College Students' Attitude, Laboratory Work with Science Writing Heuristic and Conceptual Knowledge towards Achievement: A Structural Equation Modeling Analysis

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Abstract

In this study, the achievement of Malaysian pre-university students enrolled in a Matriculation institution was attempted to be modelled. It is critical for students to succeed in college-level chemistry classes in order to upgrade to more advanced science courses and pursue science-related occupations. The goal of this study is to use Structural Equation Modelling (SEM) to create a structural model for Science Writing Heuristic (SWH) that best represents the relationships between attitude, conceptual knowledge, and laboratory work with SWH in chemistry achievement, and to see what percentage of variance in chemistry achievement can be explained by these variables. Purposive sampling was used to collect data from 171 students (72 males and 99 females) for this study, which was then analysed using a covariance-based structural equation modeling (CB-SEM) approach. In this study, a survey with a single sample design was used. The results show that employing a SEM model with all three predictors may explain 34% of the variance in chemistry achievement. Furthermore, research demonstrates that both genders' achievement in chemistry is influenced by their attitude, laboratory work with SWH, and conceptual understanding. On the other end, while attitude alone does not improve achievement, mediating laboratory work with a SWH strategy that addresses misconceptions can have an impact on chemical achievement. These data suggest that those who have a strong interest in chemistry, have good conceptual knowledge, and conduct laboratory work with SWH have a better chance of performing well in chemistry. To increase their chemistry accomplishment, matriculation colleges should incorporate certain desirable positive attitudes, laboratory work with SWH technique, and conceptual understanding into the mainstream of instruction. This research contributes in one of the area of the SEAMEO's seven priority areas in where the science education researchers have been continuously conducting the research to find effective ways with the aim of helping students. Since the academic achievement is one of the outputs of the science education, teaching strategies that promote achievement have an important place in research area. This is at par with the philosophy of Learning Science and Mathematics where learning in laboratory need to be embedded with fun and more meaningful way.

Keywords: *Conceptual knowledge; Attitude; Laboratory work with SWH; Covariance Based Structural Equation Modeling*

Introduction

Malaysia's goal of becoming a developed country has prioritised science and technology as vital subjects to master. This is especially true because science and technology are frequently regarded as driving forces behind economic progress in developed countries (Chai, 2021). Reports on scientific learning accomplishment, particularly those that indicated students' lack of motivation and diminishing ability to undertake science (Simpkins et al., 2020), raised concerns about the ability to meet the targets. Only 20% of Malaysian secondary school graduates pursue postsecondary education, according to the most recent data available from the UNESCO Global Education Digest 2020, whereas 90% of the entire secondary student population completes some form of secondary school programme. Improvements at the secondary level, which encourage more adults to pursue university education, will almost certainly result in significant increases in the overall adult population with higher education levels, indicating a better organised and more highly skilled pool of workers for the local, regional, and economies around the world.

Science is a compulsory subject in Malaysian schools from primary school to upper secondary school. Biology, chemistry, and physics are taught as elective science subjects in upper secondary. The science topics are designed to train students to be science competent, inventive, and capable of integrating scientific knowledge to daily decision-making and problem-solving in accordance with Malaysian science education philosophy. In the Matriculation Programme, chemistry is declared obligatory for all science students (Matriculation Division Ministry of Education Malaysia, 2016). Many locally and internationally studies, such the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS), have based on quantitative science evaluation to enhance student' learning outcomes. Earl et al. (2017) argued that achievement-based education will lead to students' detachment from science. For example, in Asian countries where a national education system culture inspires students to focus primarily on rote-memorizing subject concepts in order to achieve higher scores on science tests and for university entrance exams, science education in private hands has been determined to intensify students' sentimental disconnection from science (Davis et al., 2018). According to PISA science literacy data, 15-year-olds in Malaysia score 420 points, compared to an average of 501 points in OECD countries, and girls outperform boys by 11 points, which is statistically significant (OECD average: only 1 point higher for boys). The low performance in the most current PISA assessment exposes a number of fundamental issues with Malaysia's educational system and causes concerns among many Malaysians (Hin, 2018).

Despite the presence of best practises for teaching science, some classrooms become highly teacher-centred, ignoring the development and mastery of scientific and cognitive abilities among students as required by the curriculum (Artayasa, 2017). Science, as an empirical topic, encourages students to investigate and inquiry in order to gather knowledge and draw their own conclusions. For more than a decade, the inquiry–discovery strategy, which is essential in science teaching and learning, has been aggressively promoted. However, educationists have noted that science is still taught in a didactic style in many circumstances. A low percentage of teachers do not conduct experiments with their learners, and a smaller percentage focuses on demonstration. Many teachers urged pupils to merely carry out experiments according to protocols outlined in books and come to their own conclusions without much discussion (Arnott, 2020).

As a result, a model that describes the accomplishment of Malaysian pre-university students enrolled at a Matriculation college has been suggested in this work, which is based on the Covariance Based-Structural Equation Modeling (CB-SEM) technique (Hair et al., 2014). This can enable researchers in identifying the most theoretically exact and compact approximation models (Burnham & Anderson, 2013). This model essentially hypothesises and statistically describes the strength of the interactions between the components of the achievement model. Attitude, laboratory work with SWH, and conceptual knowledge toward achievement are all components of this study. Previous related studies show that various factors influence the improvement in chemistry (Brothers & Reilly 2021; Lucas et al., 2021). The new revised with extra component in the suggested model will be a good resource for educators and curriculum developers to formulate and execute their teaching approaches so that these approaches will ultimately be effective in improving student performance in chemistry throughout Matriculation colleges.

Attitude towards Chemistry and Relationship with Achievement

Schmidt and Kelter (2017) define attitude as a complex framework that includes affective, cognitive, and behavioural components, each of which influences the others in a continuous process. Attitude is operationalized in a variety of ways by researchers in the field (Vilia & Candeias 2020; Ross & Gonzalez, 2020). For example, Roebianto (2020) found three sub components of attitudes connected to achievement: attitude toward chemistry (enjoyment and curiosity), achievement motivation (effort), and science concepts. Flaherty (2020) employed three subcontracts to evaluate attitudes: affect (like science), cognitive competence, and value to explore the causal links between science and science achievement in White middle school children over time (usefulness of science). Liou (2021) discovered that an indirect effect model of attitudes and achievement over time fit the data the most. As a result, improvements in science have an impact on students' attitudes toward science, and favourable attitudes toward science are associated with higher performance (Kapici et al., 2020). As a result, the definition of attitudes employed in this study is a person's attitude toward chemistry, rather than their liking or disliking of chemistry or having "positive or negative feelings" about chemistry.

Chemistry education is supposed to be outcome-oriented and student-centered, and this can only be done if students are ready to learn and teachers use the relevant methodologies and techniques to do so (Partanen, 2020). Students are curious by nature, and they must be actively involved in the learning process, frequently educating, trying, thinking, and developing their own personal construct and knowledge (Per, 2011). Personalizing such knowledge is the only way for it to become relevant, significant, and beneficial to them. Students must actively develop their own individual knowledge and understanding in chemistry. Due to the complexity and conceptual nature of the subject, most students have difficulty with chemistry and underperform (Rodriguez, 2020). The blend of subject difficulty and some clear qualities of students, such as laboratory work that allows for effective learning and can forecast chemistry success (Seery, 2020), as well as attitudes that allow them to contribute to society.

According to Sagala et al. (2019), boys have historically shown a greater interest in science than girls in elementary school, but girls' attitudes toward science tend to diminish as they progress through high school. Furthermore, girls rated their science classes as "information to learn" and "dull" (Hanson, 2020). According to Acar (2019), the gap between male and female attitudes toward science widens as pupils progress from elementary to secondary school in ten nations. Furthermore, according to Acar (2019), the greatest growth in gender inequalities in views occurs between the ages of 10 and 14. There have been numerous attitudinal studies that have looked into the relationship between science attitude and science achievement (Ng et al., 2012). The achievement of high school students has been proven to be strongly linked to their attitudes (Moshe & Khaled, 2012). Various attitude studies have been conducted to investigate the association between science attitudes and academic achievement (Van, 2021). The achievement of high school students has been proven to be strongly linked to their attitudes (Bal, 2018). The importance of improving students' good attitudes toward chemistry is critical, and a study of the relationship between attitudes and academic accomplishment revealed that the two factors were intertwined. The goal of this study is to develop a model that can explain the importance of attitude toward learning chemistry in terms of achievement.

Conceptual knowledge and relationship with achievement

Students enrolled in higher education were strongly linked to the growth of their knowledge conceptions as they progressed through their educational experiences (O'Donovan, 2017). Students with diverse age and grades from many countries regarded chemistry as a difficult subject because it contains many complex concepts (Hordern & Tatto, 2018) and requires understanding on both macroscopic and microscopic dimensions. For instance, in matriculation chemistry courses, solution chemistry and its sub-concepts play a critical role in fully comprehending other related concepts. Knowledge that is rich in relationships is best described as "conceptual knowledge." It can be compared to a connected web of knowledge, a network in which the connecting relationships are just as important as the isolated pieces of data. Individual facts and propositions are intertwined with relationships, resulting in a network' of information. For example, a knowledge of single concepts like oxidation or more complicated concepts like redox reactions (declarative or factual knowledge), which integrates many distinct concepts according to specified rules and models. In this investigation, meaningful conceptual knowledge is defined as a student's ability to discern new information as being different from what they already know, to acknowledge discrepancies, and to construct explanations to help solve awareness conflicts, or to seek links between disparate pieces of information (Hofstein & Mamlok-Naaman, 2011). Three variables have a direct impact on students' chemistry achievement, as evaluated by course achievement: student attitude toward chemistry, conceptual knowledge, and laboratory work with Science Writing Heuristic (SWH) (an exemplar is attached in Appendix).

True comprehension necessitates not just the mastery of important concepts, but also the creation of meaningful connections that connect the concepts into a whole (Çelikkiran, 2020; Nakhleh, 2002; Nakhleh, 1992). When presenting an observation or explaining a process, Oscar (2017) discovered that thinking about chemistry involves three levels, in which the learner must see beyond the symbol and draw connections between the different levels. Despite the facts that introducing and emphasising the particulate nature of matter (sub-microscopic level) during chemistry classes can help students link the particulate nature of matter to other levels (macroscopic and symbolic level) during chemistry classes (David et al., 2003), students were never taught to think about chemistry in three levels (Schwedler & Kaldewey, 2020). Integration of these three levels is critical for conceptual knowledge as the integration of many types of data from various levels (representational) allows the data to be arranged in a coherent way (Joong, 2014). When material is well-structured, it is easier to comprehend. Concept formation is primarily concerned with motivation, orientation, and assistance. It lays a greater emphasis on thinking rather than remembering, on understanding rather than simply memorising facts, and on learning via true desire rather than intimidation (Anne & Heather, 2019).

Multiple concept areas of the matriculation chemistry curriculum represent the knowledge and understanding for conceptual comprehension in this study, and their relationships and interactions within these ideas and with respect to everyday life events are addressed. It cannot be disputed that SEM has helped us better understand the links between these variables and why conceptual knowledge is such an important predictor of achievement. From the many definitions reported in the literature, it is obvious that in order to improve students' conceptual understanding, various measurements have been introduced as aspects of meaningful conceptual learning in an attempt to improve learning chemistry.

Laboratory work with SWH and relationship with achievement

The teaching–learning technique in the chemistry curriculum is centred on practical activity aimed at mastering scientific abilities such as proses skills, manipulative skills, and cognitive skills. Students can develop these skills through scientific study and hands-on exercises in chemistry, and it has the potential to significantly improve knowledge and understanding of concepts. When investigation is properly conducted, a number of studies have shown that laboratory experiences can improve students' progress in the course (Ganasen & Shamuganathan, 2017). They believe that "direct laboratory experience is one of the best ways to have meaningful learning experiences." Other research has found that the laboratory can assist students develop a positive attitude toward science, particularly chemistry (Akçayr, 2016). Students gain considerably from practical work in the laboratory, which is a key element of chemistry teaching and learning. However, the traditional laboratory approach, which requires students to follow recipe-like procedures systematically, interrupts effective learning and hinders students from appreciating the value of practical work (Bank et al., 2020).

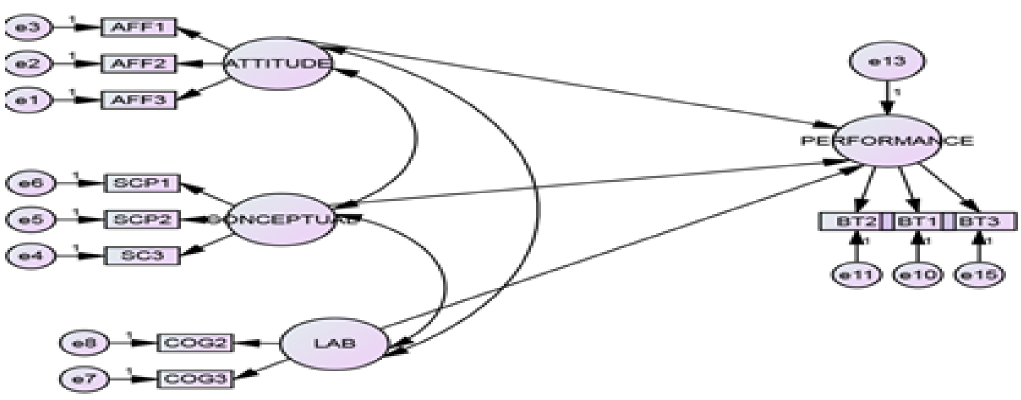
Students were encouraged to participate in various sorts of knowledge construction since the heuristic was used in conjunction with a rich activity-based curriculum. The SWH technique has yielded a number of positive results since its implementation according to Esen (2020), Mary et al. (2015), Burke et al. (2006), Ruth et al. (2013), Cronjea et al. (2013), Rudd et al. (2001), Rudd et al. (2007), ecological literacy (Balgopal & Wallace, 2009), and scientific literacy (Balgopal & Wallace, 2009). As heuristic writing was utilised in conjunction with a rich activity-based curriculum, students were encouraged to participate in multiple types of knowledge production. Embedded green chemistry experiments (SWH-GC) were designed and used by Shamuganathan and Karpudewan (2017) and Shamuganathan (2016) with significant improvement in environmental literacy among pre-university students.

Students actively constructed meaning for their stream queries by considering data points as evidence for specific statements, according to the writing data. Students who learnt employing the SWH curriculum, on the other hand, showed a greater gain in attitudes, beliefs, knowledge, and behaviour. This was most likely due to the incorporation of SWH chemical exercises, which increased the students' constructivism engagement (Golden, 2020). The SWH student template, like prior studies, asked students to construct questions, propose strategies to address these concerns, and conduct appropriate investigations (Greenbowe et al., 2007; Keys et al., 1999).

Conceptual relationship among the four factors in chemistry

As seen in the preceding discussion, these three criteria and their link to chemical achievement have been studied earlier, albeit usually in distinct studies. Three factors have a direct impact on students' chemistry achievement, as evaluated by their course achievement: students' attitude toward chemistry, their conceptual knowledge, and their laboratory work. Although relationships between these variables are expected, they are set to correlate in this model, as illustrated in Figure 1.

Figure 1 Proposed hypothesized model



Using the proposed model following hypotheses has been tested:

1. Laboratory work with SWH positively influences achievement.
2. Conceptual knowledge positively influences achievement.

3. Attitude towards learning chemistry positively influences achievement.
4. Conceptual knowledge influences laboratory work with SWH.
5. Attitude towards learning chemistry influence laboratory work with SWH.

Methodology

The purpose of this research was to predict the chemistry achievement of Malaysian pre-university students (average age 19 years) using statistics from a chemistry attitudes questionnaire, a chemical concepts test, a laboratory SWH questionnaire, and a mid-semester performance score. According to Etikan et al. (2016) purposeful sampling, also known as probability sampling, is the deliberate selection of a sample based on its characteristics. The above-mentioned tool was used to develop the accomplishment model, which was then utilised to test five hypotheses that quantitatively analyse the relationship between the model's components. The model was empirically tested using structural equation modelling and maximum likelihood estimation (AMOS version 18).

Research Participants

The study's participants came from a pre-university matriculation college in Malaysia's Northern Region. These students were picked for their academic achievements and will continue their undergraduate studies in scientific subjects like as medicine, engineering, and teaching at local and international universities. There are a total of 14 matriculation centres in Malaysia, each of which follows the same programme. These pupils are among the highest achievers in Malaysia's secondary school leaving examination (Malaysian Certificate Examination). The participants in this study were matriculation students enrolled for the 2019/2020 academic year. The participants were in semester 2 at the time of the study. Physical and organic chemistry are required for students to study for 11 months during semester 2 of the pre-university degree. This study included 171 students with an average age of 18 years old from five different classes.

Instrument

At total of 180 Questionnaire on Attitude was administered to the students during the lecture hour intervals. The return questionnaire consist of 171 questionnaires were returned giving the return rate of 95 % which is high. Students' attitude toward chemistry was measured by the attitude toward the subject of Chemistry Inventory version 2 (Gardner et al., 1998). consists of 15 items. Construct on attitude towards chemistry consisted of 4 items based on five-point Likert Scale ranging from 1 (never) to 5 (always). The items reflect on attitude of students towards the enjoyment of chemistry learning experiences, the development of interests in chemistry and chemistry-related activities, the development of an interest in pursuing a career in chemistry or chemistry related work, For instance item AFF1 was presented *as I would like to have chemistry lesson more often* .This item tests the students' towards the enjoyment of chemistry learning experiences and students need to indicate to what extent they agree with the statement. AFF2 was presented as *I'm capable of interpreting the world around me using chemistry knowledge*. This item tests the students' development of interest in chemistry and chemistry related activities and students need to indicate to what extent they agree with the statement. AFF3 was presented as *Chemistry knowledge is necessary for my future carrier*. This item tests the students' development of interest in pursuing a carrier in chemistry and chemistry related carrier and students need to indicate to what extent they agree with the statement.

Conceptual knowledge was administered using Chemistry concept Inventory with 20 multiple choice questions, five question per concepts. The questions were parallel with Bloom taxonomy and testing four concepts on chemistry matriculation syllabus. The Laboratory Questionnaire developed and validated by Hofstein et al. (1976) and modified by Vermaak (1997) consists of 28 items. Construct on laboratory towards chemistry consisted of 4 items based on five-point Likert

Scale ranging from 1 (never) to 5 (always). The items reflect on some practical aspects of laboratory work with SWH, how laboratory work with SWH is considered as a way of learnings the enjoyment of chemistry learning experiences, for instance item COG2 was presented *as more time should be devoted to SWH type of experiment.* Students need to indicate to what extent they agree with the statement. COG1 was presented *as I prefer doing SWH lab work as it makes me learn more, I will do better in my final exam*.

Data Analysis

The major goal of this model testing process is to figure out how well the hypothesised model fits the sample data. A confirmatory factor analysis (CFA) was performed on the predicted three-factor structure model using Analysis of Moment Structure AMOS 18 to reach the conclusion (Bryne, 2004). The individual items' and the overall measurement model's reliability and validity were examined by CFA. To create estimates in the measurement model, the programme used Maximum Likelihood (ML) estimation. The instrument's reliability in this study was evaluated by the researcher and estimated as internal consistency (Cronbach's alpha). Cronbach's alpha is a regularly used metric for determining how closely various indications for a latent variable are related. The indicators should have a Cronbach's alpha of 0.70 or higher as a general rule (Spector, 1994). In this study, chi-square (2), Goodness-of-Fit Index (GFI), Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA) were used to measure model fit, as suggested by Byrne (2004). Finally, path coefficients and t-values are calculated for the postulated associations to determine their magnitude and statistical significance.

Results

To rule out construct validity, the measurement model for each construct in the QEL, which includes attitude, belief, knowledge, and REB, was examined. The extent to which a group of measured items accurately reflects the theoretical latent construct they were supposed to measure is known as construct validity. Convergent and discriminant validity were the two components of construct validity. Convergent validity of a construct can be tested using one of three methods (factor loadings; variance extracted; composite reliability) as shown in Table 1 and discriminant validity as shown in Table 2.

Table 1 Measurement Model of CB-SEM

Variable	Question Item	Loading	AVE	CR
Attitude	AFF1	.55	.513	.741
	AFF2	.66		
	AFF3	.65		
Labwork	COG2	.91	.513	.731
	COG3	.55		
Conceptual	SCP1	.65	.515	.791
	SCP2	.72		
	SCP3	.85		
Performance	BT1	.77	.665	.884
	BT2	.78		
	BT3	.88		

Table 2 CB-SEM with Discriminant Validity

	Attitude	Labwork	Conceptual	Performance
Attitude	**.603**			
Labwork	.559	**.659**		
Conceptual	.040	.466	**.559**	
Performance	.034	.551	.553	**.688**

Items with a load more than 0.5, an AVE greater than 0.5, and a CR greater than 0.7 have been kept, as suggested by Bagozzi and Yi (1988). According to Gefen & Straub (2005), items with an AVE more than 0.5 have appropriate convergent validity, and those with a CR greater than 0.7 have adequate internal consistency. The square root of the AVE was checked against the inter correlations of the construct with the other components in the model to guarantee discriminant validity after ensuring convergent validity (Chin, 2010; Fornell & Larcker, 1981).

As seen in Table 3, the square root of the AVE outperformed the correlations with other variables for the entire construct. As a result of the evidence of appropriate reliability, convergent validity, and discriminant validity, the measurement model was deemed satisfactory. We next proceeded to examine the hypotheses that had been created for this study.

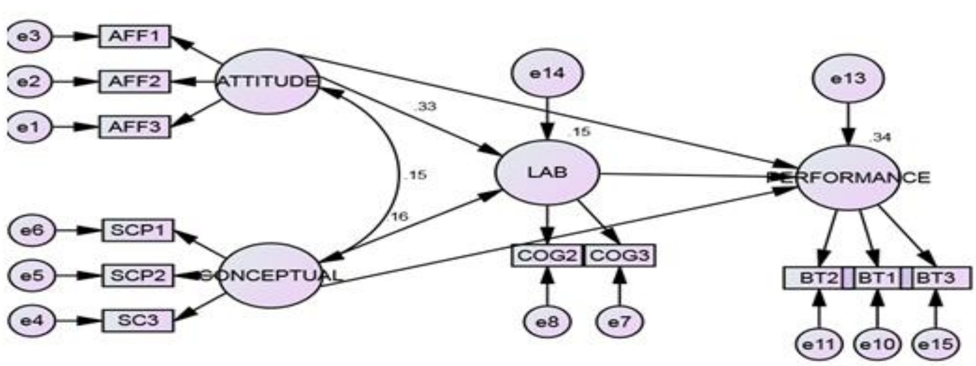
Table 3 Path Coefficient (Direct Effect) with Significant Effect

Path	Beta value	SE	*t*- value
Attitude→ Lab	.58	.17	3.28 **
Attitude → Achievement	.60	.08	2 .53*
Conceptual → Lab	.73	.12	3 .29**
Conceptual → Achievement	.54	.15	3.09 **
Lab → Achievement	.71	.13	2.58 *

***p* <.0.01

Table 3 shows the results of evaluating the first five hypotheses. According to Table 3, attitude has a substantial impact on laboratory work (β= 0.58; p<0.01) and achievement connected to conceptual knowledge acquisition (β= 0.54; p<0.01). It was also discovered that conceptual knowledge has a substantial impact on students' laboratory task acquisition (β= 0.73; p<0.01). Furthermore, attitude has a substantial impact on achievement (β= 0.60; p<0.01) and laboratory work has a significant impact on achievement (β= 0.71; p<0.01). As a result, all five hypotheses were confirmed, as illustrated in Figure 2.

Figure 2 Beta values and R-square values of path diagrams



Following the establishment of the structural model, the aforementioned model was examined to see if it fit the data. Several indices were created in order to assess the measurement model's fitness. The goodness-of-fit (GFI) is 0.938; the normed fit index (NFI) is 0.898; the comparative fit index (CFI) is 0.953; the Tucker Lewis Index (TLI) is 0.933; and the root mean square error of approximation (RMSEA) is 0.064. GFI, NFI, CFI, and TLI values of 0.9 and above, according to Hair (2009), indicate a well-fit model. In terms of RMSEA, a value of 0.03 to 0.08 is considered good. As a result of the foregoing observations, we can deduce that the measurement fitted the data well.

Discussion

The environmental literacy of pre-university students was modelled in this study who were students enrolled in a Malaysian Matriculation College. Apparently in the context of social science studies, planned behaviour theory recommended attitude and knowledge as determinants of general social behaviour (Shamuganathan & Karpudewan, 2016). Various education models have been presented, all of which are based on the notion of planned behaviour, which incorporates attitude and knowledge as two key components that influence achievement (Ajzen, 2011). Laboratory work with SWH was deemed a psychological area that explicitly affects performance, in addition to attitude and conceptual understanding (Rudd, 2001). As a result, chemistry performance of matriculation students has been modelled in the context of this study based on attitude, conceptual knowledge, and laboratory work using SWH.

Five hypotheses were established and tested using CB-SEM analyses based on the findings of the study. The results of the CB-SEM analysis demonstrate that all of the hypotheses tested were confirmed. The study demonstrated that in the context of the pre-university students in a Malaysian matriculation college, the students' attitude toward chemistry, laboratory work with SWH, and conceptual knowledge of chemistry all influence their chemistry achievement. There are no differences in attitudes toward chemistry, conceptual understanding, or laboratory work preference between boys and girls in terms of achievement, hence the same accomplishment model can be utilised for both genders. Similar outcome has been reported by in a study reported among college students' attitudes toward chemistry lessons (Heung, 2019). Despite the fact that there are no differences between boys and girls, girls are more likely than boys to have negative feelings about the difficulty of chemistry courses (Potvin & Hasni, 2014). It's likely that females' opinions are influenced by "social norms," or, to put it another way, societal preconceptions. The assumption that "boys are born to be scientists or chemists" is reflected in girls' perceptions of chemistry as difficult. Gender equity should be an aim of science education, given that the majority of books, films, television shows, and newspaper articles feature male scientists.

Other academics who conducted studies on students' attitudes about chemistry found the results to be disappointing. Students' attitudes about chemistry tended to be unfavourable to neutral, according to Kubiatko et al. (2017) and Salta and Tzougraki (2004). We hypothesised that students would have less positive views as a result of teacher-centered learning, a lack of inquisitive activities, and a focus on results rather than process. Other academics who conducted studies on students' attitudes about chemistry found the results to be disappointing (Chatterjee & Bhattacharjee, 2020). We hypothesised that children would have less positive views as a result of teacher-centered learning, a lack of inquisitive activities, and a focus on results rather than process.

Conclusion

The purpose of this research is to develop a model that explains the environmental literacy of pre-university students enrolled in a Malaysian matriculation institution. With an R^2 of 0.34, the achievement model produced from this study was deemed to have a relatively good model fit. The findings are also consistent with a study conducted in Turkey , which found that performance significantly predicts the relationships among endogenous variables (attitude, conceptual knowledge, laboratory work with SWH) demonstrated and regarded as a significant determinant of learning chemistry success and achievement (Potvin & Hasni ,2014) . This model appears to be consistent with other models developed in the United States based on the theory of planned behaviour, in which the model significantly predicts meaningful learning in chemistry using structural equation modelling and demonstrates these variables as significant determinants of chemistry achievement (Song & Zhou, 2021).

Recommendations and implication of the study

This study developed a model that describes matriculation students' accomplishment in Malaysia. In some ways, the development of this model addresses the lack of a tangible model that might be utilised to analyse the chemistry achievement of young high-achieving Malaysian students. However, the approach developed in this work has limitations in terms of universality. Because the models exclusively reflect high-achieving Malaysian students enrolled in matriculation colleges, they lack generalizability. The approach could only be used to the remaining 13 matriculation colleges in Malaysia's various states. Following that, more research is needed to validate the paradigm provided in this work. It is also proposed and encouraged that research or studies be conducted utilising this paradigm at the country's matriculation colleges and other pre-university level institutions in various contexts. The college might use the accomplishment model proposed in this study to assess to what extent the programme implemented enhanced students' conceptual understanding, attitude, and laboratory work based on SWH, resulting in improved achievement.

Significance and Contribution in Line with Philosophy of LSM Journal

This article contributes by illustrating vigorous Covariance-based Structural Equation Modeling (CB-SEM) approach to create a structural model for 'Science Writing Heuristic' (SWH) that best represents the relationships between attitude, conceptual knowledge, and laboratory work with SWH in Chemistry achievement. Exemplary SWH approach is also appended as reference for science learning.

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Appendix: Exemplary Science Writing Heuristic (SWH) (adapted from Hand et al., 2009)

	Student-centred Lab
Pre-laboratory discussions	a. Students write beginning questions (BQs). b. Together the class discusses which BQs to investigate. c. Students talk about how to divide the tasks among groups, and what data needs to be collected. d. Students prepare class data table on chalkboard
Student perform experimental work	a. Students perform lab work necessary to answer their own questions. b. Students talk with other group members and other lab groups about what they are finding.
Data Collection	a. Each group enters data in class data table on the chalkboard. b. Groups who have finished "their" part walk around the classroom to check with other groups to determine whether any other group needs help in completing their task or calculation.
Discussion	a. As soon as more than half of the data has been entered in the table, students begin to look for trends to answer their BQs. If data does not agree with an apparent trend, they may repeat their work. b. When all data is on the board, students critically evaluate the information. c. Students work together to negotiate meaning, construct a concept, answer BQs. d. Students write and discuss an appropriate claim and provide supporting evidence.