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Development and Perceptions of Chemistry Trainee Teachers on Design, Content and Usability of e-CBM for Chemical Bonding Topic

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Abstract
Chemical bonding serves as a fundamental concept in the study of chemistry and is vital in the understanding of structures, properties and reactions of chemical compounds. Multiple studies in the literature have reported that chemical bonding is considered by students and educators as one of the most complex topics in chemistry. The application of electronic modules as an educational tool for chemistry topics has gained extensive use due to its effectiveness in enhancing learning outcomes by facilitating the interactive and dynamic engagement with complex chemical concepts. Herein, we report the development of an electronic module via Genially platform for the chemical bonding topic called e-CBM using the ADDIE instructional design framework. This study evaluated the perceptions of 103 chemistry trainee teachers selected through a simple random sampling technique on the design, content and usability of e-CBM. This study revealed that the e-CBM exhibited high validity for the perceptions on the design, content and usability among the respondents and warrants the need for further investigation to assess its effectiveness as a teaching aid for the chemical bonding topic.

Keywords: electronic module, chemical bonding, e-CBM

Introduction

Chemical bonding stands as a fundamental concept in chemistry required in understanding various subject matters, including but not limited to inorganic and organic compounds, chemical energy and thermodynamics, and chemical reactions [1]. It is regarded as a complex topic by both chemistry students and educators according to the literature [2]–[5]. Due to the abstract nature of the chemical bonding principles, this requires proficiency in various mathematical and physical concepts including but not limited to geometry, energy and electrostatic forces by the students.

The integration of conceptual knowledge with visual-spatial skills are necessary for students in acquiring chemistry concepts comprehensively [6]. Challenges in visualizing and comprehending the shape and structure of molecules in chemical bonding are associated with inability to achieve a high level of visual-spatial abilities [7], [8]. Another independent study has reported a trend among students to transform the

molecule representation in wedge-dash structure into a Fischer projection, regardless of the different spatial arrangements inherent in the two forms of representation [9].

As employing two-dimensional representations of molecules in teaching chemical bonding conferred low efficacy in improving conceptual understanding and visual-spatial skills among students, educators have opted for interventions involving three-dimensional molecular models. The presentation of three-dimensional model representations on virtual platforms certainly assists in visualizing chemical molecules as compared to physical models [10]. A parallel study has demonstrated that the application of three-dimensional virtual models has advanced the visualization of atomic arrangements in chemical bonds [11]. Genially is a virtual platform that enables educators to create interactive presentations, infographics and games for educational purposes. Its user-friendly interface offers several advantages including dynamic content delivery which promotes engagement and positive virtual learning experience allowing the educators to craft visually appealing and interactive educational materials [12]–[15].

Herein, we reported that a module called electronic chemical bond module (e-CBM) was developed and the perceptions of chemistry trainee teachers from Bachelor of Education (Chemistry) program at Universiti Pendidikan Sultan Idris (UPSI) on three aspects of e-CBM including design, content and usability were evaluated. This study demonstrated that e-CBM has high validity in terms of these aspects and warranted a further study to be conducted to evaluate the effectiveness of e-CBM as a teaching aid for the chemistry teachers in Malaysia.

Materials and methods

Study Design

The design of this study was developmental research focussing on the development of an innovative teaching aid called e-CBM for the analysis of perceptions on the design, content and usability by the chemistry trainee teachers at UPSI. The Development of this educational tool was systematically guided by the ADDIE model, a widely applied instructional design framework. ADDIE is an acronym for five-step processes: analysis, design, development, implementation and evaluation. This perception-based study employed a quantitative approach through questionnaires covering the aspects of design, content and usability of e-CBM which allowed efficient data collection from a large sample size within a relatively short period of time.

Development of e-CBM

The development of e-CBM was based on the ADDIE instructional design framework that involved a sequential process in producing this module. The tasks involved in each phase are summarized in Table 1.

Table 1. Application of the ADDIE instructional design framework in developing e-CBM

Phase	Task
Analysis	Perform a need analysis to identify a chemistry topic in need of a virtual teaching aid based on the literature.
Design	Apply suitable learning theories and determine design and content of e-CBM .

Development	Develop e-CBM, determine the validity of e-CBM and conduct a pilot study to measure reliability of e-CBM.
Implementation	Distribute questionnaires to the chemistry trainee teachers at UPSI.
Evaluation	Analyze the perceptions of chemical trainee teachers on the design, content and usability of e-CBM.

Population and sample

This study involved the participation of chemistry trainee teachers currently enrolled in their sixth and seventh semesters, pursuing a Bachelor of Education (Chemistry) degree at UPSI. In ensuring fair and unbiased representation of the target population, a simple random sampling technique was applied in selecting the respondents. The sample size was determined in accordance with Krejcie and Morgan Table, a widely referred standard for determining sample size in research [16]. The population size for this study was 140 chemistry trainee teachers at UPSI in 2022, enlisting 15 respondents for a pilot study and 103 respondents for an actual study.

Research instruments

The questionnaire containing sections for respondent information and aspects of e-CBM including the design, content and usability served as the research instrument in this study. This assessment used a 4-point Likert scale: point 1 (strongly disagree), point 2 (disagree), point 3 (agree) and point 4 (strongly agree). The questionnaire was validated by two lecturers from the Department of Chemistry, Faculty of Science and Mathematics, UPSI. A pilot study involving 15 respondents was carried out to gauge the reliability of the questionnaire. Data analysis yielded a Cronbach's Alpha value of 0.957, indicating a highly reliable research instrument and this allowed the actual study to be conducted in the evaluation phase of the ADDIE model.

Data analysis

Descriptive statistical analysis using the Statistical Package for Social Science (SPSS) application package was applied in analyzing the data retrieved from the questionnaire for the assessment of perceptions of the chemistry trainee teachers on the design, content and usability of e-CBM.

Results and discussion

In ensuring that the development process of e-CBM was comprehensive and effective, the systematic phases of the ADDIE model was followed in developing this module.

Analysis phase

A needs analysis was conducted to identify a topic in need of virtual instructional support by referring to the wealth of information in the literature. Several studies have suggested that the chemical bonding topic is widely known as a complex topic by both chemistry teachers and students [2]–[5].

Design phase

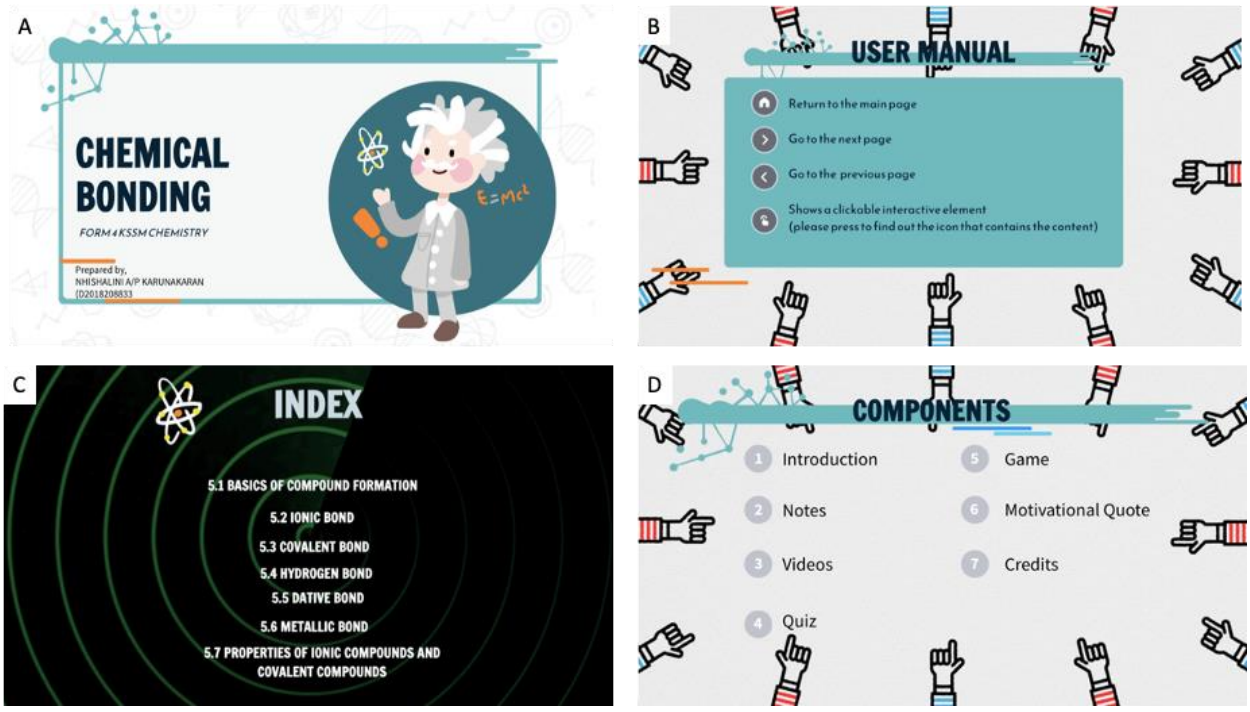
There were two learning theories referred to in designing e-CBM: constructivism and cognitive theories.

Constructivism is a learning theory that suggests knowledge is actively constructed by learners building upon previous knowledge and experiences [17], [18]. Another learning theory referred to in designing this module was cognitive theory, a psychology-derived theory that informs how information is processed by the human brain and involves brain-mediated processes including memorizing information, critical thinking and problem-solving in acquiring knowledge [19]. By incorporating these learning theories in designing e-CBM, this module was aimed to allow active learning in understanding of the chemical bonding topic.

Development phase

e-CBM was developed on the Genially platform which allowed the incorporation of interactive features in enhancing the overall aspects of design and functionality of the module. The front page of the module is shown in Figure 1A, while Figure 1B shows an interface with instructions on how to use e-CBM on Genially. Figure 1C outlines the contents of the chemical bonding topic in the index. Figure 1D presents the overview of the module components including the introduction, notes, videos, quiz, game, motivational quote and credits.

Figure 1. The main user interfaces of e-CBM include the front page (A), user manual (B), Index (C) and components (D).



Validity refers to the ability in conducting an accurate research equipped with the right tools and experimental settings to generate reliable results. In this study, e-CBM was validated by two lecturers from the Department of Chemistry, Faculty of Science and Mathematics, UPSI. The inter-rater agreement or reliability for categorical variables can be evaluated by the statistical measure expressed by the Cohen's Kappa coefficient [20]. The values of Cohen's Kappa coefficient can be interpreted as follows: no agreement (0.00), none to slight agreement (0..01-0.20), fair agreement (0.21-0.40), moderate agreement (0.41-0.60), substantial agreement (0.61-0.80), near perfect agreement (0.81-0.99) and perfect agreement

(1.00). Table 1 shows Cohen's Kappa coefficient values given by each expert for face and content validity for e-CBM questionnaire. The Cohen's Kappa coefficient values for face validity of e-CBM questionnaire given by both experts were 1.00 and 0.97 respectively, yielding an average value of 0.99. For content validity of e-CBM questionnaire, Cohen's Kappa coefficient values were 1.00 and 0.98 given by each expert, resulting in an average value of 1.00.

Table 1. Face and content validity of e-CBM questionnaire based on Cohen's Kappa coefficient values.

Expert	Face validity	Content validity
1	1.00	1.00
2	0.97	0.98
Average	0.99	1.00

In light of Cohen's Kappa coefficient average values, this implied the robustness and reliability of the questionnaire as a research instrument for the next phase of the study. This indicated that the questionnaire can be confidently used to determine the perceptions of chemistry trainee teachers at UPSI on the design, content and usability of e-CBM.

Implementation and Evaluation Phases

In the implementation phase, the questionnaire was distributed to the respondents to gauge their perceptions on the design, content and usability of e-CBM. The data generated from the questionnaire was analyzed in the evaluation phase and presented in Table 2.

Table 2. Perceptions of chemistry trainee teachers on the design, content and usability of e-CBM.

Aspect	Mean value	Standard deviation value	Interpretation
Design	3.961	0.148	Very high
Content	3.967	0.130	Very high
Usability	3.961	0.148	Very high

One of the aspects in ensuring the effectiveness of an e-module in serving as an educational tool significantly depends on its design. The design of e-CBM was evaluated in terms of the content arrangement, visual display, color schemes, image suitability, font types and spelling accuracy. Embedding these aspects in the questionnaire allowed the analysis of overall user experience and its applicability as a teaching aid for chemical bonding topic. According to the responses, e-CBM received good ratings of point 3 (agree) and point 4 (strongly agree) on the 4-point Likert scale across all items in the questionnaire yielding a mean value of 3.961 and a standard deviation value of 0.148, shown in Table 2.

In addition to the module design, the effectiveness of an e-module as an educational tool appears to be profoundly dependent on its content. The content of e-CBM was evaluated for its alignment with the chemistry textbook, adaptability for group learning, suitability of questions, correctness of chemical formula and applicability of assessment purposes. Evaluation of these aspects allowed a thorough understanding of the strength and applicability of the content in various educational settings. Based on the responses, it is noteworthy that e-CBM gained good ratings of point 3 (agree) and point 4 (strongly agree) on the 4-point Likert scale across all items in the questionnaire yielding a mean value 3.967 and a standard deviation value of 0.130, outlined in Table 2. Collectively, these findings demonstrated positive and appealing perceptions of the design and content of e-CBM among respondents.

The perception of e-CBM usability was evaluated in terms of ease of use, attraction towards the module, improvement of student understanding, learning experience and applicability for revision. In parallel with the responses, this module garnered favorable ratings of point 3 (agree) and point 4 (strongly agree) on the 4-point Likert scale across all items in the questionnaire yielding a mean value of 3.961 and a standard deviation value of 0.148, shown in Table 2. High validity ratings on the perceptions of e-CBM showcased that it was a well-received module and its likelihood to be a valuable educational tool.

In the actual teaching settings, chemistry e-modules have been proven as one of the effective teaching aids. For instance, CHEMBOND3D is one of the e-modules developed for the chemical bonding topic that is effective in enhancing the knowledge and visual-spatial skills among students [21]. In parallel, other studies have reported that e-modules developed for chemistry topics improved critical thinking and problem solving skills among students [22], [23]. Therefore, it is imperative to evaluate the effectiveness of e-CBM in improving the understanding of students in the chemical bonding topic.

Conclusion

In conclusion, an electronic module called e-CBM was successfully developed following the ADDIE model and received high validity for perceptions of the chemistry trainee teachers on the design, content and usability of the module. This finding warrants a need for a further investigation to be conducted to evaluate the effectiveness of this module among chemistry teachers in secondary schools across Malaysia. The subsequent study would provide valuable information on its applicability and benefits in the actual teaching settings in the secondary schools.

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