UNIVERSITI PUTRA MALAYSIA

MODELING RELATIONSHIPS OF MATRICULATION STUDENTS' AFFECTIVE AND COGNITIVE FACTORS AND ACHIEVEMENT IN ORGANIC CHEMISTRY

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By

AZRAAI BIN OTHMAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor Philosophy

November 2016

DEDICATIONS

To my beloved father, Allahyarham Hj. Othman Bin Hj. Mamat (May 25, 1949 – December 21, 2005), who always inspired and encouraging, I could not have completed this without you. I always love you and miss you.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfilment of the requirement for the degree of Doctor Philosophy

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Chairman : Othman Bin Talib, EdD
Faculty : Educational Studies

Modeling the learning of organic chemistry among matriculation students requires the integration of cognitive and affective factors and students' performance. The cognitive factors include spatial ability and prior conceptual knowledge, whereas affective factors involve student attitude and self-efficacy. This study reviews Novak's Model of Education that is relevant to the need for learning in organic chemistry. The literature reviews the importance of cognitive and affective factors that influence students' achievement in organic chemistry. This study explores the integration of cognitive and affective factors using Structural Equation Modeling (SEM) analysis. Models was developed and validated through the correlational relationships among factors using student responses regarding Attitude towards Organic Chemistry Questionnaire (ATOCQ), The Purdue Visualization of Rotations Test (ROT), Chemistry Conceptual Inventory (CCI), and Organic Chemistry Achievement Test (OCAT).

SEM, involving Confirmatory Factor Analysis, was used to analyse the data. Four types of fitness indexes, RMSEA, GFI, CFI, and Chisq/df, were used to evaluate the fit of all models. Analysis of data started with confirming the fit of the first-order measurement model of Affective Factors, containing the student's self-efficacy and attitudes construct. The analysis showed that all models fit the empirical data well, as indicated by the RMSEA value of less than 0.08, GFI and CFI values above 0.90 and Chisq/df value less than 5.0. This implies that the tools have validity in measuring each of the latent variables. The three models, namely the Proposed Model (Model 1) and Competing Models (Model 2 and Model 3), all achieved the fit indexes, with

Model 3 being the best representative model to show the relationship between these achievement-relevant variables.

The models were also tested on empirical data and described the direction and magnitude of the relationship between cognitive and affective factors on students' achievement well. Overall, the direct effect for model 3 (13.4%) was greater than for model 1 (12.2%) and model 2 (12.8%). Prior conceptual knowledge (8.4%) was the most important predictor for students' achievement in this study, followed by student's self-efficacy (4.5%) and spatial ability (0.7%). With regard to students' attitudes toward organic chemistry, there was no direct effect on their achievement. Indirect effects for cognitive factor and affective factor on students' achievement existed for model 2 and 3 only. For model 2, the indirect effects exist for the relationship between self-efficacy with student achievement where the attitude act as a mediator while for model 3, the indirect effects exist to the relationship between prior knowledge with student achievement where self-efficacy acts as a mediator. In conclusion, the findings of this study highlight the role of cognitive and affective factors on students' achievement in learning organic chemistry.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

MODEL HUBUNGAN ANTARA FAKTOR AFEKTIF DAN KOGNITIF DAN PENCAPAIAN PELAJAR MATRIKULASI DALAM KIMIA ORGANIK

Oleh

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Model pembelajaran kimia organik dikalangan pelajar matrikulasi memerlukan integrasi diantara kognitif, afektif, dan pencapaian pelajar. Faktor-faktor kognitif termasuk keupayaan spatial dan pengetahuan konsep terdahulu pelajar manakala faktor afektif melibatkan sikap pelajar dan efikasi kendiri. Kajian ini mengkaji Model Baru Pendidikan Novak yang berkaitan dengan keperluan pembelajaran dalam bidang kimia organik. Kajian literatur mengulas kepentingan faktor-faktor kognitif dan afektif yang mempengaruhi pencapaian pelajar dalam kimia organik. Kajian ini meneroka integrasi faktor kognitif dan afektif menggunakan analisis Model Persamaan Berstruktur (SEM). Model-model telah dibangunkan dan disahkan melalui hubungan korelasi antara faktor-faktor dengan menggunakan maklum balas daripada pelajar berdasarkan kepada Soal Selidik Sikap Terhadap Kimia Organik, Ujian Pemutaran Visualisasi Purdue, Inventori Konseptual Kimia, dan Ujian Pencapaian Kimia Organik.

SEM, dimana melibatkan Analisis Faktor Pengesahan telah digunakan untuk menganalisa data. Empat jenis indeks fit, RMSEA, GFI, CFI, dan Chisq/df telah digunakan untuk menilai nilai fit bagi kesemua model. Analisis data dimulakan dengan mengesahkan nilai fit untuk model pengukuran tahap pertama bagi Faktor Afektif yang mengandungi konstruk efikasi kendiri dan sikap pelajar. Analisis menunjukkan kesemua model fit dengan data empirikal dengan baik dimana nilai RMSEA adalah kurang daripada .08, nilai GFI dan CFI adalah lebih daripada .90 manakala nilai Chisq/df adalah kurang daripada 5.0. Ini menunjukkan bahawa instrumen mempunyai kesahan dalam mengukur setiap pembolehubah pendam. Tiga model telah diperkenalkan iaitu Model Cadangan (Model 1) dan Model Persaingan (Model 2 dan Model 3) telah mencapai indeks

fit dengan Model 3 merupakan model perwakilan terbaik yang menunjukkan hubungan antara pencapaian-pembolehubah berkaitan yang mana memberikan dapatan yang lebih baik.

Model-model juga diuji berdasarkan data empirikal dan menerangkan dengan baik tentang arah dan magnitud hubungan antara faktor kognitif dan afektif dengan pencapaian pelajar. Secara keseluruhan, jumlah kesan langsung bagi model 3 (13.4%) adalah lebih besar berbanding model 1 (12.2%) dan model 2 (12.8%). Pengetahuan konsep terdahulu (8.4%) adalah peramal terpenting bagi pencapaian pelajar dalam kajian ini dan disusuli dengan efikasi kendiri pelajar (4.5%) dan keupayaan spatial (0.7%). Untuk sikap pelajar terhadap kimia organik, tidak terdapat kesan langsung kepada pencapaian pelajar. Kesan tidak langsung bagi faktor kognitif dan faktor afektif kepada pencapaian pelajar wujud untuk model 2 dan 3 sahaja. Untuk model 2, kesan tidak langsung wujud untuk hubungan antara efikasi kendiri dengan pencapaian pelajar dimana sikap berperanan sebagai mediator manakala untuk model 3, kesan tidak langsung wujud untuk hubungan antara pengetahuan konsep terdahulu dengan pencapaian pelajar dimana efikasi kendiri berperanan sebagai mediator. Sebagai rumusan, dapatan daripada kajian ini mengutamakan peranan Faktor Kognitif dan Afektif terhadap Pencapaian Pelajar.

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I certify that a Thesis Examination Committee has met on 16 November 2016 to conduct the final examination of Azraai Bin Othman on his thesis entitled "Modeling Relationships of Matriculation Students' Affective and Cognitive Factors and Achievement in Organic Chemistry" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Degree of Doctor Philosophy.

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LIST OF ABBREVIATIONS

ACS	American Chemical Society
AGFI	Adjusted Goodness of Fit Index
AMOS	Analysis of Moment Structure
ASCIv2	Attitude toward the Subject of Chemistry Inventory version 2
ATOCQ	Attitude Towards Organic Chemistry Questionnaire
AVE	Average Variance Extracted
BMKPM	Bahagian Matrikulasi Kementerian Pelajaran Malaysia (Matriculation Division, Ministry of Education)
BPPDP	Bahagian Penyelidikan dan Perancangan Dasar Pendidikan (Division of Research and Planning Education Policy
CAEQ	The Chemistry Attitudes and Experiences Questionnaire
CCI	Chemistry Conceptual Inventory
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CR	Composite Reliability
DV	Dependent Variable
GFI	Goodness of Fit Index
IV	Independent Variable
KBSR	Kurikulum Baru Sekolah Rendah (New Curriculum for Primary Schools)
KBSM	Kurikulum Bersepadu Sekolah Menengah (Integrated Curriculum for Secondary Schools)
KSSR	Kurikulum Standard Sekolah Rendah (Standard Curriculum for Primary Schools)
KSSM	Kurikulum Standard Sekolah Menengah (Standard Curriculum for Secondary Schools)
M	Mediator
MI	Modification Indices
MOE	Malaysian Ministry of Education
NFI	Normed Fit Index
OECD	Economic Co-operation and Development

OCAT	Organic Chemistry Achievement Test
PISA	Programme for International Student Assessment
RMSEA	Root Mean Square of Error Approximation
ROT	Purdue Visualization of Rotations Test
SEM	Structural Equation Modeling
TFI	Tucker-Lewis Index
TIMMS	The Trends in International Mathematics and Science Study
TMI	Targeted Misconception Inventory
VSEPR	Valence Shell Electron Pair Repulsion

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CHAPTER 1

INTRODUCTION

1.1 Preamble

According to the TIMMS (Trends in International Mathematics and Science Study) report in 2007 and PISA (Programme for International Student Assessment) report in 2009, Malaysian students' performance, especially in science, is below the minimum level of requirement. Indeed, 43% of students' performance in science was below the minimum level of requirement in the TIMSS test, whereas 20% of students did not manage to achieve the minimum requirement set in the PISA test. For the minimum level in PISA, students should demonstrate an understanding of the basic science concepts without the application of this scientific knowledge in their daily lives. It was clear that the limited scientific knowledge of students is only applied to a certain number of common situations. Consequently, the students will only manage to provide explicit evidence-based scientific explanation, but will tend to struggle to form conclusions or interpret simple investigations (MOE, 2012b).

TIMMS is a series of international assessments of mathematics and science knowledge of students around the world. It focuses on providing the same elements in the curriculum for participating countries (Martin, Mullis, Foy, & Stanco, 2012). PISA is a worldwide study conducted by the Organisation for Economic Co-operation and Development (OECD) among member and non-member nations of 15-year-old school students based on their scholastic performance in mathematics, science, and reading (OECD, 2016). PISA focuses on the assessment of applications for real-world issues, regardless of the curriculum of the participating countries. Hence, TIMMS and PISA are used as benchmarks for the level or quality of science education in the participating countries (MOE, 2012b).

Besides reporting on students' performance, findings from the TIMMS report in 2007 and PISA in 2009 also indicated that the existing science education in Malaysia is incapable of developing human capital that is highly and globally competitive. The Ministry of Education (MOE) in Malaysia has since introduced the Standard Curriculum for Primary Schools or *Kurikulum Standard Sekolah Rendah* (KSSR) in 2011 to improve the existing curriculum, in order to achieve and maintain this on-going national objective.

1.2 Background of Study

Currently, the Malaysian Education System is comprised of six-year primary education (Standards One to Six), five-year secondary education which consists of three years of lower secondary (Forms One to Three) and two years of upper secondary (Forms Four to Five), and another one or two years of pre-university education (Matriculation or Form Six), followed by a three to five year college or university undergraduate programme. Table 1 shows the mandatory age and study period for all students in Malaysia.

Table 1: The mandatory age and study period in the Malaysian Education System

Level / Grade	Age	Period (years)
Kindergarten	4 – 6	3
Primary School (Standard 1 – 6)	7 – 12	6
Secondary School (Form 1 – 5)	13 – 17	5
Pre-University (Form 6 and Matriculation)	18 – 19	2
University (Undergraduate)	20 – 24	4 – 5

Science education at secondary school level in Malaysia has gone through rapid changes since independence. Commencing with the traditional science curriculum, also known as Secondary Schools Old Curriculum *(Kurikulum Lama Sekolah Menengah)*, the Ministry of Education implemented the Modern Chemistry Curriculum in 1973. In 1989, the Modern Chemistry Curriculum was replaced with the Integrated Curriculum for Secondary Schools *(Kurikulum Bersepadu Sekolah Menengah or KBSM)* and was revised in 2002. The changes in these implemented curriculums have indirectly suggested some approaches which are capable of improving students' understanding in line with the National Education Philosophy and Philosophy of the National Science Education (MOE, 2010). In 2011, the government launched the Standard Curriculum for Primary Schools *(Kurikulum Standard Sekolah Rendah or KSSR)* which was implemented in stages and its effects can be seen in 2017, whereas the Standard Curriculum for Secondary Schools *(Kurikulum Standard Sekolah Menengah, KSSM)* will be implemented in all secondary schools in Malaysia (MOE, 2012b).

In Malaysia, the transition phase for some students between the secondary and tertiary education level is through a matriculation programme, under the jurisdiction of the Matriculation Division established by the MOE. The matriculation curriculum is designed in accordance with the integrated concept of Matriculation Programme and the National Education Policy, whereby qualified students are chosen based on merit (academic and extra-curricular) from their results obtained in the Malaysia Certificate of Education *(Sijil Pelajaran Malaysia or SPM)*. The matriculation programme is a preparatory programme for students to pursue higher education in Malaysian institutions and overseas in the fields of science, technology and accounting. Thus, this curriculum indirectly serves as a bridge for students to make good use of the knowledge they have learnt in their first-year university curriculum for their respective course or field of study.

Chemistry is a compulsory and core subject for all students of the matriculation programme who specialise in science and technical fields. The chemistry curriculum for the matriculation program, which includes 50% of organic chemical components, is designed to provide students with the knowledge of chemistry in preparation for courses related to science and technology at the undergraduate level in institutions of higher learning and overseas (MOE, 2012a).

Organic chemistry is a major component of the chemistry curriculum, which must be learnt by students whose majors are science subjects. Students learn organic chemistry during the second semester in the matriculation programme and the topics cover almost all aspects of the basic organic chemicals, including introduction to organic chemistry, hydrocarbons, benzene compounds and their derivatives, haloalkane, hydroxy compounds, carbonyl compounds, carboxylic acids and their derivatives, amines, amino acids and polymer compounds (MOE, 2012a).

The rationale of designing an organic chemistry curriculum in the matriculation programme is to strengthen and broaden the knowledge of students pertaining to organic chemistry, as well as take their existing knowledge regarding chemistry in secondary level into account. Consequently, this organic chemistry curriculum not only provides students with knowledge of chemistry in preparation for their first-degree level study, but also indirectly serves as a means to help them pursue careers in science and technology.

As mentioned earlier in the preamble, 20% of Malaysian students failed to achieve the minimum standard in science and mathematics as measured in PISA 2009 (MOE, 2012b). The percentage of students failing to achieve the minimum standard in science and mathematics continued to decline in 2011, with students' scores decreasing by 6.3% (Martin, Mullis, Foy & Stanco, 2012). This is unacceptable and indirectly portrays the ineffectiveness of education provided in the Malaysian classrooms to improve students' performance (Osman & Sukor, 2013).

Osman and Sukor (2013) claim that the major problem causing the decline in students' performance is the complicated teaching and learning methods used by teachers, which have resulted in students' perception of science as a difficult subject to learn. Science, including organic chemistry, has always been considered difficult for students to learn and for teachers to deliver (Johnstone, 1991; Krapp & Prenzel, 2011; Lim, 2007; Ng, Lay, & Areepattamannil, 2012). For instance, Ng *et al*. (2012) stressed that the perception that science is difficult is due to the influence of varying emotions and predispositions of the students themselves when learning science.

Specifically in science education, organic chemistry has been identified as a difficult subject by many students (Grove & Bretz, 2012). Grove and Bretz (2012) found that this is due to the use of abstract explanations of chemical phenomena. Students find organic chemistry difficult because it requires three-dimensional thinking, especially for organic chemistry reactions (Talanquer, 2011). The nature of chemistry itself makes it a difficult subject to teach, learn and understand, as the abstract chemical concepts require multi-level thinking skills. Johnstone (1991) introduced the 'Triangle of Chemistry' which contains macroscopic, sub-microscopic and symbolic levels of thinking in organic chemistry, representing the three-dimensional multi-level of thinking in organic chemistry.

In addition, there are certain areas or topics in organic compounds which have been reported and identified by both teachers and students as difficult to teach and learn, namely Structural Formulae, Functional Groups, Characteristics of Organic Compounds and Organic Reactions (types and mechanisms) (O' Dwyer & Childs, 2011). Once again, the three-dimensional multi-level of thinking plays an important role during in depth discussions on all these topics, especially in discussions about organic chemistry reactions. This is because organic chemistry reactions not only involve the structure of the compound, but also electron movement which is essential for the reaction to take place.

Nevertheless, previous studies have showed that there are factors that affect students' achievement in organic chemistry. Xu, Villafane, and Lewis (2013) reported that prior conceptual knowledge and attitudes had a positive impact on first year students' achievement in the US. Attitudes also significantly impacted on fourth year Indonesian public secondary school students (17 years old) (Kususanto, Fui, & Lan, 2012). Furthermore, other factors like student's self-efficacy (Merchant *et al*., 2012; Villafañe, Garcia, & Lewis, 2014) and spatial ability (Danili & Reid, 2010; Taber & García-Franco, 2010) are the important aspects that influence the achievement of students in organic chemistry. In Malaysia, a case study was carried out in first year organic chemistry undergraduate students undertaking basic organic chemistry, finding that students' cognitive ability influenced their achievement (S. Kan, Cha, & Chia, 2015).

To improve students' learning performance in chemistry, teachers should perceive teaching of chemistry in three different and inter-related ways, such as experiences, models and visualizations (Talanquer, 2011). Although chemistry is often considered as a difficult subject to learn, teaching and learning of chemistry at a higher level is undeniably necessary and highly demanding. This is due to the nature of chemistry itself as central to science and consequently, an adequate knowledge of chemistry is essential for learning other natural sciences such as biology, physics, geology and ecology (Chang, 2010). In addition, knowledge of chemistry is significant to prepare students for higher level of education and pursue careers related to science and technology. In this case, especially for learning of organic chemistry, this study or course deals with all aspects of the chemistry in carbon compounds, which are the building blocks for all living organisms. Organic chemistry is not only vibrant and diverse, but it is also complex and vast with lots of areas to cover. It is important to learn organic chemistry as a part of chemistry education to identify and find ways to overcome the difficulties experienced by students when learning organic chemistry.

1.3 Problem Statement

Learning organic chemistry involves learning organic molecular structure, electron movement and chemical reaction (Flynn & Ogilvie, 2015), therefore, students need to develop high visual-spatial ability for abstract organic chemistry concepts (Talanquer, 2011; Wu & Shah, 2004). The main difficulty in learning organic chemistry is students' lack of three-dimensional thinking skills or visualisation ability, which can help them to understand the concepts of organic chemistry (Domin, Al-Masum, & Mensah, 2008; Ellis, 1994; Merchant *et al*., 2012).

Anderson and Bodner (2008) conducted a case study of 7 students undertaking an organic chemistry course in Purdue University. Interviews were conducted and the questions covered students' understanding of organic chemistry concepts, discussing student's ideas about course concepts, as well as related topics such as their difficulties and strategies for learning organic chemistry. In this qualitative study, Anderson and Bodner found that students experienced difficulties in understanding the underlying organic chemistry concepts, especially in explaining the mechanism reactions; students were unable to visualise the arrangement of the molecules and electron movement involved in mechanism reactions.

Kan *et al.* (2015) also found that students faced difficulties in understanding the concepts in organic chemistry if they do not have three-dimensional thinking. In their study of first year undergraduate students undertaking basic organic chemistry in Universiti Malaysia Terengganu, they found that to achieve a deeper understanding of organic chemistry, students require a thorough conceptual understanding rather than simply memorising the facts. If students only memorise the concepts of organic chemistry reaction without having any understanding of the concepts, learning organic chemistry becomes more difficult, resulting in a high affective filter which includes high anxiety, low self-confidence and low motivation within students (Grove & Bretz, 2012; Mayer, 2002).

Students' understanding is usually measured by their performance or achievement in formal examination (Brandriet, Ward, & Bretz, 2013; Xu *et al.*, 2013) or conceptual test (Merchant *et al*., 2013; Potgieter & Davidowitz, 2011). There are many variables contributing to students' achievement such as prior knowledge (Bayrak, 2013; Hailikari & Nevgi, 2010; Rushton, Hardy, Gwaltney, & Lewis, 2008; Xu et al., 2013), spatial ability (Bodner & Guay, 1997; Hegarty, Stieff, & Dixon, 2013; Merchant *et al*., 2013), attitude (Coll, Dalgety, & Salter, 2002; Giallousi, Gialamas, & Pavlatou, 2013; Heredia & Lewis, 2012; A. Kan & Ş, 2006; Lang, Wong, & Fraser, 2005; Xu *et al*., 2013) and self-efficacy (Kan & Ş, 2006; Merchant *et al*., 2012; Villafañe *et al*., 2014). However, these variables of prior knowledge, spatial ability, attitude and self-efficacy are often examined separately to determine their impact on student's achievement in organic chemistry. There is a lack of studies that examine the integration of all these variables in organic chemistry.

In the research of chemistry education, it is believed that the integration between variables has more impact on student achievement (Kim & Song, 2010; Stamovlasis, Tsitsipis, & Papageorgiou, 2012). Several learning models in predicting students' achievement in organic chemistry have been developed. For example, Merchant *et al*. (2012) investigated the relationships between the variables of spatial ability, self-efficacy and chemistry on the learning achievement of college chemistry students. In another study, Xu *et al.,* (2013) reported that mathematical ability, conceptual knowledge and attitude towards chemistry. Many learning models related to science and chemistry that can help to predict student achievement have been proposed. However, only a few studies lead to the integration of cognitive (prior knowledge and spatial ability), affective (attitudes and self-efficacy) and student achievement in learning organic chemistry as proposed in Novak's New Model of Education (Brandriet *et al.*, 2013). Furthermore, if the research findings are to be applied to the Malaysian context, none of these studies reported on the modeling of the relationship of students' affective and cognitive factors and achievement in organic chemistry at pre-university level. In addition, this study introduces prior knowledge, spatial ability, attitudes and self-efficacy as variables which are closely related to cognitive and affective factors, as well as mediator variables that can impact on students' achievement.

1.4 Objective

The objectives of this study are:

1.4.1 to test model fits data of hypothesised model based on the relationship between cognitive factors, affective factors and students' achievement in organic chemistry.
1.4.2 to determine the direct effect of cognitive and affective factors on students' achievement in organic chemistry.
1.4.3 to determine the mediating effect for students' achievement in organic chemistry in the relationship between cognitive and affective factors.

1.5 Research Question

This study aims to answer the following research questions

1.5.1 Does the hypothesised model, based on the relationship between cognitive factors, affective factors and students' achievement in organic chemistry, fit the sample data?
1.5.2 What are the significant direct effects of cognitive and affective factors on students' achievement in organic chemistry?
1.5.3 Are there significant direct effects of cognitive factors on students' achievement in organic chemistry?
1.5.4 Are there significant direct effects of affective factors on students' achievement in organic chemistry?
1.5.5 What are the significant mediators for students' achievement in organic chemistry in the relationship between cognitive and affective factors?

1.6 Hypotheses

Hypotheses were constructed based on the findings from the previous research as follows:

H_1: Spatial ability has a direct and significant effect on student achievement.
H_2: Prior knowledge has a direct and significant effect on student achievement.
H_3: Self-efficacy has a direct and significant effect on student achievement.
H_4: Attitudes have a direct and significant effect on student achievement.
H_5: Prior knowledge mediates the relationship between spatial ability and student achievement.
H_6: Self-efficacy mediates the relationship between attitudes and student achievement.

1.7 Conceptual Framework

Based on the theoretical framework discussed in Chapter 2, the five variables of spatial ability, prior knowledge, attitudes, self-efficacy and student achievement were combined to model the relationship of students' affective and cognitive factors and achievement in organic chemistry as shown in Figure 1. The spatial ability, prior knowledge, attitudes and self-efficacy are independent variables, while the student's achievement is the dependent variable. Each variable is measured by tools developed as detailed in Chapter 3. In particular, modeling the relationship of students' affective and cognitive factors and achievement in organic chemistry enables all the objectives to be achieved, providing answers to the research questions. In addition, the relationship between spatial ability, prior knowledge, attitudes, self-efficacy and student's achievement will be tested to determine whether the model fits the data and at the same time, the direct effects, indirect effects and the overall effect of the independent variable can also be determined. Mediating variables for this study can also be identified through indirect effects.

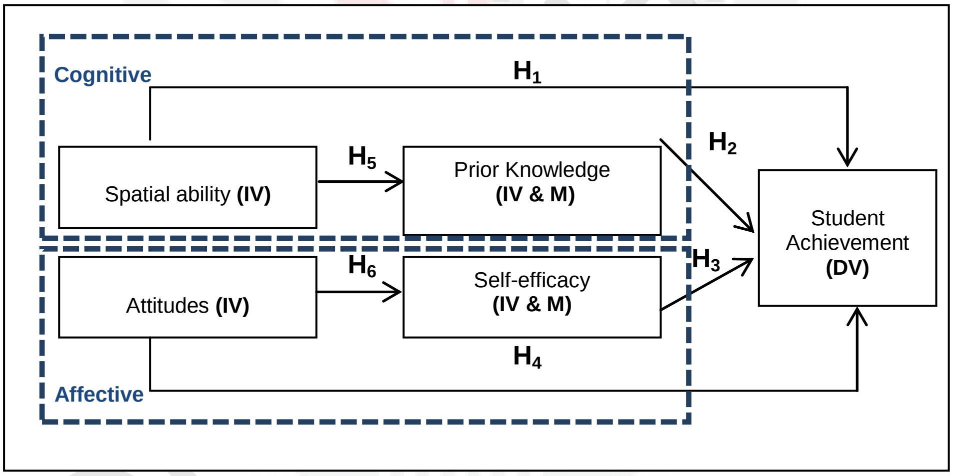

Figure 1: Conceptual framework modeling the relationship between students' affective and cognitive factors and achievement in organic chemistry.

1.8 Limitations of Study

This study involves matriculation students from the Year One Science Matriculation Programme since chemistry is offered as one of the subjects in this programme. The students are from the May 2014/15 intake, placed in the matriculation colleges of peninsular Malaysia (Negeri Sembilan Matriculation College, Kelantan Matriculation College and Johor Matriculation College).

The study is valid for the target population; however, it can only be generalised to different locations and populations if the characteristics of the respondents and sampling methods are similar to studied samples. The major reason for the selected the Year One Science Matriculation Programme was that students in any matriculation colleges around Malaysia have similar academic performance when they enrol in the matriculation programme.

1.9 Significance of Study

In this study, there are three main contributions to the body of knowledge including theoretical, methodological and practical aspects of chemistry education research. Regarding the theoretical aspect, this study explains Novak's New Model of Education, where Novak (2010) relates the relationship between cognitive (thinking), affective (feeling) and students' achievement (performance) domains. These three domains are not only part of the learning experience, but there must also be an active integrated. Successful education must focus on more than the student's cognitive ability, student's affective factors and achievement are also important.

With regard to the methodology, this study also contributes a new teaching and learning model in organic chemistry. Figure 2 indicates the model of the relationship of students' affective (attitudes and self-efficacy) and cognitive (spatial ability and prior knowledge) factors and achievement in organic chemistry. This model is not only useful as a basis and guide for the design of learning outcomes of organic chemistry, but also encourages positive attitudes, which in turn stimulates their achievement in learning.

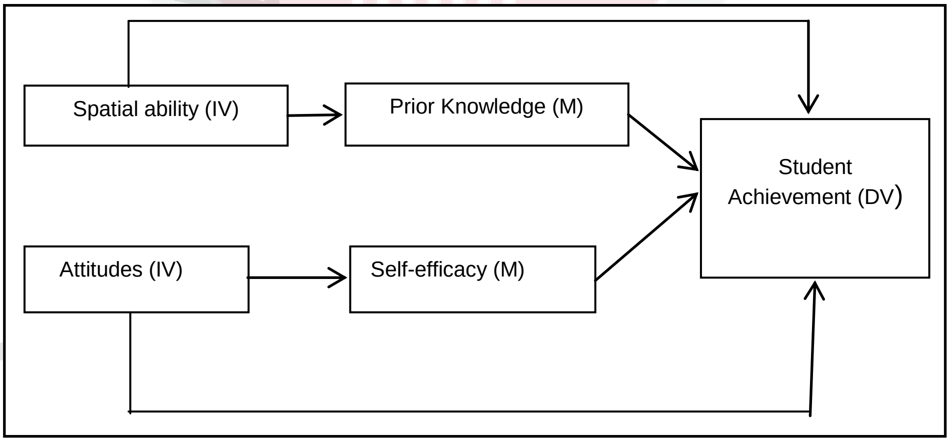

Figure 2: Proposed model for relationship of students' affective and cognitive factors and achievement in organic chemistry.

Furthermore, this study also introduces the prediction model for student achievement in organic chemistry. Three types of prediction models have been developed, namely the Learning Model, Cognitive Model and Affective Model of Students' Achievement in Organic Chemistry.

Figure 3 indicates the first prediction of the learning model of student achievement in organic chemistry. This prediction model consists of cognitive factors (spatial ability and prior knowledge) and affective factors (attitudes and self-efficacy) in relation to student achievement. This model will be used to analyse the causal effects of cognitive and affective factors on student achievement.

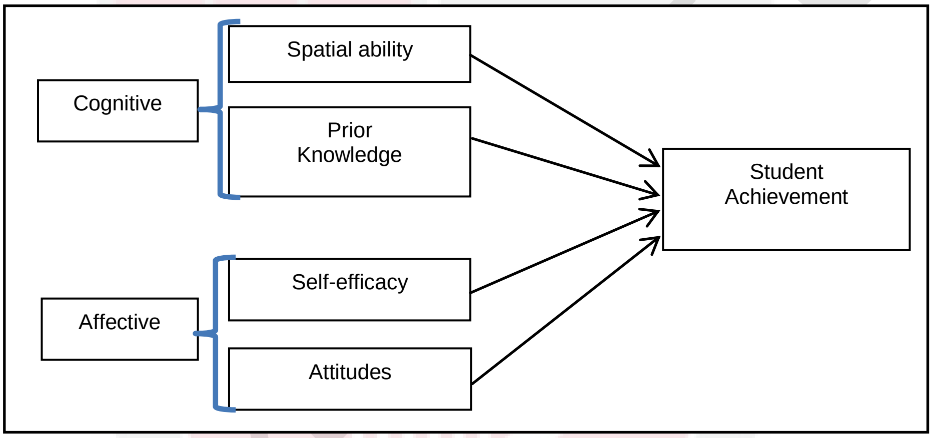

Figure 3: Learning model of students' achievement in organic chemistry.

Figure 4 shows the second prediction of the cognitive learning model in organic chemistry. This prediction model consists of the relationships between cognitive factors (spatial ability and prior knowledge) and student achievement. This model is used to analyse the causal effects of cognitive factors on student's achievement.

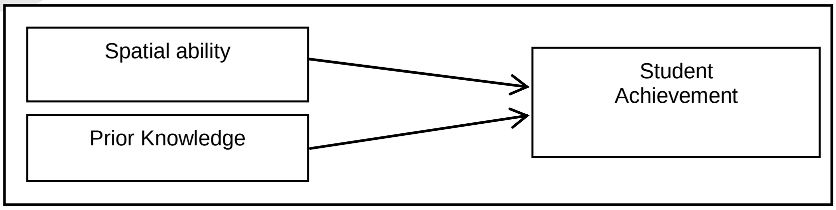

Figure 4: Cognitive learning model in organic chemistry

Figure 5 shows the third prediction of the affective learning model in organic chemistry. This prediction model consists of the relationships between affective factors (self-efficacy and attitudes) and student achievement. This model is used to analyse the impacts of affective factors on student achievement.

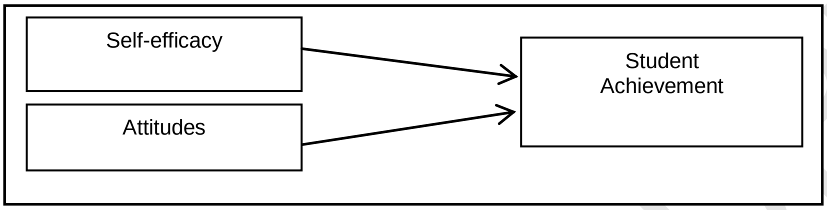

Figure 5: Affective learning model in organic chemistry

In addition, there are two additional models consisting of a mediator variable as shown in Figures 6 and 7. The mediator is added in these two models to determine the indirect effects between IV to DV.

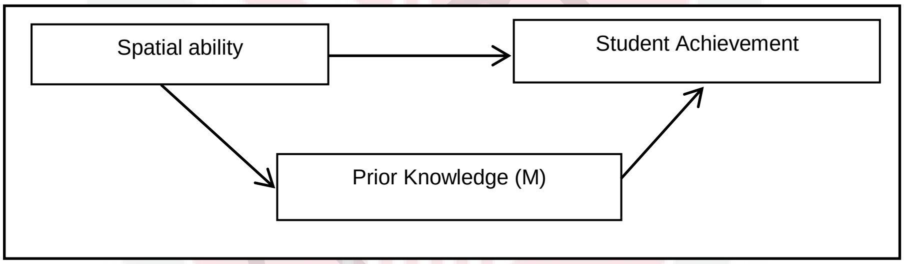

Figure 6: Cognitive learning model in organic chemistry (mediator)

Figure 6 shows the cognitive learning model in organic chemistry with the presence of prior knowledge as a mediator. This prediction model is used to determine whether the mediation effects are complete mediation, partial mediation or non-mediation. The direct effect is the effect from spatial ability which links directly to student achievement, while the indirect effect is the effect from spatial ability that links indirectly to student achievement through prior knowledge.

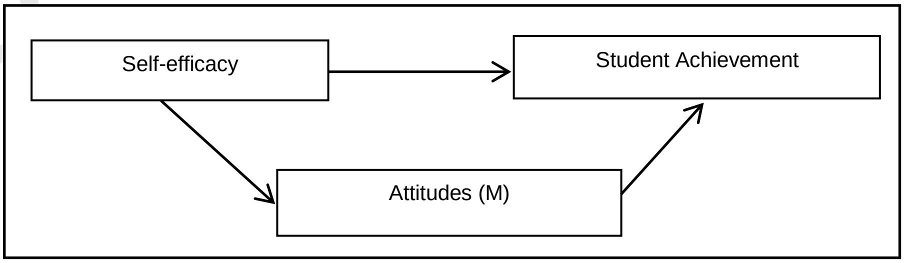

Figure 7: Affective learning model in organic chemistry (mediator)

Figure 7 indicates the affective learning model in organic chemistry with the presence of attitudes as a mediator. This prediction model is used to see whether the mediation effects are complete mediation, partial mediation or non-mediation. The direct effect is the effect from self-efficacy that links directly to student achievement, while the indirect effect is the effect self-efficacy that links indirectly to student achievement through attitudes.

In terms of the practical aspect, this study provides a perspective relating to student learning in organic chemistry, based on the relationship between the cognitive and affective factors with the students' achievement. Research on the cognitive and affective factors with the students' achievement relationship has predominantly focused upon students' difficulties learning organic chemistry (Childs & Hanly, 2011; Chittleborough & Treagust, 2007; Grove & Bretz, 2012; Kim Chwee, Mocerino, Treagust, & Chandrasegaran, 2012; O' Dwyer & Childs, 2011; Sirhan, 2007). This research study contributes to understanding how the relationship between prior knowledge and spatial ability (cognitive factors) and attitudes and self-efficacy towards learning organic chemistry (affective factors) has an impact on students' achievement.

1.10 Operational Definition

1.10.1 Cognitive Factor

Cognitive factors are related to the individual thinking system. In this study, there are two factors which are related to student's cognitive ability, namely student's spatial ability and prior conceptual knowledge.

1.10.2 Affective Factor

Affective factors are non-cognitive factors involving the behavioural tendency of an individual to act towards something, such as learning achievement. In this study, affective factors consist of students' attitudes towards learning organic chemistry and their self-efficacy in learning organic chemistry.

1.10.3 Spatial ability

Researchers have perceived spatial ability as a complex and multifaceted skill. From previous findings, most researchers consider only two major components in spatial ability, spatial relation and spatial orientation (Merchant *et al*., 2013). The main difficulty in learning organic chemistry is because students lack three-dimensional thinking skills (visualisation ability), which can help them to understand the concepts of organic chemistry (Ellis, 1994). Bodner and Guay (1997) stated that spatial ability of students in learning chemistry are interrelated to their visualisation ability that can aid in the interpretation of scientific phenomenon in chemistry. In this study, spatial ability refers to the visualisation skills of students in understanding the topics in organic chemistry. Spatial ability is measured using the Purdue Visualization of Rotation Test (ROT) developed by George M. Bodner and Roland B. Guay in 1997.

1.10.4 Prior conceptual knowledge

The fundamental idea in meaningful learning is that learning takes place through the assimilation of new concepts and propositions into existing concepts (prior conceptual knowledge) as well as propositional frameworks held by the learner (Ausubel, 1963). Based on the statement above, it is clear that students develop their own conceptual understanding through the process of assimilation between new concepts and their previous knowledge. In this study, prior conceptual knowledge is defined as existing knowledge in the student's cognitive system that is related to the learning of organic chemistry. Prior conceptual knowledge is measured using the Chemistry Conceptual Inventory (CCI), a two-tier multiple-choice instrument designed to identify students' difficulty or incorrect ideas regarding the basic concepts in chemistry, especially in chemical bonding.

1.10.5 Student self-efficacy

According to Albert Bandura (1986) in his book '*Social foundations of thought and action: A social cognitive theory*', self-efficacy is defined as one's perception of his/her own ability to perform a specific task with a certain level of proficiency. This construction is relevant to student learning because if a student feels that he or she is incapable of tasks which are necessary in learning a subject, he or she will try to avoid those tasks. In this study, student's self-efficacy can be related to the student's own perception of their own ability to perform a specific task with a certain level of confidence, especially when it comes into accomplishing a task in organic chemistry experiment and assignment. Student's self-efficacy is measured using the Attitude towards Organic Chemistry Questionnaire (ATOCQ), which consists of two constructs, namely student's self-efficacy (14 items) and attitude towards chemistry (7 items). ATOCQ was adapted from The Chemistry Attitudes and Experiences Questionnaire (CAEQ) (Dalgety, Coll, & Jones, 2003) and Attitude towards the Subject of Chemistry Inventory version 2 (ASCIv2) (Xu *et al*., 2013).

1.10.6 Students' attitudes towards chemistry

In the Theory of Planned Behaviour, Ajzen (1991) stated that attitude towards behaviour is combined with normative beliefs (beliefs about the normative expectations of others) and control beliefs (beliefs about the factors which control the performance of the behaviour) that will eventually produce an intention known as the antecedent of behaviour. In relation to this theory above, attitude towards chemistry can be best described as what students think and how students feel about chemistry as a discipline to be learned (Bauer, 2008). The students' positive attitude in learning is important to stimulate their achievement in the classroom. In this context, students' attitudes towards chemistry can thus be defined as why they think and feel about organic chemistry as a subject to learn and is measured using ATOCQ.

1.10.7 Student achievement

Examination scores are often used to measure student achievement in the general chemistry course. In the United States of America, course grade can be a relevant criterion to investigate student progress towards eventual careers in chemistry. More general measurement tools, especially national exams such as the chemistry exams prepared by the Examinations Institute of the American Chemical Society's (ACS) Division of Chemical Education, can be used as an alternative to measure student achievement (Xu *et al*., 2013). In the Malaysian matriculation programme, student achievement is usually measured by a final exam, the Matriculation Programme Semester Examination. Students are graded based on their performance in this exam; however, in this study, student achievement will be measured based on their scores from the Organic Chemistry Achievement Test (OCAT), a two-tier multiple choice instrument consisting of 30 multiple choice questions designed to measure student's achievement of organic chemistry at matriculation level.

1.10.8 Year One Science Matriculation Programme

Year One Matriculation programme involves the study of science stream (Module I, Module II or Module III) for one year (two semesters) and the students are placed in the nationwide matriculation colleges.

1.10.9 Matriculation Students

Students from the Year One Science Matriculation Programme can choose to follow either Matriculation Programme Science Module I, II or III and are placed in matriculation colleges throughout the country.

1.10.10 Structural Equation Modeling (SEM)

SEM is a second generation multivariate statistical analysis developed to analyse the inter-relationships among multiple variables in a model simultaneously. In addition, it can be used to perform the function of statistical techniques such as confirmatory factor analysis (CFA), the causal modeling between latent variables, analysis of variance and multiple linear regression (Byrne, 2001).

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