2	I understand the purpose of laboratory experiments.	1.00	Retained
3	I feel confident handling laboratory apparatus.	1.00	Retained
4	Laboratory sessions are well-connected to theory and help improve my understanding of chemistry concepts.	1.00	Retained
5	I can follow laboratory instructions correctly.	1.00	Retained
6	I am aware of laboratory safety rules.	1.00	Retained
7	There is sufficient laboratory equipment for practical work.	1.00	Retained
8	The laboratory environment is safe and conducive to learning.	1.00	Retained
9	I understand how to record and analyse experimental results.	1.00	Retained
10	I need guidance while performing experiments.	0.80	Retained
11	The time allocated for laboratory work is sufficient.	1.00	Retained
12	I feel nervous during chemistry practical examinations.	1.00	Retained
13	Laboratory activities improve my scientific skills.	1.00	Retained
14	I face challenges in understanding experimental procedures.	0.80	Retained
15	I feel confident writing laboratory reports.	1.00	Retained

Table 5: Content Validity Results for Perceptions of Chemistry Items

No.	Questionnaire Item	I-CVI	Decision
1	I perceive chemistry as a difficult subject compared to others.	0.80	Retained
2	I perceive that strong memorisation is needed in chemistry.	0.80	Retained
3	Chemistry is viewed as a subject that requires high attention to detail.	1.00	Retained
4	I perceive chemistry as a subject that requires a creative mindset.	1.00	Retained

5	I perceive chemistry as logically structured.	1.00	Retained
6	I perceive chemistry as important for scientific literacy.	1.00	Retained
7	I perceive chemistry as examination oriented.	1.00	Retained
8	Chemistry is viewed as a subject requiring strong mathematical skills.	0.80	Retained
9	I perceive chemistry as interesting when taught effectively.	1.00	Retained
10	Chemistry is perceived as time-consuming to learn.	1.00	Retained
11	I perceive chemistry as a subject that develops problem-solving skills.	1.00	Retained
12	Chemistry is perceived as relevant to environmental and societal issues.	1.00	Retained
13	I perceive chemistry as a subject that encourages critical thinking.	1.00	Retained
14	Chemistry is perceived as challenging but achievable.	1.00	Retained
15	I perceive chemistry as dependent on laboratory work.	1.00	Retained
16	Chemistry is perceived as a subject that requires conceptual understanding rather than memorisation.	1.00	Retained
17	I perceive chemistry as meaningful and valuable.	1.00	Retained
18	Overall, I have a positive perception of chemistry.	1.00	Retained

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Volume: 8 Issue: 31 (September 2026) PP. 132-148

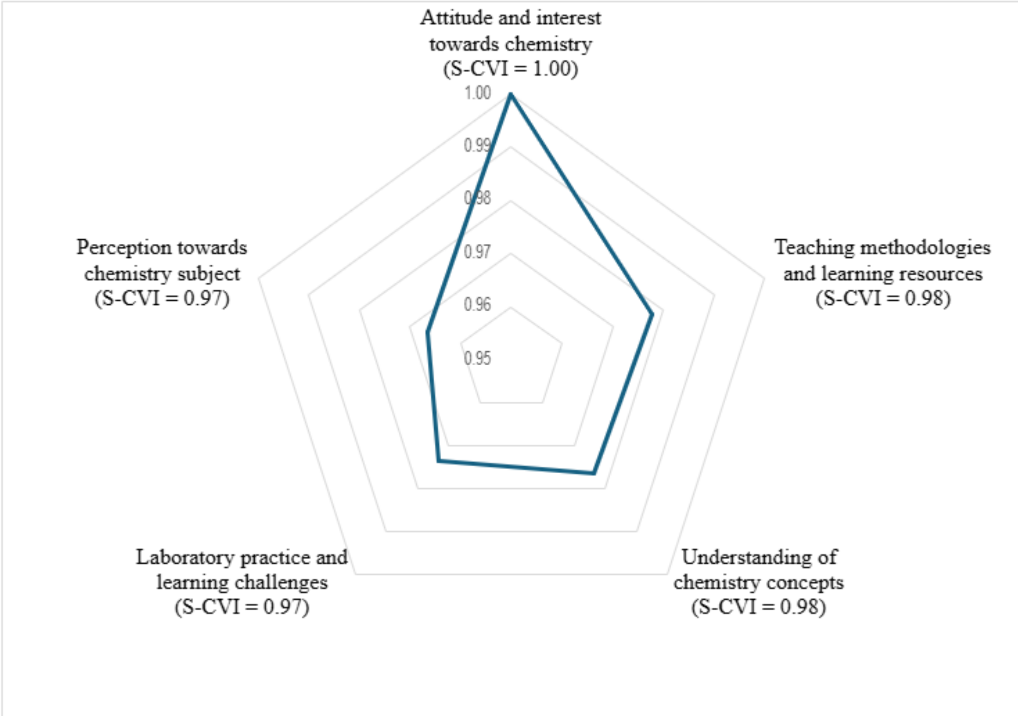

Figure 2: S-CVI/Ave Values for the Five Domains in the Second Delphi Round

Chemistry Learning Experiences of STEM Foundation Students

The responses from 142 STEM Foundation students were analysed using descriptive statistics. As shown in Figure 3, the mean scores across the five domains ranged from 3.84 to 4.11, indicating generally positive chemistry learning experiences among the students.

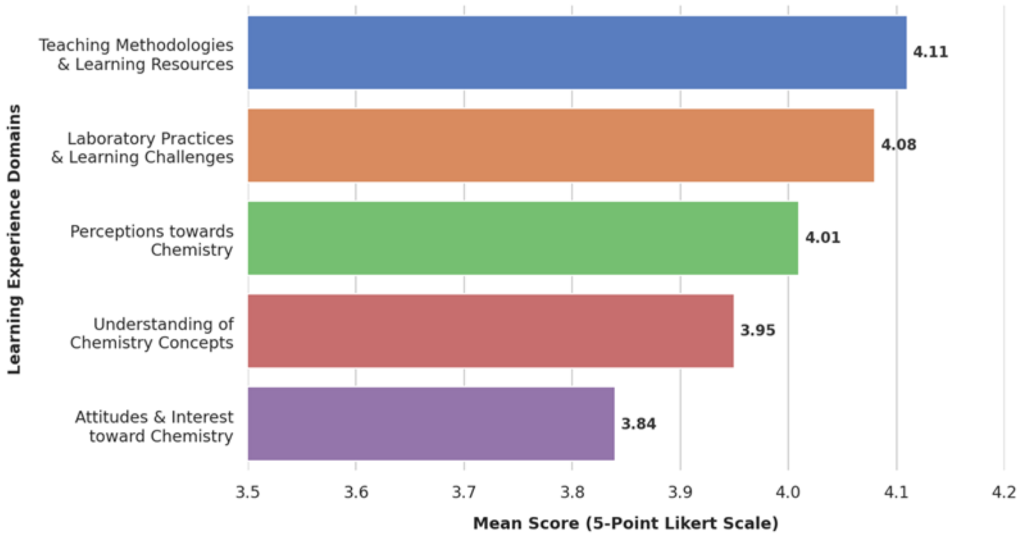

Figure 3: Mean Scores of Students' Chemistry Learning Experiences Across the Five Domains

The highest mean was recorded for teaching methodologies and learning resources (M = 4.11). This suggests that students generally viewed the teaching approaches, learning materials, technology, classroom interaction, and lecturer support positively in supporting their chemistry learning. This finding is consistent with Glenn and Odeleye (2024), who reported that course instructors and course structure were important factors shaping students' perceptions of chemistry.

The laboratory practices and learning challenges domain recorded the second-highest mean (M = 4.08). Students generally responded positively to their practical learning experiences, although specific difficulties related to laboratory work may still exist. Practical activities can support students in connecting theoretical knowledge with experimental skills and practical applications (Agustian et al., 2022). However, as this domain also included items related to learning challenges, further examination of individual item responses may provide a clearer understanding of the specific difficulties experienced by students.

The students' perceptions of chemistry also recorded a positive mean score (M = 4.01). Students generally recognised chemistry as valuable for scientific knowledge, problem-solving, critical thinking, careers, and everyday life. This positive response suggests that students recognised the broader relevance of chemistry beyond classroom learning. Despite these positive perceptions, chemistry can remain challenging because students are required to understand abstract concepts and make connections across different levels of chemical representation (Taber, 2013).

The understanding of chemistry concepts domain recorded a mean score of 3.95, indicating that students generally responded positively to their understanding of chemistry concepts. However, the score was slightly lower than those for teaching and learning resources, laboratory practices, and perceptions of chemistry. This finding may reflect the conceptual demands of chemistry, particularly the need to connect observable phenomena with submicroscopic and symbolic representations. Previous studies have similarly identified difficulties in connecting these representations as an important challenge in developing students' conceptual understanding of chemistry (Laohapornchaiphan & Chenprakhon, 2024; Nelsen et al., 2026).

The lowest mean score was recorded for attitudes and interest towards chemistry (M = 3.84), although the overall response remained positive. Compared with the other domains, this finding suggests that students showed relatively lower levels of interest and motivation towards chemistry. This finding deserves attention because students' attitudes and interest are closely related to their engagement with chemistry learning. Previous studies have shown that students' interest and attitudes towards chemistry learning are associated with factors such as self-efficacy, motivation, learning strategies, learning experiences, and instructional support (Chen et al., 2026; Musengimana et al., 2021; James et al., 2025). Students may therefore have positive views of their learning environment and recognise the value of chemistry while still showing comparatively lower personal interest in the subject.

Overall, the findings show that STEM Foundation students reported generally positive chemistry learning experiences across five domains. Teaching methodologies and learning resources received the most positive responses, while attitudes and interest recorded the lowest mean score. Although the differences between the means were relatively small, the comparatively lower score for attitudes and interest suggests that positive views of the learning environment may not necessarily be accompanied by equally strong personal interest and motivation towards chemistry. Therefore, chemistry teaching at the foundation level should continue to support effective teaching and learning resources while also providing learning experiences that encourage students' interest, motivation, and active engagement with chemistry.

Conclusion

This study developed and established the content validity of a questionnaire designed to assess chemistry learning experiences among STEM Foundation students. Using a two-round Delphi method, the questionnaire items were reviewed and refined based on expert feedback. In the second round, all retained items achieved I-CVI values ranging from 0.80 to 1.00, while the S-CVI/Ave values across the five domains ranged from 0.97 to 1.00. These findings show a high level of expert agreement and provide evidence that the questionnaire items were relevant to the intended areas of assessment.

The findings from 142 STEM Foundation students showed generally positive chemistry learning experiences across all five domains, with mean scores ranging from 3.84 to 4.11. Teaching methodologies and learning resources recorded the highest mean score (M = 4.11), while attitudes and interest towards chemistry recorded the lowest (M = 3.84), although students' responses in this domain remained generally positive. The comparatively lower score suggests that greater attention could be given to strengthening students' interest, motivation, and active engagement in chemistry learning.

Overall, this study provides a content-validated questionnaire for examining chemistry learning experiences among STEM Foundation students. The findings also highlight the importance of maintaining effective teaching practices and learning resources while continuing to support students' interest and engagement in chemistry. However, the study was conducted at a single institution, which may limit the generalisability of the findings. In addition, content validity represents only one aspect of instrument validation. Future studies should examine the reliability and other measurement properties of the questionnaire and evaluate its use with larger and more diverse student populations.

Acknowledgements:	The authors would like to express their sincere gratitude to STEM Foundation Centre, Universiti Malaysia Terengganu, Malaysia for providing the necessary resources and support throughout the course of this research. Special appreciation is extended to Professor Dr. Muhammad Safiih Lola who contributed valuable insights and constructive feedback, which greatly enhanced the quality of this paper.
Funding Statement:	No Funding
Conflict of Interest Statement:	The authors declare that there is no conflict of interest regarding the publication of this paper. All authors have contributed to this work and approved the final version of the manuscript for submission to the International Journal of Modern Education (IJMOE).
Ethics Statement:	This study was conducted in accordance with ethical research standards. Informed consent was obtained from all participants prior to data collection. Participation was voluntary, and respondents were assured of confidentiality and anonymity. The data collected were used solely for academic purposes.
Author Contribution Statement:	All authors contributed significantly to the development of this manuscript. Mohamad Hussin Zain and Mimi Syazwani Suhaimi were responsible for the conceptualization, methodology, and overall supervision of the study. Rosmalini Razali, Nur Aliesya Sofea Azlan, and Muhammad Marwazi Muhammad Zaki handled data collection, analysis, and interpretation of results. Nurfarah Aini Mocktar contributed to the literature review, drafting, and critical revision of the manuscript. All authors read and approved the final version of the manuscript prior to submission.

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