

Analytical Separation Method: A Student's Perception on Analogy-based Teaching for Terminology

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Analytical Separation Method is a chemistry course offered at Universiti Teknologi MARA (UiTM), Malaysia. This course covers the application of chromatographic techniques, whereby students must be able to describe the principles and terminologies used and relate them with suitable analogies. A strong understanding of this course plays a major role in the development of solid knowledge amongst graduates to survive in the job market. An auspicious method to understand the analytical separation method has not been identified so far, therefore, limits their opportunities for career development in the future. According to the Pedagogical Content Knowledge (PCK) method, teachers must first understand the knowledge before presenting the information to students during the teaching process. If we can recognise this concept clearly, efforts towards the teaching of science will lead to a new achievement. Analogy-based teaching was found to be capable of increasing students' understanding with regards to the subject matter. The present research successfully identified the level of understanding towards terminology and analogy along with the readiness of students to use an alternative teaching method across campuses, and the readiness concerning the usage of different interactive teaching tools. Quantitative measurement was conducted via SPSS using a sample of 128 students from four different campuses. Based on the analysis, most of the students faced difficulties in accurately translating and relating to the terminologies (57.8%) and analogies (55.5%) concerning the theories without proper guidance. According to the overall mean score (4.18), the range of positive agreement signified the student's readiness towards the usage of interactive tools during teaching and learning sessions. There was no significant difference in students' level of understanding on analogy across campuses, however, a significant difference was found in students' level of understanding on terminologies used across campuses. In pairwise comparisons, there was a statistically significant difference (p -value = 0.009 < 0.05) between Kuala Pilah (K) and Arau (A) campuses.

Keywords: terminology; analogy; descriptive statistics; Kruskal Wallis

I. INTRODUCTION

The Analytical Separation Method course is offered for Bachelor of Science (Hons.) Chemistry, AS202 and Bachelor of Science (Hons.) Chemistry with Management, AS222 at Universiti Teknologi MARA (UiTM), Malaysia under the

course code CHM510. This course emphasises the fundamental principles of analytical separation methods which are useful and applicable in separation-based chromatography applications especially during the research activities in final year projects and industrial training. Apart from CHM510, such a course is also offered for the Diploma

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of Microbiology (AS114) students under the course code CHM260 - Basic Instrumental Analysis, which explains the fundamentals of separation in two chapters that include Gas Chromatography (GC) and High-Performance Liquid Chromatography (HPLC). This indicates the importance of analytical separation principles for students majoring in science regardless of the study level.

Separation is commonly defined as the action or state of moving or being moved apart (Guzlek *et al.*, 2009). In science, the separation of components is often performed prior to any analysis. Separation-based chromatography is an analytical method comprising sampling, sample preparation, and detection methods to determine quantitatively and qualitatively the presence of individual substance (also known as analyte) from a mixture. Generally, separation-based chromatographic techniques are a combination of sample preparation methods coupled with chromatographic instruments, such as gas chromatography (GC), liquid chromatography (LC), and capillary electrophoresis (CE). There are many detectors available in the market to be equipped with chromatographic instruments, such as Flame Ionisation Detector (FID), Electron Capture Detector (ECD), Thermal Conductivity Detector (TCD), Visible (Vis), Photo Diode Array (PDA), Refractive Index (RI), and Evaporative Light Scattering (ELS) (Chen *et al.*, 2012; Kowalski *et al.*, 2013; Molaei *et al.*, 2022).

Knowledge of the separation method has been successfully applied in many leading research studies, such as food (Janelle *et al.*, 2015; Peng *et al.*, 2020), antioxidants (Ma *et al.*, 2020), and drug delivery (Ruz *et al.*, 2004; Tekkeli & Kiziltas, 2016). Apart from that, potential employment opportunities are also available at leading research bodies, such as the Malaysian Agricultural Research and Development Institute (MARDI), National Institutes of Biotechnology Malaysia (NIBM), SIRIM Berhad, and Sime Darby Berhad, that are equipped with a complete chromatography laboratory. Due to this situation, it is important to develop an interactive teaching tool to ensure that students can master this course through the fundamentals prior to the exploration and analysis at a higher level. Job opportunities and career development are promising for those with the expertise and strong background in analytical separation method. Most recently, Ghent

University in Belgium was looking to recruit new assistant positions for column synthesis and advanced chromatography effective in October 2021. Besides that, Exxon Mobil as the world's leading company, offers employment opportunities as an analytical scientist to chemistry graduates with specialised expertise in separation methods.

To understand the separation methods, students must be well versed with the basic principles and fundamental concept including terminologies, for instance, mobile phase, stationary phase, polarity, analyte, retention time, and interaction. An earlier study by Abimbola in 1988 addressed the issues on terminologies and the need for science educators and researchers to use consistent terminology during scientific report writing. Furthermore, Abimbola highlighted that theories, languages, conventional approach, time, and self-commitment are barriers to learn chemistry worldwide. Woldeamanuel and co-authors revealed that the factor that affects students' perception of a chemistry course is the difficulties in understanding the scientific language and terms which has not been addressed well so far (Woldeamanuel *et al.*, 2014). Another language-related issue that has been debated is the emergence of English into the chemistry curriculum which is believed to make the subject more challenging (Taber *et al.*, 2020). Therefore, these issues should be solved in order to introduce simpler explanations that can reach the target audience.

Nowadays, the theory often put forward by conventional methods appears to be the difficulty in engaging students. To overcome this issue, laboratory sessions are a common practical approach used to assist and enhance students' understanding through visualisation which creates an opportunity for them to understand the principle behind the chemistry theories (Nakhleh & Malina, 2002). Miller *et al.* (2004) conducted an interesting survey on students' attitudes towards conceptual understanding of chemical instrumentation in analytical separations. In their survey, they discovered that the students have interactive engagement during laboratory sessions that allowed them to make connections between "chemistry" and the "real world" (Miller *et al.*, 2004). However, time was insufficient to complete the tasks. Therefore, it is urgent to expose students to the theory, purpose, and fundamentals of the separation

method beforehand, along with the detailed concept and procedures to operate separation-based instruments to alleviate time-related issues. In addition, another disadvantage of laboratory sessions is due to the availability of chromatography-based instruments, limited skilful people to operate the instruments, and tedious maintenance; therefore, its significance is limited.

Witteck *et al.* (2007) explored a project based on separation technique amongst students in a laboratory. In their study, students were required to conduct experiments on separations based on distillation, extraction, filtration, chromatography, adsorption, and centrifugation. They were allowed to refer to textbooks and internet sources to execute their plan and solve the given problem in the open task. A poster presentation was required to display students' understanding. However, the format of presentation was not clarified (Witteck *et al.*, 2007); therefore, this provided the opportunity for a wide range of presentation formats as the tools to convey the students' understanding.

Students' understanding is made possible through reading and memorisation. However, obstacles may arise if reading and memorisation of the subject matter is carried out without further understanding, as agreed by Klemm (2007). Common and available approaches to understand terminologies in analytical separation methods involve PowerPoint presentations, laboratory practical, recall, reading, and memorisation techniques. Among these methods, analogy-based presentations have not been explored so far to analytical separation methods. Analogy-based presentation as a teaching tool is found to be simple and effective in minimising the risk of random concepts, misleading and misconception with a wide range of alternative conceptions. Taber and co-worker discussed the implication of alternative conceptions in the learning of chemistry. They revealed that people's conceptions vary along a dimension of commitment, which differs from one to another person and varies from different levels of training and expertise (Taber *et al.*, 2012); hence, the effort to build the commitment for chemistry subject is crucial to the current teaching and learning environments.

Therefore, this study deduces a new approach via analogy and terminology to help students before memorising, as suggested by Oliva (2007) and Genç (2013), as this approach

was deemed more enjoyable, interesting, and so much fun. In the present work, the level of understanding of terminologies and analogies among undergraduate students in four selected campuses were identified. Furthermore, a comparison towards the students' level of understanding on terminologies and analogies across campuses was conducted. Besides that, the readiness of the students to use interactive teaching material was also discussed. The analysis was quantitatively measured using SPSS and R-Plus software through a sample of 128 students from four campuses in Universiti Teknologi MARA.

II. MATERIALS AND METHOD

The collected samples involved students from four different campuses in Universiti Teknologi MARA, who enrolled in CHM510 - Analytical Separation Method course. Responses were obtained from 128 students from a sample population of 158 students, which accounted for an 81% response rate. An analytical cross-sectional study had been conducted between October 2020 until November 2020. A self-developed questionnaire was given to the students to acquire the necessary information. In this study, primary data was obtained by conducting a closed-ended online questionnaire to ensure that the accuracy and consistency of the data were aligned with the study objectives. The measurement scale used was the five-point Likert scale on a continuum from strongly disagree (1) to strongly agree (5) to measure either positive or negative responses to a particular statement.

This study applied a non-probability sampling known as the convenience sampling technique owing to the advantage of being less expensive and time-consuming (Sekaran and Bougie, 2016). In this sampling technique, the units that became a sample were collected without a specific probability structure. The selection applied was not completely randomised, and the resultant sample provided summaries and conclusions on the sample involved only. The data obtained were quantitatively analysed using SPSS software.

The method of analysis used in this study included descriptive analysis and comparison of means to attain the objectives of this study. The statistical analyses used in this study were descriptive statistics comprising frequency distribution and measures of central tendency. It is known as

a summary measure that attempts to describe data with a single value that represents the centre of its distributions. However, the measures of central tendencies are not sufficient to specify the data. Thus, dispersion measurement is used to evaluate the variability in the data. Furthermore, the statistical analyses also included a comparison of means on independent groups (campuses) to measure and evaluate the level of understanding among students regarding the terminology and analogy used in the analytical separation method course offered in four campuses. Table 1 indicates the procedures of conducting those analyses as follows.

Table 1. Method of analysis used in this study

No.	Objectives	Method of Analysis
1.	To identify the level of understanding of terminology and analogy among students.	Descriptive statistics
2.	To assess the readiness of the student to use interactive teaching material that aligns with Education 5.0.	Descriptive statistics
3.	To make a comparison towards students' level of understanding on terminology and analogy across campuses.	Comparing three or more independent means; ANOVA / Kruskal Wallis test

III. RESULT AND DISCUSSION

A. Reliability Analysis

In the preliminary analysis, the reliability test was conducted using Cronbach's alpha measurement to estimate the internal consistency of the online questionnaire. The reliability test was essential to determine the level of understanding among students while answering the online questionnaire that could also be used as an assessment tool to evaluate the consistency of the questions used in the online questionnaire. Essentially, the purpose of the reliability test was to determine whether the students understood what the questions required and evaluate how the students perceived and answered the questions. The reliability analysis was carried out by measuring Cronbach's alpha to estimate the internal consistency of the online questionnaire. Table 2 summarises the Cronbach's alpha results for all items under the variables

terminology, analogy, and readiness. The reliability test was high, indicating the items used were reliable.

Table 2. Cronbach's alpha coefficient

Variables	Number of Items	Cronbach alpha, α
All items	10	0.842
Terminology	4	0.794
Analogy	4	0.829
Readiness	2	0.722

B. Demographic Profile

Table 3 shows the percentage of male and female students involved in this study (n=128). The students were predominantly female and accounted for 87.5 percent, while male students accounted for 12.5 percent. The A campus accounted for the highest number of students with 50.8 percent of which exceeded half of the students involved. Table 3 also shows the distribution of students according to their gender and campus.

Table 3. The distribution of students according to their gender and campus

Demographic	Frequency	Percent	
Gender	Male	16	12.5
	Female	112	87.5
Campus	A	65	50.8
	J	21	16.4
	K	21	16.4
	S	21	16.4

A = Arau
J = Jengka
K = Kuala Pilah
S = Shah Alam

C. Descriptive Analysis

Table 4 shows the responses obtained were attributed to the level of understanding based on terminology (mobile and stationary phases, retention time, interaction, analyte, and polarity) while analogy had been used in the Analytical Separation Method (CHM510) subject among students. In this study, the 5-point Likert scale was used with rank order by assuming the interval between the scale was dissimilar and inappropriate to represent the ordinal data using mean and standard deviation (Jamieson, 2004). Therefore, the median and mode were used by the primary measurement of central

tendency in this study to display the distribution, while the bar chart analysis had been used to visualise the distribution. Based on terminology responses (Figure 1), 50 percent of the students agreed (scale 4) to strongly agreed (scale 5), which demonstrated a clear understanding towards the terminologies used in the CHM510 syllabus indicating that they were able to re-explain correctly. From modal value perspectives, most of the students agreed with this statement. However, the response percentages showed a slight decrease in the item that relates the terminologies to theories without assistance (scale 3). The findings indicated that the level of students' understanding without intensive guidance may become a challenge for the lecturers in the teaching and learning process in the course, CHM510, because in terms of the interpretation of contexts and technical texts, terminology plays an important part. Further support should be offered to students either for pre- or post-terminology teaching. This is due to the "mind wondering" phenomena that may act as another challenge to understand terminologies in depth. This phenomena builds a barrier to all mental activities during the learning process, where the mind tends to be distracted from the existing situation to unrelated opinions. Even though this barrier has never been reported earlier for terminology issues, it was documented as one of the common challenges in a self-directed learning barrier (Kohan *et al.*, 2017); therefore, should be addressed clearly. Understanding the specific terminology of technological and scientific contexts helps students to understand the document's key message and deliver the content more effectively. In analogy terms (Figure 2), the

result showed that 50 percent of students agreed (scale 4) to strongly agreed (scale 5) in showing an understanding of the analogies related to daily life situations. This is because the analogy serves as a link between the teaching materials and the abstract domain (Lolita, 2015). Besides, Gokhan *et al.* (2012) concluded that employing analogies can enhance the extensive understanding of complicated scientific concepts and also assist the students in overcoming misconceptions about scientific terms. Students showed an understanding of each terminology by using analogies and being able to re-explain terminologies in simple and understandable words, which is aligned with the Structure-Mapping Theory. From modal value perspectives, most of the students agreed with this statement. In contrast, the response showed a slight decrease in rank if students needed to accurately relate analogies to theories without assistance (scale 3). The findings concluded that students tend to face difficulties in the learning process if lecturers did not guide their students. Besides that, most students only memorise the terminology but not the content of the study (Gokhan *et al.*, 2012). Hence, the students will not recognise that they can use analogical reasoning when attempting to solve a particular problem and probably form other connections and inferences that are different from those that the lecturers intended. Lolita (2015) reported that the analogies used to develop the students' ability meant that they were able to take what had been learned and apply it to their daily life, which is aligned with the Pedagogy Theory. Unfortunately, the data showed that the students did not meet the criteria discussed.

Table 4. Descriptive statistics on the level of understanding of terminology and analogy

Level of understanding of terminology and analogy		Median	Mode
		\tilde{x}	\hat{x}
Terminology	1. The terminologies of this course were easily distinguished from each other.	4	4
	2. Students can clearly understand the definition of each terminology.	4	4
	3. Students can accurately and correctly re-explain terminologies.	4	4
	4. Students can accurately relate the terminologies to theories without assistance.	3	3
Analogy	1. The analogies used in this course can be related to daily life situations.	4	4
	2. Students can understand the definition of each terminology by using the analogy.	4	4
	3. Students can re-explain terminologies in simple and understandable words.	4	4
	4. Students can accurately relate analogies to theories without assistance.	3	3

3 = neutral, 4 = agree

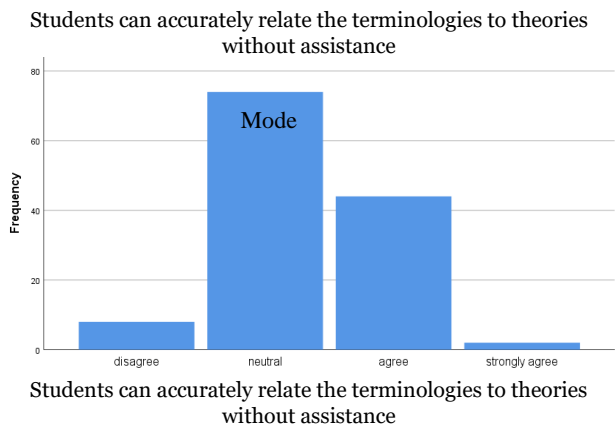
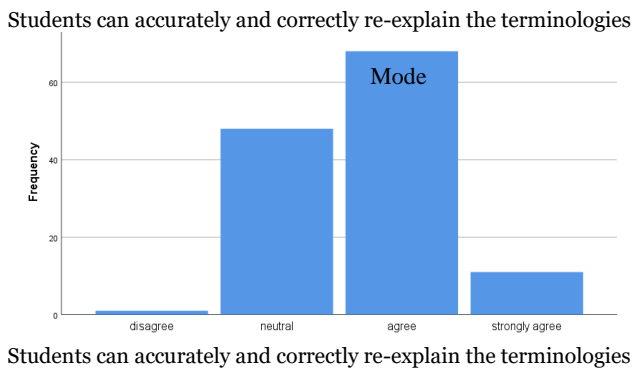
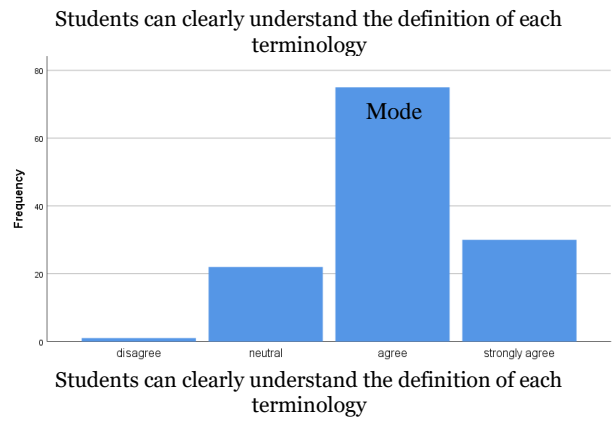
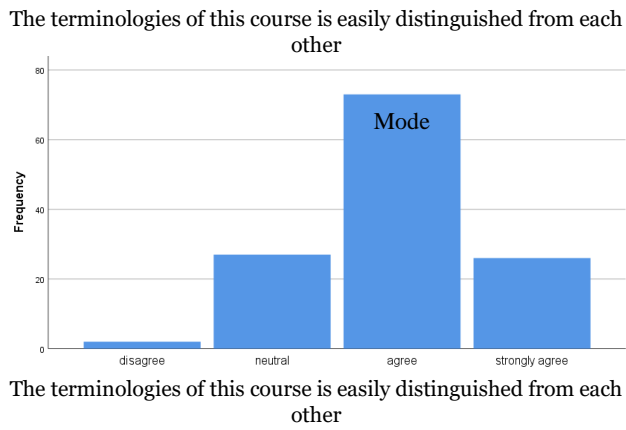


Figure 1. Level of understanding of terminology

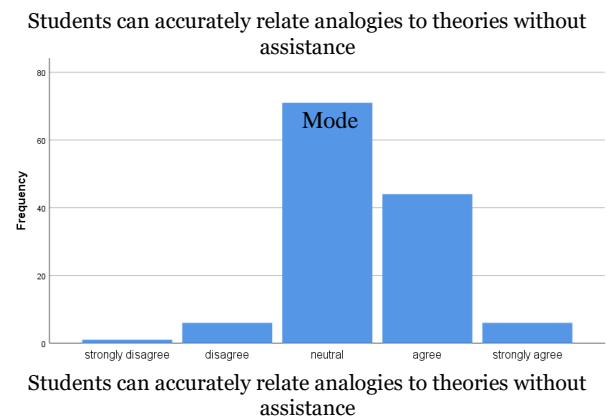
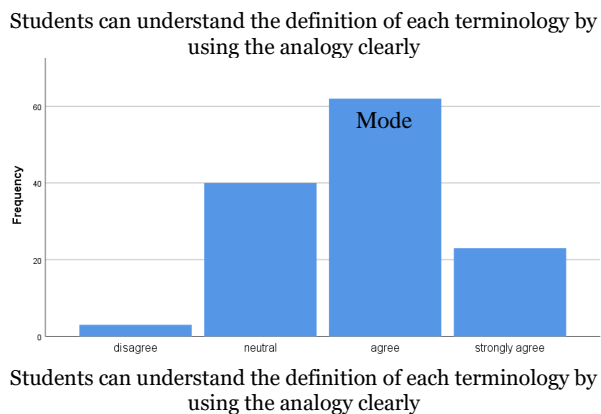
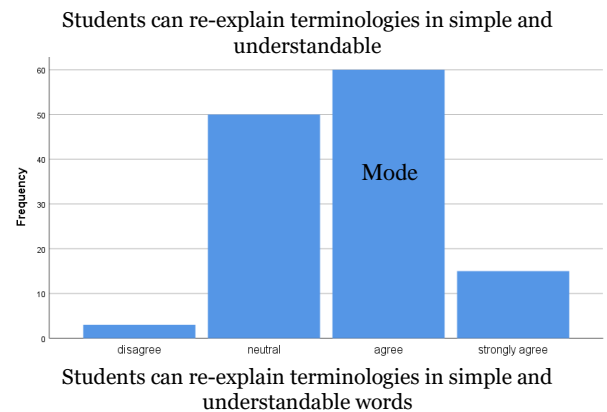
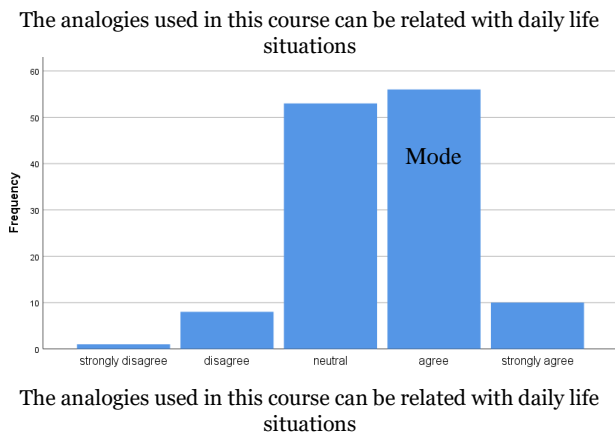


Figure 2. Level of understanding of analogy

The descriptive analysis assessed the readiness of students in using interactive teaching material that had been aligned with Education 5.0 as introduced by the Ministry of Education, Malaysia. Table 5 shows a positive agreement frequency distribution towards the readiness of the students in using interactive teaching material. Most students agreed to use interactive materials for better assessment and learning satisfaction. According to Senthamarai (2018), interactive teaching styles such as video, e-books, and comic cartoons offer a good learning environment and are beneficial in grasping attention and participation among students. Chandrasekaran (2014) reported that the students who learned through the interactive methods could better relate

the data and thus, remember the theories. The findings showed that the students were more confident when the presentation of analogies and terminologies in CHM510 were subjected to video, e-book, and cartoons that were more interesting and useful. The CHM510 course could not be delivered accurately without proper and interactive teaching methods, and content knowledge of terminologies and analogies. Moreover, the methods that are too old or undeveloped should be changed to make the teaching and learning process more productive and meaningful. Al-Rawi (2013) stated that the lecturer method only concentrates on the information rather than learners.

Table 5. Frequency distribution on the readiness of students to use interactive teaching materials aligned with Education 5.0

Readiness of students		Frequency	Percent
The terminologies used in this course should be delivered through more interesting methods (video, e-book, cartoons).	Disagree	2	1.6
	Neutral	18	14.1
	Agree	48	37.5
	Strongly agree	60	46.9
The terminologies used in this course should be delivered with more creative analogies.	Neutral	29	22.7
	Agree	62	48.4
	Strongly agree	37	28.9

In addition, the Likert scale can create a simple average questionnaire response over a set of individual questions or items. Table 6 shows the mean, median, standard deviation, and skewness values for the students' readiness towards the use of interactive material during the teaching and learning (T&L) session. According to the overall mean score across campuses, the range of positive agreement indicated student's agreement towards the statement. This is supported by the negative skewness value of the distribution (skewed to the left) showing most of the responses indicated agree (scale 4) to strongly agree (scale 5).

Table 6. Readiness of students to use interactive teaching material aligned with Education 5.0

Campus	Mean	Median	Std. Deviation	Skewness
K	4.12	4.00	0.610	- 0.503
J	4.33	4.50	0.639	- 0.730

S	4.33	4.50	0.639	- 0.571
A	4.10	4.00	0.680	- 0.414
Total	4.18	4.00	0.657	- 0.481

D. Comparison of Means

A normality test was used to assess data distribution. The Shapiro-Wilk test serves the exact same purpose as the Kolmogorov. The Shapiro-Wilk test is more appropriate for small sample sizes which are less than 50 samples, but can also handle sample sizes as large as 2000 (Razali & Wah, 2011). For this reason, the Shapiro-Wilk test was used as the numerical means of assessing normality. The normality test is presented in Table 7.

Table 7. Test of normality

Variable	Shapiro-Wilk		
	Statistic	df	p-value
Terminology			
K	0.933	21	0.155
J	0.921	21	0.091
S	0.886	21	0.019
A	0.960	65	0.035
Analogy			
K	0.929	21	0.134
J	0.955	21	0.420
S	0.917	21	0.076
A	0.961	65	0.036

However, the distribution of terminology and analogy across campuses did not show a significant normal distribution (where p-value must be greater than 0.05) as required for a one-way analysis of variance (ANOVA). Therefore, the nonparametric Kruskal Wallis test was used to compare students' level of understanding on terminology and analogy across campuses. This test is a rank-based nonparametric test to determine if there are statistically significant differences between three or more independent groups. On average, the mean rank among the four campuses indicated students' levels of understanding on terminology and analogy (Table 8). The initial data analysis indicated that there was a slight difference in the mean score among campuses on the terminology and analogy, where the K campus scored higher than other campuses.

Table 8. Mean rank among campuses on the terminology and analogy

Variables	Campus	Mean Rank
Terminology	K	80.76
	S	73.12
	J	64.17
	A	56.57

Analogy	K	75.24
	J	66.43
	A	62.30
	S	58.64

Based on Table 9, a Kruskal Wallis test showed that there was a statistically significant difference in the terminology mean score among campuses ($\chi^2(3) = 8.327, p = 0.04 < 0.05$), with a mean rank score of 80.76 for K, 73.12 for S, 64.17 for J, and 56.57 for A. Hence, H_0 was rejected and it was concluded that there was a significant difference in students' level of understanding of terminology across campuses.

Furthermore, a Kruskal Wallis test showed no statistically significant difference in the analogy mean score among campuses ($\chi^2(3) = 2.610, p = 0.456 > 0.05$) with a mean rank score of 75.24 for K, 66.43 for J, 62.30 for A, and 58.64 for S. Hence, H_0 was not rejected and it was concluded that there was no significant difference in students' level of understanding on analogy across campuses.

Table 9. Summary of hypothesis testing

No.	Null Hypothesis	Test Statistics, P-value
1	The distribution of Terminology is the same across campuses.	8.327, 0.040
2	The distribution of Analogy is the same across campuses.	2.610, 0.456

Moreover, this study covered the Kruskal-Wallis test which included a post hoc test to determine whether any differences lie across campuses. Table 10 shows the post hoc test to determine whether the mean score on terminology is statistically and significantly different among campuses. Pairwise comparisons indicated there is a statistically significant difference between the K and A campuses (Test statistic = 24.193, p-value = 0.009 < 0.05). The results supported the earlier analysis that indicated there is a difference in the terminology mean score among campuses K (80.76) and A (56.57).

Table 10. Pairwise comparisons

Campus 1 – Campus 2	Test Statistic	P-value
A – J	7.597	0.409
A – S	16.550	0.072
A – K	24.193	0.009
J – S	-8.952	0.429
J – K	16.595	0.143
S – K	7.643	0.500

IV. CONCLUSION

The majority of the students exhibited good agreement in terms of terminology and were easily able to identify them from one another, indicating that they had grasped the definition and re-explained terminologies correctly. In terms of analogies, the results showed that the majority of the students agreed that the analogies relate to real-life scenarios, demonstrating that they clearly understood each terminology and were able to use analogies, implying that they were able to re-explain terminologies in simple and understandable words. However, when students were required to relate terminologies and analogies to theories without the

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assistance of lecturers, their responses showed a slight decrease in rank. As a result, learning without guidance may become a difficult task for students. Subsequently, most of the students were in positive agreement to use interactive materials for better assessment and learning satisfaction but require a higher level of creativity and effort. The need to create appealing notes may necessitate sacrificing their time but will result in new skills among educators. There was no discernible difference between campuses in terms of students' grasp of analogies. However, there was a considerable variance in the amount of terminology awareness across students between campuses. Pairwise comparisons have indicated there was a statistically significant difference between the K and A campuses. The findings corroborated a prior study that found a difference in terminology mean scores between campuses in K (80.76) and A (56.57).

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