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Enhancing Ionic Compound Formulation: Assessing the Efficacy of 'Fit-Me-Ion' among Malaysian Secondary Students

Siti Khatijah Deraman[a], Hussein Hanibah[a*], Nor Zakiah Nor Hashim[a] and Siti Aishah Wahyul Anwar[b]

[a]Centre of Foundation Studies, Universiti Teknologi MARA, Cawangan Selangor, Kampus Dengkil, 43800 Dengkil, Selangor Darul Ehsan, Malaysia, [b]Fakulti Pendidikan, Aras 5 & 7, Bangunan FSK 1, 5, Kampus Puncak Alam, 42300 Bandar Puncak Alam Selangor Darul Ehsan, Malaysia

Corresponding Author Email: drhussein@uitm.edu.my

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Abstract

Using a quantitative case study design, the 'Fit-Me-Ion' to write the chemical formulae of ionic compounds was developed to identify the level of understanding of Malaysian secondary students by comparing the performance before and after utilizing ‘Fit-Me-Ion’ to write the chemical formulae of ionic compounds. The data was collected from a sample of thirty Form 4 (Grade 10) secondary school students residing in Bagan Serai, Perak. A series of identical questionnaires concerning the chemical formulas of the ionic compound were administered distinctly throughout the pre-test and post-test. An additional set of questionnaires was issued after the administration of the pre-test and post-test to ascertain the students' perspectives on the utilisation of 'Fit-Me-Ion'. The acquired data were analysed utilising version 25 of the Statistical Package for the Social Sciences (SPSS). According to the study's findings, the degree to which students see the use of 'Fit-Me-Ion' to compose the chemical formulae of ionic compounds favourably has been demonstrated. Additionally, a greater proportion of students demonstrate a moderate level of comprehension, as most of the students earned B grades on the post-test after employing 'Fit-Me-Ion'; nevertheless, students exhibited a progressive enhancement in their level of understanding in comparison to the pre-test. In addition, the results indicated a notable disparity in the performance of the tests before and after the implementation of 'Fit-Me-Ion' for formulating ionic compounds. It can be deduced that the students perceive this approach as enhancing their comprehension and efficacy when it comes to composing the chemical formulas of ionic compounds. The implementation of 'Fit-Me-Ion' as a pedagogical aid for Form Four students to compose the chemical formulas of ionic compounds is regarded as efficacious.

Keywords: Chemical Formulae, Fit-Me-Ion, Ionic Compounds, Bagan Serai, Pedagogical

Introduction

Developing an accurate molecular formula is a foundational principle that all chemistry students must grasp before to delving into more advanced theories and concepts. This is critical to compose a precise chemical balancing equation. Learning the ability to solve chemical equations is a fundamental requirement for all chemistry students. Therefore, in this study, the 'Fit-Me-Ion' pairing game board was suggested as a spatial conceptualising technique for denoting the chemical formulas of ionic compounds. To facilitate students' comprehension of the notion underlying the composition of chemical formulae for ionic compounds, it is critical to employ hands-on games that utilise spatial concepts. As opposed to adhering to fixed theories, concepts, or principles, game boards such as jigsaw puzzles have thus far enhanced comprehension of spatial relations through the application of a pragmatic approach that employs the concept of jigsaw puzzles to solve problems in a logical manner that fits the current situation.

Students can learn challenging subjects using game boards by analysing the rules, analysing the concept, and searching for correlations to verify the correctness or incorrectness of their responses. Nonetheless, learners will find the use of a gaming board entertaining and enlightening (Gupta, 2019). As stated by Kurniawan et al (2017), the incorporation of game boards into chemistry instruction at an introductory level can be advantageous for students as it provides a broader perspective than traditional textbooks and a more captivating and effective method for facilitating students' comprehension of specific chemistry concepts.

The purpose of this research is to ascertain the perspectives of Form 4 (Grade 10) students regarding the application of the 'Fit-Me-Ion' method for composing chemical formulas of ionic compounds. In addition, the purpose of this research is to determine which fourth-grade children have mastered the concept of composing chemical formulas for ionic compounds via the Fit-Me-Ion method. Additionally, this research endeavours to assess the difference in performance between Form 4 pupils who completed the chemical formulae for ionic compounds using 'Fit-Me-Ion' and those who did not.

Theoretical Background

Chemistry is present in all aspects of human existence. In addition, chemistry includes the study of matter and its structures, including the processes and motivations underlying the synthesis and degradation of compounds. Matter composes every material in nature, including our bodies. Undoubtedly, chemistry is among the natural disciplines that aid in our comprehension and awareness of the world. Chemists often perceive the breadth and profundity of knowledge covered in these courses as perplexing (Knudtson, 2015). Understanding and mastering chemistry became arduous because of a pessimistic perspective in chemistry classes and ineffective study techniques.

Symbolic language in the field of chemistry encompasses a diverse array of forms that are predominantly employed during the educational process. Scientific elements, symbols are important for the composition of chemical formulas and equations. Composing chemical equations with chemical formulae, molecules, and ions at their proper oxidation or value is essential and vital to understanding (Balaji & Singhal, 2019). However, pupils perceived the task of composing chemical equations as onerous due to their inability to accurately create the formulae for the chemical compounds (Damanhuri et al., 2019). To alleviate overcrowding, the Ministry must design a new curriculum using the total number of school hours as a baseline to omit non-priority subjects and competencies. In addition, the curriculum will incorporate holistically the skills and credentials that are deemed essential for achievement in the contemporary globalised world. This includes the ongoing prioritisation of hands-on science instruction. Educators are required to enhance their knowledge and competencies by preparing primary and secondary school instructors to instruct a current curriculum. Simultaneously, they are tasked with increasing student engagement through the implementation of innovative learning approaches and an enhanced curriculum that incorporates higher-order thinking (HOTS) skills and the application of innovative method skills.

Games can be considered pedagogical tools that enhance creative and cognitive processes, including but not limited to problem-solving, perspective-taking, and imaginative thinking, which are all essential for comprehension. Additionally, interactive materials can capture students' interest and promote collaboration (Izzah et al., 2016). The utilisation of games as an interactive learning approach has been considered as a potential instrument to assist students in enhancing their enthusiasm. This method also believed to increase the comprehension and problem-solving abilities amount the pupils. It is already gaining popularity as a useful exercise for encouraging pupils to study independently. Learners still find the use of a game board to be entertaining and enlightening.

Limited research has been conducted on game boards, including jigsaw puzzles, to determine the nature of the stimulus that students receive when learning to write the chemical formulas for ionic compounds (Damanhuri et al., 2019). Learning experiences provide students with the opportunity to study through games, thereby increasing their engagement in the learning process. Students could visualise the chemical formulas for ionic compounds, as well as interpret, articulate, and apply the notion if they learned it using game boards. Students would be better able to comprehend how to solve connected difficulties as a result.

Consistent with the findings of Kurniawan et al (2017), despite the students' perception of chemistry as a difficult subject, the researchers demonstrated that it is, in fact, a captivating field that likely necessitates additional research or strategies to enhance students' motivation, achievement, and performance. The integration of innovative instructional resources is important to cultivate chemistry as an intellectually stimulating discipline. Implementation of games in the classroom will develop a novel and captivating instructional approach that enhances the learning experience. However, commercially published games pertaining to chemistry are limited in number.

Assembling chemical formulas into equations presents a formidable obstacle that chemistry students must surmount to achieve academic success in the field. Instructional aids that facilitate the conceptualization of these intricate pieces or ideas are essential for the benefit of both instructors and learners. It is necessary to develop new instructional materials to promote chemistry as an engaging subject (Kurniawan et al., 2017).

A common occurrence is for pupils to commit the rules to memory and erroneously implement specific rules when confronted with chemistry problems that require more than the stipulations for formulaic writing. As a result, pupils manipulate chemical formulas and

prefer to study them as mathematical notions rather than comprehending the underlying concept (Damanhuri et al., 2019). Because of the insufficient initiative exhibited in the classroom and the inadequate methodology of the traditional teaching approach, students are unable to formulate chemical formulas for ionic compounds due to their inadequate critical thinking skills. Consequently, for Form fourth-grade chemistry students to comprehend the idea underlying the formulation of chemical formulas for ionic compounds, an efficient process design is necessary.
Therefore, the objective of this research is to ascertain the perceptions of Form Four students on the use of "Fit-Me-Ion" to generate chemical formulas for ionic compounds. In addition, the purpose of this research was to determine which Form Four could compose chemical formulas for ionic compounds via the "Fit-Me-Ion" method. In addition, this research compares the performance of Form fourth-grade children before and following the implementation of 'Fit-Me-Ion' for composing chemical formulas of ionic compounds. In pursuit of this objective, this research may serve as a manual for form four students attempting to compose chemical formulas for ionic compounds.

Spatial Theory in Learning Chemistry
In order to comprehend chemistry, pupils must grasp processes such as the formation of ionic bonds from ionic substances through the use of symbolic, sub-microscopic, and macroscopic components. For macroscopic depiction, substances such as sodium chloride are visible to students. In chemistry classes, pupils in the interim determine the symbols of the compound and the creation of ions in water through experimentation alone.

Lamar (2020) states that the researcher resolved the challenges encountered by students while attempting to correlate their perceptions of the chemistry topic with these three photos. It is necessary to practise and integrate these representations with instructors as chemistry fundamentals are taught. By resolving students' concerns regarding ionic compounds using three distinct representations, this idea has the potential to enhance students' spatial abilities in comparison to those who study chemistry more traditionally. In a similar vein, symbolic representation was deliberated upon by balancing the calculations on a mathematical level is preferable to comprehending the concept. According to Lamar (2020), Johnstone was a trailblazer in the development of the triangular theory of three main representations utilised in chemistry, which is illustrated in Figure 1. By utilising these three domains to facilitate concepts, researchers can effortlessly transition between all three domains.

However, students encounter challenges when attempting to traverse the triangular shape from edge to edge without being able to locate the centre. Additionally, students favour conceptualising chemical subjects in terms of reactions they observe and employing symbols to depict those events. It is critical to acknowledge that to comprehend chemistry, one must evaluate the three primary representations. However, students often attempt to avoid this responsibility by focusing on the apex rather than the intersection of all three representations.

The scarcity of tangible resources frequently prevents pupils from utilising them as visualisation aids. Students who are tasked with solving distinct challenges should modify or rotate a three-dimensional image to accomplish their objectives. A learner lacking developed spatial skills may experience confusion when confronted with the numerous alterations occurring inside visuals (Lamar, 2020).

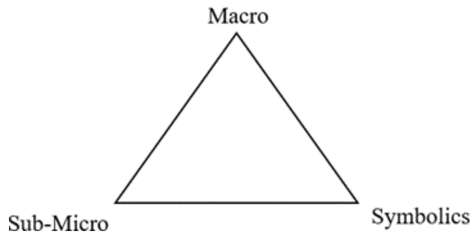

Figure 1: Three Representations of Chemistry

Game Board Learning

Tsai et al (2020) found that students' comprehension of the definition of ionic compounds in formulas is comparatively diminished when compared to students who primarily utilise the crisscross approach (Figure 2). In response to the challenge that students face in juggling units of ionic chemical equations, a variety of educational games have been developed to assist them with this topic (Lamar, 2020). Instead of actual balancing substances, manipulatives are utilised in the game activity. Most games primarily emphasise the mathematical principles involved in balancing the ion formulae unit. While the practises aid in the comprehension and enhancement of recognising and balancing ion compounds, students must still commit the information to memory and recall.

Incorporating chemical concepts into board game formats has the potential to enhance students' motivation and focus (Tsai et al., 2020). Further investigation has suggested that science board games may assist students in conceptualising the application of scientific information to practical scenarios. Hence, if the scientific method is the only aspect that has been gamified, then secondary school students who have acquired solely the foundational principles of chemistry are incapable of participating in gaming activities. Hence, the incorporation of contemporary scientific board games into chemistry curriculum development is imperative. Most of the prior research demonstrates that an effective educational board game can increase students' interest in chemical concepts, facilitate the connection between the gameplay process and their real-life situations, and aid in the transition of learning by enabling students to visualise and relate what they have learned to their everyday lives.

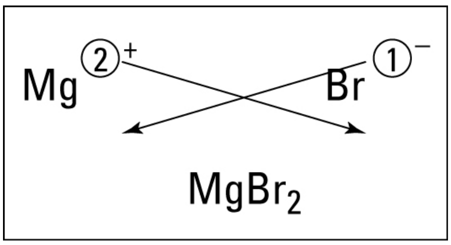

Figure 2: The Criss-Cross Method

Rationale for the Study

According to prior studies, students frequently encounter difficulties in memorising chemical formulas and accurately applying rules, which results in excessive dependence on mathematical interpretation rather than conceptual comprehension. This is a substantial obstacle to autonomous learning and understanding of chemical theory. Educators rely heavily on teaching aids to bridge this gap and improve the academic achievement of their students. The incorporation of game boards has been identified as an effective strategy for fostering student engagement and facilitating the understanding of concepts. Game boards communicate knowledge innovatively and engagingly, in addition to giving tactile stimulation. This creates an alternate and captivating instructional method. Furthermore, they address the students' desire for stimulation and prevent monotony within the educational setting, therefore augmenting the standard of instruction. The purpose of this research is to give instructors recommendations for utilising instructional materials to enhance students' chemistry learning. This study investigates the potential of including game boards, such as puzzles, to augment students' comprehension and involvement with chemical formulas. By employing efficient pedagogical approaches and utilising cutting-edge resources such as gaming boards, pupils can surmount obstacles to learning and acquire expertise in composing chemical formulas, specifically those about ionic compounds employing the 'Fit-Me-Ion' method. The primary objective of this research is to improve students' proficiency in chemistry and cultivate a favourable disposition towards the subject matter, making a valuable contribution to an overall educational experience.

Previous Research

Innovative teaching tools and approaches have developed as potent resources in the field of chemistry education to augment student engagement and grasp of foundational scientific principles. A variety of instructional methods, including game-based learning, tactile representations, and interactive puzzles, are incorporated into these instruments to facilitate the learning and teaching of chemical ideas. This article presents a comprehensive examination and evaluation of several pivotal research that investigate the efficacy of these novel methodologies in the field of chemistry teaching. Our objective is to emphasise the significance of utilising cutting-edge pedagogical approaches to establish dynamic and captivating educational settings that cultivate students' comprehension and admiration of chemistry principles.

The research conducted by Knudtson (2015) regarding "ChemKarta" contributes significantly to the body of knowledge regarding its efficacy as a teaching tool for undergraduates studying organic functional groups. Through the utilisation of qualitative analysis on a sample of 15 participants chosen from an introductory-level organic chemistry course, this study demonstrates the game's effectiveness in enhancing understanding and eliciting positive responses. Through the utilisation of purposive sampling and qualitative approaches, it was possible to conduct an exhaustive analysis of student opinions. The efficacy of ChemKarta in fostering active learning and attendance is supported by the students' favourable feedback and the ease of comprehension it requires to operate. Moreover, by scrutinising the distinctions between secondary and undergraduate pupils, it becomes evident that this concept holds true for students throughout all tiers of education. Overall, the research supports the notion that ChemKarta should be integrated into organic chemistry curricula as a supplementary resource. Furthermore, it is suggested that further research be undertaken to examine its broader applicability and effectiveness across diverse educational environments.

Jamil (2016) conducted a quantitative study to examine the initial responses of mathematics and statistics professors at UiTM Negeri Sembilan towards the XRace game board as an interactive learning tool. By use of purposive sampling, the sample was constituted of instructors and pupils who had applied game-based learning. The survey questionnaires served as the principal research instrument in this study. Using SPSS version 22, descriptive and correlation analyses of the gathered data were conducted. The results of the research indicated that the XRace game board fostered a motivating environment for students to explore mathematical and statistical principles, therefore accommodating their interests and enhancing the learning experience. To address a research void, the current investigation aims to assess the perspectives of four students concerning the application of "Fit-Me-Ion" to derive chemical formulas for ionic substances. Furthermore, the purpose of this study is to assess the level of understanding demonstrated by fourth-grade students regarding the utilisation of 'Fit-Me-Ion' to develop chemical formulas. Through this action, it enhances the overall understanding of interactive learning tools that are employed in many academic environments.

Kavak and Yamak (2016) conducted an exhaustive investigation to determine whether "Picture Chem" effectively aids students in comprehending fundamental chemical laboratory apparatus. The study sample consisted of twenty first-year Physics Education students and eighteen Chemistry Pre-Service instructors. A combination of qualitative and quantitative methods was employed, including t-tests conducted before and during the experiments. Alongside open-ended SWOT analyses and an examination of laboratory apparatus, thirty pre- and post-testing items were comprised of blank entries. The results indicated that 'Picture Chem' was perceived as enjoyable, inspiring, intellectually stimulating, and cost-effective, implying its efficacy in facilitating the acquisition of knowledge. However, a clear research void exists as the prior study's sample comprised solely of first-year physics and pre-service chemistry students. On the other hand, the current investigation broadens the evaluation to include students in form four of secondary school, therefore scrutinising the impacts of the game at a discrete level of education.

Kurniawan, Kurniasih, and Jukardi conducted a study in 2017 to assess the comprehension levels of students regarding the structure and potential of voltaic cells using board and card games. The research investigation comprised chemistry instructors and pupils hailing from ten high schools situated in Pontianak. Data of the learning process was collected by a review of the pertinent literature, document analysis, survey questionnaires, and cluster random sampling by a quantitative technique. The results indicated that the created games functioned as a captivating educational resource in the field of electrochemistry, aiding students in their understanding of the essential composition and capabilities of voltaic cells. However, an area of investigation that necessitates further scrutiny is the current study's utilisation of 'Fit-Me-Ion' to educate pupils regarding the construction of chemical formulae for ionic compounds. This emphasises the need for further investigation into the impact of different instructional materials on the academic achievements of students pursuing chemistry.
Singhal and Balaji initiated a qualitative inquiry in 2019 to aid blind and visually impaired (BLV) students in understanding chemical notations and equations through the use of stackable 3D printed atom representations. The study included fifteen graduate students engaged in non-chemistry courses and ten middle school pupils (grades 6–10). The study employed sequential sampling to assess the effectiveness of the tactile models through observational approaches.

The results indicated that 90% of the respondents regarded the models as intuitive and advantageous for understanding chemistry principles. On the other hand, a subset of 10% experienced challenges when attempting to connect the units and regarded the process as time-consuming. Furthermore, four out of twenty-five pupils with visual impairments demonstrated the ability to distinguish between models based on hue, with just moderate difficulty. It is important to acknowledge that the research scope was restricted to BLV students only, and form four scientific students were not included in the examination of the suitability of tactile representations. Further research may be necessary to examine the broader ramifications and effectiveness of these models in enhancing chemistry education for students who are both sighted and visually impaired.

In 2019, Damanhuri, Kumar, Borhan, Sani, and Taha conducted a quantitative study to determine whether jigsaw puzzles improved students' comprehension of the chemical formulae of ionic compounds. The study involved the participation of 115 scientific stream students from two secondary schools located in the Larut, Matang, and Selama District. The students were selected using purposive sampling, and as part of the process, they completed pre-tests, jigsaw puzzle exercises, post-tests, and survey surveys. The students demonstrated positive attitudes towards the instructional method due to the effectiveness of jigsaw puzzles in improving their ability to generate chemical formulas for ionic compounds, as evidenced by the application of descriptive and inferential statistics to the data. However, there is still a lack of research in this area; hence, the current study focuses on utilising 'Fit-Me-Ion' to educate thirty secondary school students about chemical formulae for ionic compounds while covering conceptual content. Further research may be necessary to compare the effectiveness of different pedagogical approaches in enhancing students' understanding of chemical formula concepts across multiple academic contexts.

Using a comparative media study methodology, the purpose of the 2019 study by Gupta was to evaluate student performance in chemistry via the perspective of game-based learning. By employing a hybrid methodology that incorporated both quantitative and qualitative approaches, the research study utilised a sample size of 63 students. Pre-tests, post-tests, and open-ended surveys were employed as research instruments. The results of the data analysis, which utilised one-way ANOVA and paired t-tests, indicated that students had a lower preference for textbooks compared to other forms of media, including game-based learning. However, there is a lack of research in the study on the assessment of student performance in various media forms, including game-based learning. The purpose of this study, on the other hand, is to evaluate the effectiveness of the educational tool known as "Fit-Me-Ion" in educating thirty secondary school students about ionic compound chemical formulas using conceptual material. Further research might be undertaken to assess and contrast the effectiveness of different instructional approaches within the domain of chemistry education, with the ultimate goal of enhancing students' academic achievements.

Çelikler et al (2019) developed "Ion Hunters," an innovative instructional resource in the form of a game, with the intention of augmenting students' comprehension of anions and cations. A total of twenty-two students who possessed previous experience in chemistry training took part in the study. In conjunction with a quantitative research methodology, the researchers employed a purposive sampling technique to assess the impact of the game on student motivation and learning enjoyment. The results of the study demonstrated a significant increase in student motivation and satisfaction, highlighting the effectiveness of Ion Hunters in fostering active participation in the domain of chemistry education and promoting student engagement. This suggests that the utilisation of game-based learning aids, such Ion Hunters, could potentially enhance student engagement and lead to improved learning outcomes in the field of chemistry.

An inquiry was initiated by Ang et al (2020) to explore an innovative approach that combines digital and physical educational escape rooms for the purpose of reinforcing chemical bonding principles. The research done in 2020 involved the participation of 53 students who were enrolled in a first-year general chemistry course at Nanyang Polytechnic. The researchers employed survey questionnaires as research instruments and utilised a combination of qualitative and quantitative methodologies to gather data and analyse student feedback. The findings of the research revealed that the pupils held positive sentiments concerning the novel teaching approach, acknowledging the beneficial impact of escape rooms on academic performance. Furthermore, the students opted for the immersive element that is characteristic of an authentic escape room setting. The primary aim of the previously indicated research undertaking was to develop an innovative method for strengthening the foundational knowledge of chemical bonding among first-year general chemistry students. Conversely, the current inquiry focuses on assessing the effectiveness of the 'Fit-Me-Ion' tool in educating fourth-grade pupils regarding the chemical formulas of ionic compounds. This represents a deviation from the prior pedagogical methodology and target audience.

The purpose of the research undertaken by Gilbert et al (2020) was to enhance students' understanding of polymer chemistry using ChemEscape, an interactive puzzle-solving platform. The study had 169 students who were selected via purposive sampling; a quantitative research methodology was employed. In 2019, the research was conducted. The research assessed the ability of students to identify functional group patterns in isotactic, syndiotactic, and atactic polymer materials using ChemEscape and survey questionnaires. The findings suggested that the students held the exercise in high regard because of its effectiveness in augmenting their comprehension of the course content. It is noteworthy that higher scores were assigned to the effectiveness of only two worksheet nomenclature exercises. Overall, ChemEscape received the highest rating of enjoyment out of ten instructional activities. The current inquiry shifts its focus from utilising ChemEscape to identify functional group patterns in polymer samples to evaluate the effectiveness of 'Fit-Me-Ion' as an instructional tool for fourth-grade pupils concerning the chemical formulas of ionic compounds.

The study findings derived from a multitude of studies offer significant contributions to the understanding of how various instructional tools and approaches can be utilised to improve chemistry education. These studies provide evidence that the implementation of novel methods, such as game-based learning, interactive puzzles, and tactile representations, can effectively enhance student motivation, engagement, and understanding of chemistry ideas. The results emphasise the significance of customising educational resources to address the unique requirements of pupils from various socioeconomic origins and educational backgrounds. Although specific tools could be more appropriate for university courses, others might be more beneficial for high school pupils. Furthermore, these findings underscore the necessity for constant investigation and assessment of novel educational methodologies to perpetually enhance chemistry education. Through the evaluation of tools such as 'Fit-Me-Ion' and an analysis of their wider utility, educators have the power to enhance pedagogical approaches and guarantee that students have superior learning experiences. In general, the results of this study make a valuable contribution to the comprehension of successful instructional approaches in the field of chemistry education. They underscore the significance of utilising cutting-edge resources to improve the academic achievements of students in a variety of academic environments.

Objectives of the Study
The objective of this quantitative case study is to assess the effectiveness of the instructional tool 'Fit-Me-Ion' in improving the comprehension and skill level of Form Four pupils regarding the composition of chemical formulas for ionic compounds. The research analysis examined the academic achievement of 30 students from Bagan Serai, Perak, both before and after the installation of the 'Fit-Me-Ion' programme and determined how the students perceived its utilisation. By employing SPSS for the examination of data, the study unveiled those pupils held a favourable opinion of 'Fit-Me-Ion' and that comprehension levels increased substantially following its deployment. The results of this study indicate that 'Fit-Me-Ion' can assist students in formulating chemical formulas for ionic compounds, thereby emphasising its potential as an educational tool that can improve chemistry education.

Methodology
The objective of this research is to determine how Form Four grade students perceive the application of "Fit-Me-Ion" when composing chemical formulas for ionic compounds. Additionally, the purpose of this research is to assess the amount of comprehension that Form Four grade students have on the use of "Fit-Me-Ion" to calculate the chemical formulas for ionic compounds. Therefore, to address each of the research inquiries, this study employed a quantitative methodology. This research employs three instruments and has thirty participants that comprise the sample. Preliminarily, pre-test questionnaires were sent to a single group. The pre-test questionnaire was administered to ascertain the students' comprehension level before employing the 'Fit-Me-Ion' tool for formulating chemical equations about ionic substances. The researcher then illustrated how 'Fit-Me-Ion' may be implemented in the collection of samples. Subsequently, post-test questionnaires were disseminated to ascertain the efficacy of the 'Fit-Me-Ion' application. After using the 'Fit-Me-Ion' tool, the post-test was administered to determine the degree of comprehension of the students regarding the composition of chemical formulas for ionic compounds. During this time, a single set of survey questionnaires was disseminated to determine how students felt about the application of "Fit-Me-Ion" in formulating chemical formulas for ionic compounds. The acquired data were subjected to analysis utilising Statistical Package for the Social Sciences, version 25. (SPSS).

Research Framework
Given that this is an experimental study with a sample size of only 30, a quantitative methodology was employed. An experimental quasi-design; (one-group design). Comparable to an experiment with a quasi-independent variable and/or no control group is a quasi-experiment. Hence, to examine the research aims of this study, a single-group pre-test and post-test design technique is necessary.

Constituents and Sampling

This study's population consists of Form Four pupils from a secondary institution in Bagan Serai, Perak, Malaysia. The population under consideration consists of Form Four students who are enrolled in a chemistry course. It is anticipated that one session will consist of around 30 to 35 pupils. This study's sample consists of a mere 30 pupils. This study employed convenience sampling, a non-probability sampling technique. The samples were selected primarily based on their pursuit of pure science, as evidenced by the inclusion of chemistry courses in their academic curricula.

Questionnaire

A questionnaire, as well as a pre-test and post-test, are administered as part of this research endeavour.

The questionnaires were utilised in this investigation to address research questions. The rationale for selecting the questionnaire was its convenience and uniformity. Creating a single set of questions involves only a few sheets of plain paper, which is an extremely straightforward process. When just blank surveys require samples, obtaining and collecting data is simplified and expedited. For the closed-ended questions in this study, Likert scale questionnaires were utilised; samples were required to select and check the statements/items presented in the questionnaires.

The questionnaire for this research comprises two sections, denoted as Part A and Part B. Respondents are required to provide demographic information in the surveys. Participants are required to provide their gender. Part A comprises eight items or statements, whereas Part B comprises six items or statements. The survey was utilised to address the research inquiries pertaining to this investigation.

Validity and Reliability

The graphic presented below (Figure 3) provides a concise overview of the 'Fit-Me-Ion' formation phase. Phase one entails the researcher's first determination of which chemistry-related information and concepts pertinent to the researcher's strategy and goods ought to be incorporated into the board game. Phase two consists of investigating the difficulties and concerns that students encounter when studying chemical elements and the concept of forming ionic compounds. Phase three consists of establishing the objectives and constructing the game system. During Phase 4, the investigator conducted internal evaluations, including a game quality review, and came upon a pilot study. Additionally, certain criteria have been modified to assure the board game's applicability.

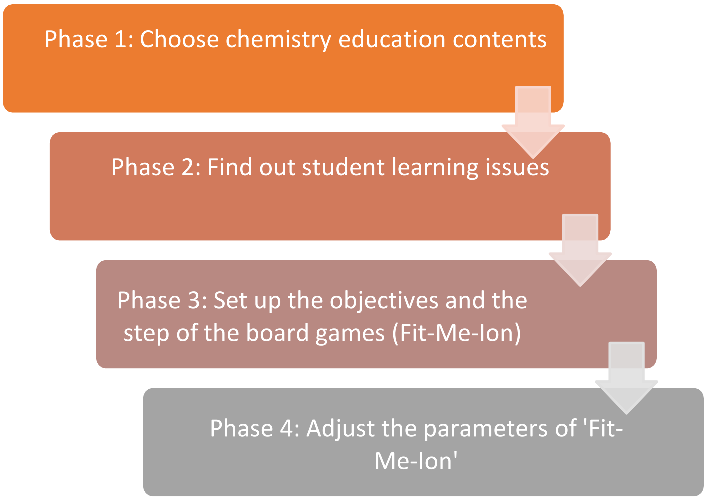

Figure 3 Steps for developing the board game

The matching board game Fit-Me-Ion draws inspiration from jigsaw puzzles. The mystery head associated with each model denotes the ion's number. Students must collaborate to complete the formulas for the ionic compound using the fittable problem. Students are required to comprehend the connections between chemical elements, associated methodologies, and practical products while pairing cards. Students can acquire the desired fittable board from the other groups by solving the various tasks. Figure 4 illustrates an instance of the 'Fit-Me-Ion' model before its printing on the board, with the size specified.

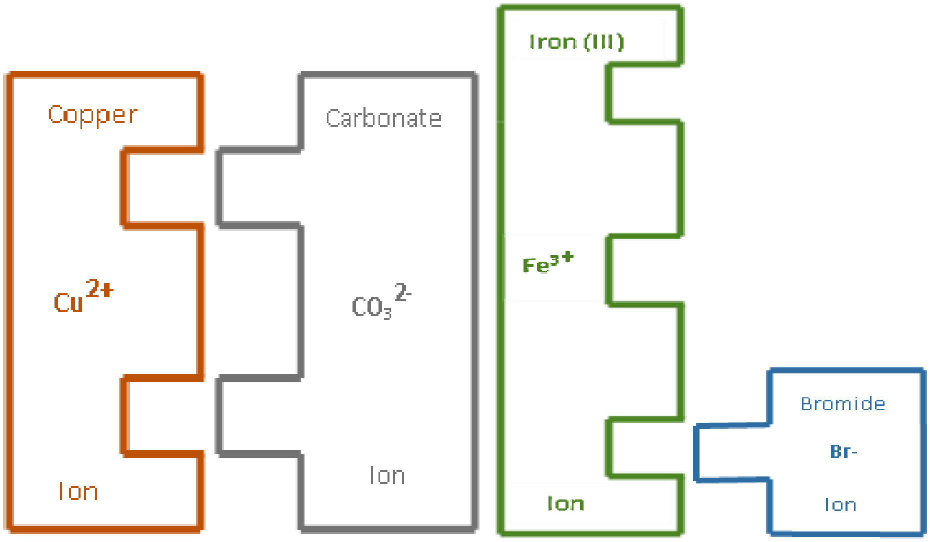

Figure 4: The Model of ‘Fit-Me-Ion’

The processes of gathering data

The process of collecting, assembling, and quantifying the data obtained from the samples is known as data collection. Collecting data is essential for addressing the research inquiries posed in this investigation. Obtaining the consent of several parties is necessary to ensure the correct execution of this investigation. The endorsement of the supervisor is a prerequisite for proceeding with the analysis-related research plan. Furthermore, to proceed, the researcher is required to submit a letter of clearance to the Dean of the Faculty of Education at Universiti Teknologi MARA (UiTM) Puncak Alam, Selangor Malaysia. Thirdly, authorization from the Ministry of Education, Malaysia is required for the researcher to perform the study. Following this, the researcher is required to consult with the class teacher and seek approval from the selected secondary school before proceeding with the study.

Initial Study
A series of self-designed questionnaires were employed in this study to address the research inquiries. As a result, a preliminary investigation is undertaken to evaluate the questionnaire's adequacy for the present study. A total of thirty students enrolled in the Chemistry course at UiTM Puncak Alam's Faculty of Education participated in this preliminary investigation.

Analysis of Data
The process of examining and converting data into relevant information is known as data analysis. This methodology is crucial for answering every research question posed in this study. The raw data acquired from this investigation were subjected to analysis using version 25 of the Statistical Package for Social Science (SPSS). After collecting completed surveys from the students, individual responses were entered manually, one at a time, into version 25 of the Statistical Package for the Social Sciences (SPSS). Following the successful loading of the data, an analysis was conducted utilising descriptive statistics and one paired sample test to address all the research inquiries about this study. By utilising this method, every conclusion can be displayed in detail, facilitating straightforward comparisons.

Results
A study's findings consist of the information uncovered through the administration of survey questionnaires. 30 Form Four students from a secondary school in Bagan Serai, Perak, participated in the analysis. The findings concerning the research questions were further elaborated upon in this section.

General Findings: Demographic Information
Gender and Race
The data shown in Table 1 indicates that the majority of the participants in this study were female, including 23 students. According to the data presented in Table 2, 43.3% (n=13) of the students are Malay, 16.1% (n=16) Chinese, and 3.3% (n=1) Indian participated. The data indicates that a significant proportion of the participants in this research were of Chinese descent, comprising 16 individuals.

Table 1
Gender

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Male	7	23.3	23.3	23.3
	Female	23	76.7	76.7	100.0
	Total	30	100.0	100.0	

Table 2
Race

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Malay	13	43.3	43.3	43.3
	Chinese	16	53.3	53.3	96.7
	Indian	1	3.3	3.3	100.0
	Total	30	100.0	100.0	

Findings and Analysis Based on Research Question 1: What is the Form Four students' perception in utilizing 'Fit-Me-Ion' to write the chemical formulae for ionic compounds?
Students have a strong opinion (Mean=3.90, SD=0.548) about item number one, "I am really interested in the field of chemistry," as shown in Table 3. Conversely, chemistry is seldom perceived as a simple topic by pupils (Mean=3.03; SD=0.765). The data in the table indicates that a moderate proportion of students find chemistry to be an intriguing topic (Mean=3.53, SD=0.076). Except for that, students' perception of the chemistry instructor's teaching technique as fascinating is notably low (Mean=3.17, SD=0.834). On occasion, some students believe (Mean=3.47, SD=0.776) that "composing the chemical formulas for ionic compounds is not a challenge for me." Furthermore, as shown in Table 3 (Mean=3.60, SD=0.776), students have a moderate understanding of the chemical formulas for ionic compounds. The students have a strong opinion that the incorporation of 'Fit-Me-Ion' into the teaching and learning process makes it more engaging (Mean=4.20, SD=0.814).

As shown in the table, students place the highest value (Mean=4.33, SD=6.06) on statement number 8, "Writing the chemical formulas for ionic compounds with 'Fit-Me-Ion' is simple." Additionally, statement number 9, "Teaching aids such as 'Fit-Me-Ion' are fascinating," receives the lowest rating (Mean=4.33, SD=0.844). Other than that, students have a favourable opinion of item number 9, which states, "I have gained a better knowledge of ionic compound principles through the use of 'Fit-Me-Ion'" (Mean=4.00, SD=0.871). Certain students are most ecstatic (Mean=4.13, SD=0.900) about item number 11, which states, "To gain a better grasp of this topic, I will write the chemical formulae of ionic compounds using the 'Fit-Me-Ion' method." In a similar vein, item number 12 emphasises that students hold a positive perception (Mean=4.10, SD=0.960) regarding their increased confidence in utilising 'Fit-Me-Ion' to resolve inquiries about ionic compounds. Additionally, the table reveals that students provided a moderate rating (Mean=3.90, SD=0.803) for item number 13, which states, "After being given the notion of a 'Fit-Me-Ion,' I feel more interested in chemistry." In addition to item number 14, most students (Mean=4.13, SD=0.860) concur that the implementation of 'Fit-Me-Ion' can enhance one's performance in relevant subjects.

Table 3
The perspective of students regarding the application of "Fit-Me-Ion" in composing chemical formulas for ionic compounds

	N	Mean	Std. Deviation
1. I'm very interested in chemistry subject	30	3.90	.548
2. I think chemistry is an easy subject	30	3.03	.765
3. I think chemistry is an intriguing subject	30	3.53	.776
4. I feel the use of the teaching method of chemistry teacher is interesting	30	3.17	.834
5. I have no issue writing the chemical formulae of ionic compounds	30	3.47	.776
6. I understand the concept of the chemical formulae of an ionic compound	30	3.60	.814
7. I think the usage of 'Fit-Me-Ion' more interesting in the teaching and learning process	30	4.20	.847
8. The usage of 'Fit-Me-Ion' to write the chemical formulae for ionic compounds are easy	30	4.33	.606
9. Teaching aids such as 'Fit-Me-Ion' is fascinating	30	4.33	.844
10. The concepts of ionic compounds by using 'Fit-Me-Ion' give me a better understanding	30	4.00	.871
11. I will use the method of 'Fit-Me-Ion' to write the chemical formulae of ionic compounds for a better understanding of this topic	30	4.13	.900
12. I feel more confident to solve the questions related to the ionic compound by using 'Fit- Me-Ion'	30	4.10	.960
13. I feel more interested in chemistry after the concept of 'Fit-Me-Ion' has been explained	30	3.90	.803
14. The utilization of 'Fit-Me-Ion' can increase my performance in related topics	30	4.13	.860
Valid N (listwise)	30		

Findings and Analysis Based on Research Question 2: What is the level of understanding of form four students to write the chemical formulae for ionic compounds using 'Fit-Me-Ion'?

The second research inquiry in this investigation aims to ascertain the degree of comprehension among fourth-grade students regarding the utilisation of the 'Fit-Me-Ion' method to calculate chemical formulas for ionic compounds, as measured by the students' post-test performance grade on a series of inquiries. As shown in the Table 4 and figure, 3.3% (n=1) of students who achieved an A on the post-test after utilising the 'Fit-Me-Ion' tool to formulate chemical formulas for ionic compounds did so. Additionally, the table indicates that among the students who obtained an A- (13.33%; n=4), the highest proportion (26.7%; n=8) obtained a B on the post-test after employing the 'Fit-Me-Ion' tool to generate chemical formulas for ionic compounds. Additionally, the chart indicates that 13.3% (n=4) of the students who earned a C+ on the post-test included in this research. Among the pupils whose post-test scores were C-, one (3.3 %; n=1) achieved the lowest percentage. In addition, the chart reveals that a negligible number of students (6.7 %; n=2) earned an E on the post-test, while only five students (16.7 %) earned a G.

Findings and Analysis Based on Research Question 3: Is there any significant difference in form four students' performance before and after utilizing 'Fit-Me-Ion'to write the chemical formulae for ionic compounds?

In order to determine the degree to which students' performance improved after employing the 'Fit-Me-Ion' tool for generating chemical formulae of ionic compounds, a paired samples t-test was used. The results of the analysis demonstrated a substantial enhancement in performance. The significance level (alpha) was less than 0.05, the t-value was 6.255, and there were 29 degrees of freedom (df) in the analysis. These values collectively indicate a noteworthy disparity in test performance before and after the implementation of 'Fit-Me-Ion'. The statistical data for the paired samples (Table 5) reveals that the mean score on the pre-test was 37.93, while the mean score on the post-test was 54.70. The respective standard deviations and standard error means are also included. Furthermore, the correlations between matched samples (Table 6) reveal a significant positive correlation (r = 0.659, p <.001) between the scores obtained before and after the test. The significance of the mean difference between pre-test and post-test scores is further validated by the paired samples test results (Table 7), which indicate a -6.255-standard deviation from the true value (p <.001) and a -16.767 mean difference (with a 95% confidence interval of -22.249 to -11.284). The results of this study emphasise the efficacy of the 'Fit-Me-Ion' tool in improving students' ability to formulate chemical formulas for ionic compounds, thereby establishing its potential as a beneficial instructional resource in the field of chemistry.

Table 4
Students in the fourth form's comprehension of how to use "Fit-Me-Ion" to compose the chemical formulas for ionic compounds

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	G	5	16.7	16.7	16.7
	E	2	6.7	6.7	23.3
	D	1	3.3	3.3	26.7
	C	5	16.7	16.7	43.3
	C+	4	13.3	13.3	56.7
	B	8	26.7	26.7	83.3
	A-	4	13.3	13.3	96.7
	A	1	3.3	3.3	100.0
	Total	30	100.0	100.0	

Table 5
Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Test	37.93	30	19.064	3.481
	Post-Test	54.70	30	15.759	2.877

Table 6
Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-Test & Post-Test	30	.659	.000

Table 7
Paired Samples Test

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	Pre-test - Post-	-16.767	14.682	2.681	-22.249	-11.284	-6.255	29	.000

Discussions

The discourse on the research outcomes centres on three primary research inquiries that seek to comprehend the level of comprehension and perception of fourth-grade students regarding the use of 'Fit-Me-Ion' to generate chemical formulas for ionic compounds, and to identify any noteworthy disparities in their performance before and after the implementation of this instrument.

The initial research question investigates the perspectives of students concerning the application of 'Fit-Me-Ion'. The analysis demonstrates that students have a generally favourable perception of this tool, as they demonstrate an interest in chemistry while also recognising its intricacy. It is noteworthy that although students perceive conventional chemistry teaching methods to be less captivating, they regard 'Fit-Me-Ion' as a more captivating and efficacious substitute. Furthermore, the student's perception of 'Fit-Me-Ion' as user-friendly and captivating contributes to an improved comprehension of principles about ionic compounds. Students that utilised 'Fit-Me-Ion' showed higher assurance in their capacity to resolve inquiries about ionic chemicals, hence bolstering this favourable image. In general, the results of this study indicate that pupils have a positive perception of 'Fit-Me-Ion' as a resource that can enhance their comprehension and involvement in the subject of chemistry.

Transitioning to Research Question 2, this inquiry seeks to evaluate the extent to which students comprehend the Fit-Me-Ion tool. An analysis of post-test scores indicates that pupils' performance significantly improved following the implementation of 'Fit-Me-Ion'. More precisely, an increased percentage of pupils attained a comprehension level that could be classified as moderate, as evidenced by the progression of grades from E to B on the pre-test and post-test evaluations. This discovery implies that the implementation of 'Fit-Me-Ion' has a beneficial effect on students' understanding and skill level when it comes to composing chemical formulas for ionic compounds.

Lastly, Research Question 3 seeks to ascertain whether the utilisation of 'Fit-Me-Ion' has a substantial impact on the performance of students before and following its implementation. A considerable improvement in students' performance is confirmed by the paired samples t-test after the implementation of 'Fit-Me-Ion' for generating chemical formulae of ionic compounds. The empirical evidence presented in this statistical analysis substantiates the efficacy of 'Fit-Me-Ion' as an instructional instrument that enhances the scholastic achievements of chemistry students.

In summary, the results of the research emphasise the favourable influence that 'Fit-Me-Ion' has on the comprehension, academic achievement, and perceptions of students on the composition of chemical formulas for ionic compounds. The findings of this study underscore the potential of 'Fit-Me-Ion' as a novel pedagogical tool in the field of chemistry education, providing instructors with a significant asset to augment students' comprehension and involvement with the material.

Conclusion

The purpose of this research was to examine the perceptions of four students regarding the use of 'Fit-Me-Ion' to generate chemical formulas for ionic compounds, their comprehension level regarding its operation, and whether there was a significant improvement in their performance before and following its implementation. Thirty students' responses were gathered quantitatively and used non-random sampling to compile and evaluate the data using SPSS. The results of the study indicated that students held favourable views of 'Fit-Me-Ion', as evidenced by gains in chemistry-related interest, self-assurance, and academic achievement after its implementation. Furthermore, paired samples t-tests revealed that the performance of students significantly improved when the 'Fit-Me-Ion' method was implemented to generate chemical formulas for ionic substances.

The students tend to memorize the formulae and incorrectly apply certain rules when solving chemistry problems that go further on the rules on writing the chemical formulae. They manipulate the chemical formulae and prefer to study them as a mathematical concept without understanding the concept. This may result that learning on their own to understand the concept that lies behind any theory in Chemistry is hard among today's students. Teaching aids allow teachers to cross the gap and improve students' academic abilities. The application of game boards in learning help student grasps the idea proves to be successful support for teachers as it is required to improve their knowledge or idea. Not only do they allow students enough chance to participate, but they also deliver knowledge in a manner that gives students a new way to interact by the utilization of the educational materials.

This research would be a guide for teachers to help students enhance their learning outcomes in chemistry. The use of teaching aids thus helps by supporting teachers in an alternative and intriguing method of instruction. The utilization of a game board offers students tactile stimuli and a chance to view content from another point. Game boards such as puzzles also make the teaching and learning experiences more appealing. Students are constantly looking for excitement and have no tolerance for

boredom. Teaching help enhances the standard of education in today's classrooms, while also providing students with the feeling of enthusiasm they desire. Teachers should show and explain to students effective teaching strategies. If this occurs, students will be able to overcome their learning difficulties specifically in chemistry. This could reduce students' distrust of chemistry and make students more

engaged in studying chemistry. Theoretically, this research would develop and strengthen students' skills to write chemical formulae for ionic compounds using 'Fit-Me-Ion'.

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APPENDIX 1

PRE-TEST ON CHEMICAL FORMULAE FOR IONIC COMPOUNDS (15 Minutes)

SECTION A

Gender: ___________________ Race:____________________

INSTRUCTIONS TO CANDIDATES

1. This question paper contains **25 QUESTIONS**.
2. Answer **ALL** questions in the provided answer space.
3. Candidates are **PROHIBITED** from bringing any books, papers, documents, images or any material containing written notes.

INSTRUCTIONS

Determine the cation and anion for the following ionic compounds.

Example: Copper (II) oxide → Cu^{2+} (cation), O^{2-} (anion)

No.	Compound	Cation	Anion
1	Magnesium nitride	Mg^{2+}	N^{3-}
2	Potassium sulphate	K^{+}	SO_4^{2-}
3	Iron (II) sulphate	Fe^{2+}	SO_4^{2-}
4	Aluminium phosphide	Al^{3+}	P^{3-}
5	Copper (II) carbonate	Cu^{2+}	CO_3^{2-}
6	Lead (II) sulphate	Pb^{2+}	SO_4^{2-}
7	Calcium carbonate	Ca^{2+}	CO_3^{2-}
8	Zinc hydroxide	Zn^{2+}	OH^{-}
9	Aluminium nitrate	Al^{3+}	NO_3^{-}
10	Aluminium bromide	Al^{3+}	Br^{-}
11	Potassium nitrate	K^{+}	NO_3^{-}
12	Sodium carbonate	Na^{+}	CO_3^{2-}
13	Zinc nitrate	Zn^{2+}	NO_3^{-}
14	Barium sulphate	Ba^{2+}	SO_4^{2-}
15	Iron (II) hydroxide	Fe^{2+}	OH^{-}
16	Magnesium chloride	Mg^{2+}	Cl^{-}
17	Potassium oxide	K^{+}	O^{2-}

18	Zinc chloride	***Zn^{2+}***	***Cl^{-}***
19	Iron (III) sulphate	***Fe^{3+}***	***SO_4^{2-}***
20	Iron (II) oxide	***Fe^{2+}***	***O^{2-}***

(correct responses are indicated in the space in Bold and italic)

SECTION B
Instruction
Generate the formula for the compound ions from the anion and cation below.
Example: Na^{+}, Cl^{-} (NaCl, Sodium Chloride)

Ni^{2+} Cl^{-} NH_4^{+} Cr^{3+} F^{-} S^{2-} PO_4^{3-} Mg^{2+} Ca^{2+} CO_3^{2-}

1. ***$MgCO_3$***
2. ***$(NH_4)_2CO_3$***
3. ***NiF_2***
4. **$(NH_4)_3PO_4$**
5. ***$CaCl_2$***

(Examples of responses are indicated in the space in Bold and italics)

APPENDIX 2
CHEMICAL FORMULA ASSESSMENT EXAMINATION FOR IONIC COMPOUNDS
(15 MINUTES)

SECTION A

Gender: ____________________ **Race:**____________________

INSTRUCTIONS TO CANDIDATES

1. This question paper contains **25 QUESTIONS**.
2. Answer **ALL** questions in the provided answer space.
3. Candidates are **PROHIBITED** from bringing any books, papers, documents, images or any material containing written notes.

INSTRUCTIONS
Determine the cation and anion for the following ionic compounds.
Example: Copper (II) oxide → Cu^{2+} (cation), O^{2-} (anion)

No.	Compound	Cation	Anion
1	Magnesium nitride	***Mg^{2+}***	***N^{3-}***
2	Potassium sulphate	***K^{+}***	***SO_4^{2-}***
3	Iron (II) sulphate	***Fe^{2+}***	***SO_4^{2-}***
4	Aluminium phosphide	***Al^{3+}***	***P^{3-}***
5	Copper (II) carbonate	***Cu^{2+}***	***CO_3^{2-}***
6	Lead (II) sulphate	***Pb^{2+}***	***SO_4^{2-}***
7	Calcium carbonate	***Ca^{2+}***	***CO_3^{2-}***

8	Zinc hydroxide	***Zn^{2+}***	***OH^-***
9	Aluminium nitrate	***Al^{3+}***	***NO_3^-***
10	Aluminium bromide	***Al^{3+}***	***Br^-***
11	Potassium nitrate	***K^+***	***NO_3^-***
12	Sodium carbonate	***Na^+***	***CO_3^{2-}***
13	Zinc nitrate	***Zn^{2+}***	***NO_3^-***
14	Barium sulphate	***Ba^{2+}***	***SO_4^{2-}***
15	Iron (II) hydroxide	***Fe^{2+}***	***OH^-***
16	Magnesium chloride	***Mg^{2+}***	***Cl^-***
17	Potassium oxide	***K^+***	***O^{2-}***
18	Zinc chloride	***Zn^{2+}***	***Cl^-***
19	Iron (III) sulphate	***Fe^{3+}***	***SO_4^{2-}***
20	Iron (II) oxide	***Fe^{2+}***	***O^{2-}***

(correct responses are indicated in the space in Bold and italic)

SECTION B
Instruction
Generate the formula for the compound ions from the anion and cation below.
Example: Na^+, Cl^- (NaCl, Sodium Chloride)

1	STRONGLY DISAGREE
2	DISAGREE
3	NEUTRAL
4	AGREE
5	STRONGLY AGREE

Ni^{2+} Cl^- NH_4^+ Cr^{3+} F^- S^{2-} PO_4^{3-} Mg^{2+} Ca^{2+} CO_3^{2-}

1. ***$MgCO_3$***
2. ***$(NH_4)_2CO_3$***
3. ***NiF_2***
4. **$(NH_4)_3PO_4$**
5. ***$CaCl_2$***

(Examples of responses are indicated in the space in Bold and italics)

APPENDIX 3
FORM FOR THE STUDY OF THE EFFECTIVENESS OF THE USE OF 'FIT-ME-ION' IN GENERATING IONIC COMPOUND FORMULAS

INSTRUCTIONS
Kindly express your level of agreement in accordance with your personal sentiments and beliefs, independent of external influences or directives.
On a scale of one to five, please indicate only one response with a dot (/).
It is highly recommended that you annotate each statement.

Students' perception of the use of 'Fit-Me-Ion' in generating chemical formulas for ionic compounds.

Gender: ___________________ Race:____________________

No.	STATEMENT	1	2	3	4	5
1	I am very interested in chemistry.					
2	I feel that chemistry is an easy subject.					
3	I find chemistry to be an interesting subject.					
4	I find the teaching methods used by the chemistry teacher to be engaging.					
5	I have no trouble generating chemical formulas for ionic compounds.					
6	I understand the concept of generating chemical formulas for ionic compounds.					
7	I find the use of 'Fit-Me-Ion' more engaging in the teaching and learning process.					
8	The use of 'Fit-Me-Ion' in generating chemical formulas for ionic compounds greatly facilitates the process.					
9	Teaching aids like 'Fit-Me-Ion' are very appealing.					
10	The concept of generating ionic compounds using 'Fit-Me-Ion' makes me understand better.					
11	I will use the method of using 'Fit-Me-Ion' in generating ionic compounds to better understand this topic.					
12	I feel more confident in solving questions related to generating chemical formulas for ionic compounds using 'Fit-Me-Ion'.					
13	I am more interested in chemistry after the concept has been explained using 'Fit-Me-Ion'.					
14	The use of 'Fit-Me-Ion' enhances my ability in related topics.					