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MAKING SENSE OF STUDENTS' ATTITUDE TOWARDS COLLEGE GENERAL CHEMISTRY: A PARTIAL LEAST SQUARES STRUCTURAL EQUATION MODELING (PLS-SEM) APPROACH

Denson Liday

Quirino State University (Philippines)

densonmarianoliday@gmail.com

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Abstract

Understanding students' attitudes towards college general chemistry is crucial for improving chemistry education and enhancing students' learning experiences. This study aimed to investigate students' attitudes towards college general chemistry and their impact on academic performance. PLS-SEM approach was conducted by assessing both the measurement and structural model components (3 dimensions, 8 constructs, and 27 hypotheses. Descriptive results unveiled an overall negative attitude (μ=2.62), linked to factors like perceived difficulty, relevance, past experiences, societal influences, and learning style variations. To address this challenge, recommendations were made, advocating improved teaching methods, supportive learning environments, bias awareness, personalized instruction, and positive chemistry experiences. Inferential statistics identified distinct negative attitudes within constructs, with Interest and Utility displaying the highest negativity (μ=2.853). These findings underscore the importance of engaging teaching strategies and highlighting the practical applications of chemistry to boost student attitudes and engagement. Additionally, profile variables like the SHS strand and academic standing significantly influenced attitude constructs, indicating the need for tailored instructional approaches and support for students from diverse backgrounds. Structural Equation Modeling (SEM) exposed direct links among attitude constructs, emphasizing the role of interest, perceived usefulness, and emotional satisfaction in shaping student attitudes and engagement. In addition, 11 hypotheses from the 3 dimensions of 8 constructs have a positive and significant effect. Notably, SEM showed that emotional satisfaction (p value=<.001) and anxiety (p value=<.001) directly impact general chemistry academic performance. Therefore, creating a positive, supportive learning environment and addressing anxiety through stress management techniques are vital for improved academic outcomes.

Keywords – Attitude, College general chemistry, PLS-SEM.

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1. Introduction

Fostering positive attitudes toward science is essential in science education, as it enhances student engagement, confidence, and interest while reducing anxiety, ultimately supporting better learning outcomes (Riegle-Crumb, Morton, Moore, Chimonidou, Labrake & Kopp, 2023).. Attitude toward science encompasses an individual's mental and emotional predispositions, including beliefs and feelings, which influence their engagement with science-related subjects and activities (Wicaksono & Korom, 2023). Students' attitudes toward learning science are shaped by factors such as content complexity, abstract concepts, and the effectiveness of teaching methods, as shown in recent studies from secondary schools in Uganda (Namayanja, 2024).Undergraduate students are expected to acquire a comprehensive knowledge of subject-specific content, and the effective delivery and evaluation of this content knowledge are facilitated through a wide range of teaching and learning strategies and approaches. However, the assessment of students' attitudes towards this content is often overlooked, despite the potential correlation between a positive attitude and higher academic achievement (Xu, Southam & Lewis, 2012). Assessing attitudes toward chemistry in undergraduate programs is essential, as recent findings show these attitudes significantly predict students' academic performance and can guide more effective instructional strategies (Abdullahi & Mohamed, 2025).Attitudes towards chemistry encompass students' inclination to react to chemistry based on the perspectives and perceptions they form through their learning experiences (Kahveci, 2015). Understanding students' attitudes towards college general chemistry is crucial for improving chemistry education and enhancing students' learning experiences. Students' attitudes towards science significantly influence their engagement, motivation, and achievement, with positive attitudes leading to higher academic performance in science subjects (İnce, 2023).Therefore, exploring and modeling the factors that contribute to students' attitudes towards general chemistry can provide valuable insights for educators, curriculum developers, and policymakers.

This research study aimed to make sense on results obtained from descriptive and inferential statistics and the partial least squares-structural equation model (PLS-SEM) and evaluation. PLS-SEM is a statistical modeling technique that allows for the exploration of complex relationships among latent variables, making it well-suited for investigating multidimensional constructs such as attitudes and other related constructs (Scharf & Maydeu-Olivares, 2019). The statistical tests used aimed to describe students' attitudes and determine factors/determinants affecting the college general chemistry academic performance of the students and evaluate inter-relationships of critical variables based from the objectives of the study. By examining these factors, the research aimed to gain a comprehensive understanding of the key influences on students' attitudes in the context of general chemistry education (Yaseen & Hattab, 2016). Understanding the relationships among these factors can inform the development of effective strategies to enhance students' attitudes and engagement in general chemistry education. Additionally, the application of PLS-SEM in this research adds to the methodological advancements in educational research, demonstrating the utility of this approach for investigating complex constructs in the context of chemistry education (Wouters, Van den Bosch & Clement, 2017). The findings of this study may contribute to the existing body of knowledge on students' attitudes towards college general chemistry, providing insights into the underlying factors that shape these attitudes.

The study draws on several key theories and constructs to examine students' attitudes towards college general chemistry using partial least squares structural equation modeling (PLS-SEM) approach. The study uses the Attitude Toward the Subject of Chemistry Inventory (ASCI), a widely used research instrument designed to measure students' attitudes toward chemistry as a subject. It was originally developed by Bauer (2008) and has since undergone various adaptations and validations in different educational contexts. Given the increasing emphasis on improving attitudes toward science, especially chemistry, the ASCI provides a reliable and discipline-specific measure that aligns well with both the research questions and target population. Also, the ASCI was selected because it is a widely used, validated instrument that aligns with the study's goals by effectively measuring both the cognitive and affective dimensions of students' attitudes toward chemistry through an accessible semantic differential format, allowing for reliable administration, analysis, and comparison across studies. Although the ASCI constructs were obtained from a single instrument, the model does not assert definitive causal relationships. Instead, it examines theoretically grounded directional associations for explanatory purposes. Given the cross-sectional nature of the data, the findings are interpreted as indicative of possible directional influences within a theoretically established attitudinal framework, rather than as conclusive evidence of causality.

The framework integrates the following theories and constructs: Attitude Theory: Attitudes play a crucial role in shaping individuals' perceptions and behaviors (Eagly & Chaiken, 1993). In this study, attitudes towards college general chemistry serve as the central construct of interest. Social Cognitive Theory (SCT): SCT emphasizes the reciprocal interaction between personal factors, environmental influences, and behavior (Schunk & DiBenedetto, 2020). Within the framework of this study, SCT can help elucidate how individual characteristics, such as prior experiences, self-efficacy beliefs, and social influences, shape students' attitudes towards general chemistry. Expectancy-Value Theory: This theory posits that individuals' attitudes are influenced by their expectations of success and the subjective value they assign to an activity or subject (Eccles & Wigfield, 2002). In the context of this study, expectancy-value theory can provide insights into how students' perceptions of the relevance, utility, and difficulty of general chemistry impact their attitudes towards the subject.

PLS-SEM is a two-stage approach. The first stage is about the assessment of the measurement model component, while the second stage is about the evaluation of the structural model component. By employing a PLS-SEM, the study aimed to describe, compare, and correlate the attitude obtained from the survey and to model and examine the relationships among these constructs in the inventory, thus providing a comprehensive understanding of the factors that contribute to students' attitudes towards college general chemistry. Theoretical underpinnings from attitude theory, SCT, and expectancy-value theory guided the data analysis and interpretation process, facilitating a nuanced exploration of the research questions.

Generally, the study sought to examine and model the data on the attitudes of students towards college general chemistry in a state university context using partial least squares structural equation modeling (PLS-SEM).

To explore the main purpose of the study the following specific objectives guided the research namely: (1) Evaluate the measurement model component of the study by (1.1) describing the extent of attitudes of the students in college chemistry using the Attitude Toward the Subject of Chemistry Inventory (ASCI); (1.2) examining if significant difference exists on the attitude towards the subject chemistry when grouped by selected critical variables of the respondents; (1.3) ranking as to the most/least exhibited positive/negative attitudes based from the constructs of the ASCI; (1.4) examining the inter-relationships among the variables in the ASCI namely; Interest and Utility (IU), Anxiety (A), Intellectual Accessibility (IA), Fear (F), and Emotional Satisfaction (ES); and to some selected profile variables as requirement for measurement model testing and evaluation; and (1.5) evaluating the Reliability and Validity of the latent variables used; and 2. Assess the structural model of the study by (2.1) evaluating and presenting the model fit and quality indices; and (2.2) testing the parameter estimates of the structural component by determining the direct effects and interrelationship between and among the main constructs of the study and (3) Present the model developed explaining the relationship and interplay of the main constructs confirming its applicability in a local higher education context.

In alignment to objective 2.2, twenty-seven hypotheses were to be tested. First, the direct effect of the profile variables selected, senior high school strand and academic standing was tested. Students' high school academic strand and overall academic standing significantly influence their performance in college-level chemistry. The high school strand, particularly those focused on science, technology, engineering, and mathematics (STEM), provides foundational knowledge and skills directly applicable to college chemistry, giving these students a clear academic advantage (Salvador, Reyes & Castillo, 2021). Similarly, a student's general academic standing reflects their study habits, cognitive abilities, and motivation, which are essential in mastering complex chemistry concepts (Delos-Santos, 2020). Both factors directly shape preparedness and academic outcomes in chemistry. Thus, this study hypothesized that: (*H1 and H2) "Senior High School Strand and Senior High School Academic Standing significantly and positively affects their General Chemistry Academic Performance"*.

Also, as anticipated in the hypothesized model, ASCI constructs are interrelated and had direct effect on the General Chemistry Academic Performance. Recent studies affirm that the five ASCI constructs, intellectual accessibility, interest and utility, fear, emotional satisfaction, and anxiety significantly influence students' academic performance and interact with one another. Intellectual accessibility enhances learning and boosts emotional satisfaction while reducing fear (Rocabado, Montes, Ferreira & Lewis, 2023). Interest and utility increase motivation and academic effort, while also decreasing anxiety and enhancing emotional satisfaction (Mani, 2022). In contrast, fear negatively affects participation and fosters anxiety, which in turn impairs cognitive performance and reduces both emotional satisfaction and perceived accessibility (Ross, Scott & Lewis, 2020). Emotional satisfaction encourages persistence and buffers the effects of fear and anxiety, supporting academic success. These constructs are interdependent and collectively shape students' engagement and achievement in general chemistry. Thus, it was hypothesized in the study that: (H3-H27) *"ASCI five (5) constructs had direct significant effects from each other and had direct significant effects on General Chemistry Academic Performance"*.

2. Methodology

2.1. Research Design

This study employed a descriptive-inferential research design to investigate the students' attitudes towards college general chemistry and critical profile variables. The study was conducted in a higher education setting, focusing on undergraduate students enrolled in college general chemistry courses.

2.2. Participants of the Study

Variables	f	%
Gender		
Male	92	53.2
Female	81	46.8
Senior High School Strand		
Non-STEM	110	35.0
STEM	63	40.0
Senior High School Academic Standing		
Non-Honor	86	49.7
With Honor	82	47.4
With High Honor	5	2.90
College General Chemistry Academic Performance		
95-97	20	11.6
92-94	57	32.9
89-91	43	24.9
86-88	40	23.1
83-85	13	7.50
Total	173	100.0

Table 1. Demographic profile of respondents (n=20)

The participants of this study were purposive sample of undergraduate students majoring in various disciplines who are currently taking college general chemistry courses. A sample size calculation was performed to determine the appropriate sample size based on the desired statistical power and effect size. The current study used the inverse square root and gamma exponential post-hoc power analysis methods to calculate the minimum sample size. With the minimum significant path coefficient = 0.197, significance level = 0.05, and power level requirement = 0.800, the minimum sample size was between 146 and 160. Thus, the study's actual sample 170 met the minimum requirement and more than adequate for the purposes of this investigation. Table 1 presents demographic data related to the sample group.

2.3. Research Instrument

The research instrument used to collect the necessary data was an online survey consisting of three parts: the first part explained the main purpose of the study and sought informed consent from the respondents in connection to Data Privacy Act; the second part determined the profile characteristics of the respondents in terms of sex, senior high school strand, senior high school academic rank/standing, and college general chemistry academic performance; the third part were survey items related to Attitude towards the Subject Chemistry Inventory (Bauer, 2008). which include Intellectual Accessibility (IA), Interest and Utility (IU), Fear (F), Emotional Satisfaction (ES), and Anxiety (A). The survey items were adopted and re-worded to align with the context of this study. A total of 20 statements were used to assess the five constructs on ASCI: IA(5 items), IU(5 items), F(1), ES(4), and A(5). All items were measured on a four-point Likert scale with 1 = strongly agree, 2 = agree, 3 = disagree, and 4 = strongly disagree respectively.

PLS-SEM is a two-stage approach. The first stage is about the assessment of the measurement component of the model, while the second stage is about the evaluation of the structural component. Presentation of the measurement component includes the validity (convergent validity and discriminant validity) and reliability of the variables involved in the study. Validity and Reliability assessments will be conducted to ensure the accuracy and consistency of the measurements. To ensure measurement accuracy and consistency, both validity and reliability assessments were conducted. Convergent validity was evaluated to confirm that indicators reflect their intended latent constructs. Reliability was measured using Cronbach's Alpha (CA) and Composite Reliability (CR). CR, typically used in SEM, tends to produce higher reliability estimates than CA.

2.4. Data Gathering Procedure

A web-based survey created using Google Forms were sent to students through the official Group Chat of their class. Data collection was conducted during the second semester of the academic year. Compliance with prescribed ethical guidelines were ensured through informed consent from the respondents by requiring them to signify understanding of the nature and purposes of the study. Personal identifiable information of the respondents was accessible only to the researcher who analyzed the data.

2.5. Data Analysis

This quantitative study employed a combination of descriptive and inferential statistics, along with Partial Least Squares-Structural Equation Modeling (PLS-SEM), It was mentioned in the previous section that PLS-SEM is a two-stage approach. The first stage is about the assessment of the measurement component of the model, while the second stage is about the evaluation of the structural component. WarpPLS 8.0 (3 months trial version), a statistical software, was utilized for conducting factor analysis and hypothesis testing, while IBM SPSS V23 was employed for descriptive and other inferential statistical tests. Prior to SEM, data were screened for missing values, outliers, and assumptions of normality. Descriptive statistics and correlation analysis were performed to establish preliminary relationships among the variables. Results of the measurement component of the model will be presented. Presentation of the measurement component includes the validity (convergent validity and discriminant validity) and reliability of the variables involved in the study. WARP-PLS software will be employed for the two-stage approach intended for the inferential objectives of the study.

3. Findings

The results of the study are presented in several sections: First is the assessment of the measurement component of the model (Reliability and Validity of the constructs, Descriptive Statistics, Comparative, and

Correlations among the constructs) and second is the Structural Model Assessment (Model Fit and Quality Indices, and testing the study's twenty-seven (27) hypotheses, and presenting model developed in the study.

Initially, the validity and reliability assessments were conducted to ensure the accuracy and consistency of the measurements. Subsequently, the hypotheses relevant to the research framework were tested.

3.1. Results for Measurement Model Components

3.1.1. Reliability and Validity

Construct reliability is an assessment of the consistency between reflective items and their intended measures (Amora & Fearnley, 2020). It is considered acceptable when both composite reliability (CR) and Cronbach's alpha (CA) are equal to or greater than 0.70 (Kock, 2020). Convergent validity, on the other hand, examines whether respondents' understanding of items associated with each variable aligns with the instrument's intended purpose. In PLS-SEM, two methods are commonly used to assess convergent validity. Firstly, item loadings should have a minimum value of 0.50 and be statistically significant ($p < 0.001$), indicating a correlation between the item and the variable. Secondly, the average variance extracted (AVE) should be at least 0.50 (Kock, 2015). AVE measures the extent to which the construct's variability exceeds that of measurement error (Kock, 2020).

Constructs	No. of Items	Factor Loadings	P value	AVE	CA	CR
1.Intellectual Accessibility (IA)	5	0.939-0.976	<0.001	0.929	0.981	0.985
2. Interest and utility (IU)	5	0.727-0.883	<0.001	0.691	0.887	0.918
3. Emotional Satisfaction (ES)	4	0.787-0.883	<0.001	0.718	0.868	0.910
4. Fear (F)	1	1.000	<0.001	1.000	1.000	1.000
5. Anxiety (A)	5	0.756-0.874	<0.001	0.702	0.893	0.922

Table 2. Item loadings, AVE, and reliability of the constructs

The results presented in Table 2 demonstrate that all five constructs surpassed the recommended threshold of 0.70 for construct reliability. Moreover, the convergent validity of the constructs within the structural model was deemed adequate, as indicated by item loadings and AVE values exceeding 0.50.

Discriminant validity is present when respondents do not confuse the items of a particular variable with those of other variables in the instrument, particularly in terms of meaning (Kock, 2015). If the square root of the AVE of a variable (any of the diagonal values) is greater than the coefficients (off-diagonal values) for any combination of this variable with another, then the items in that variable have a strong correlation (Teo, 2010). In this case, all diagonal values are higher than the related off-diagonal values which shows acceptable discriminant validity for all constructs (see Table 3).

Constructs	1	2	3	4	5
1.Intellectual Accessibility (IA)	**0.964**				
2. Interest and Utility (IU)	0.614	**0.831**			
3.Emotional Satisfaction (ES)	0.446	0.781	**0.847**		
4. Fear (F)	0.257	0.405	0.462	**1.000**	
5. Anxiety (A)	0.320	0.575	0.715	0.453	**0.838**

Table 3. Correlation coefficients and AVE of the constructs

3.1.2. Test for Descriptive Statistics

Items on Attitude Towards the Subject Chemistry		Mean	SD	Verbal Interpretation
Intellectual Accessibility	Not Challenging	2.68	.945	Disagree
	Simple	2.55	1.014	Disagree
	Comprehensible	2.56	1.013	Disagree
	Clear	2.54	1.065	Disagree
	Easy	2.56	1.008	Disagree
	Mean	2.5803	.906	Somewhat Negative Attitude
Interest and Utility	Interesting	2.81	.904	Disagree
	Worthwhile	2.74	.840	Disagree
	Good	2.87	.835	Disagree
	Exciting	2.93	.880	Disagree
	Beneficial	2.92	.824	Disagree
	Mean	2.8532	.712	Somewhat Negative Attitude
Fear	Safe	2.58	.883	Somewhat Negative Attitude
Emotional Satisfaction	Pleasant	2.74	.833	Disagree
	Satisfaction	2.76	.860	Disagree
	Comfortable	2.72	.789	Disagree
	Organized	2.76	.828	Disagree
	Mean	2.7442	.700	Somewhat Negative Attitude
Anxiety	Play	2.53	.873	Disagree
	relaxed	2.60	.784	Disagree
	secure	2.67	.863	Disagree
	fun	2.72	.878	Disagree
	attractive	2.68	.894	Disagree
	Mean	2.6393	.719	Somewhat Negative Attitude
Overall Attitude		2.6802	.577	Somewhat Negative Attitude

Table 4. Descriptive statistics result on the ASCI among the respondents

Results in Table 4 reveals that the respondents exhibited a negative attitude towards the subject college general chemistry (mean=2.68). They all disagreed to all the items on the five constructs of ASCI.Students may exhibit negative attitudes towards chemistry due to various factors. One possible reason is the perception of the subject as being difficult or challenging, which can lead to feelings of frustration or anxiety (Bucat & Nottle, 2011). Additionally, the abstract nature of chemical concepts and their perceived lack of relevance to students' lives can contribute to a negative attitude (Hofstein & Lunetta, 1982). Negative experiences with previous chemistry classes, such as ineffective teaching methods or lack of support, can also shape students' attitudes (Cooper, Grove, Underwood & Klymkowsky, 2010). Cultural and societal factors, including stereotypes and gender biases, may further influence students' perception of chemistry (Osborne, Simon & Collins, 2003). Finally, individual differences in learning styles and preferences can affect students' engagement and attitude towards the subject (Schommer, Crouse & Rhodes, 1992).

3.1.3. Test for Comparative Statistics

3.1.3.1. Comparison on the Constructs of ASCI when Grouped by Sex

Constructs	Sex of	Mean	SD	p-value	Decision
Intellectual Accessibility	Male	2.6413	.95735	0.347	Accept Ho
	Female	2.5111	.84439		
Interest and Utility	Male	3.0087	.65828	0.002	Reject Ho
	Female	2.6765	.73319		
Fear	Male	2.55	.930	0.641	Accept Ho
	Female	2.62	.830		
Emotional Satisfaction	Male	2.8723	.67987	0.010	Reject Ho
	Female	2.5988	.69897		
Anxiety	Male	2.6804	.66171	0.424	Accept Ho
	Female	2.5926	.78067		
Overall Attitude	Male	2.7514	.51693	0.083	Accept Ho
	Female	2.5993	.63124		

Table 5. Independent samples T-Test result on extent of attitude using ASCI when grouped by sex

T-test result in Table 5 shows the result on the extent of attitude using the ASCI when grouped by sex. Among the five constructs, male and female differs significantly in terms of attitude on the constructs, Interest and Utility and Emotional Satisfaction. Male tends to have a more negative attitude than female in terms of Interest and Utility and Emotional Satisfaction.

3.1.3.2. Comparison on the Extent Constructs of ASCI when Grouped According to Senior High School Strand

Constructs	Strand	Mean	SD	p-value	Decision
Intellectual Accessibility	non-stem	2.5327	.90352	0.362	Accept Ho
	Stem	2.6635	.91145		
Interest and Utility	non-stem	2.8164	.69869	0.370	Accept Ho
	Stem	2.9175	.73584		
Fear	non stem	2.52	.821	0.197	Accept Ho
	Stem	2.70	.978		
Emotional Satisfaction	non-stem	2.7068	.66434	0.355	Accept Ho
	Stem	2.8095	.76030		
Anxiety	non-stem	2.5709	.70689	0.098	Accept Ho
	Stem	2.7587	.73014		
Overall Attitude	non-stem	2.6290	.56106	0.123	Accept Ho
	Stem	2.7695	.59686		

Table 6. Independent samples T-Test result on ASCI when grouped by senior high school strand

T-test result in Table 6 shows the result on the extent of attitude using the ASCI when grouped by senior high school strand. In the context of this study, no significant difference was exhibited in between the two groups. It implies that both groups of respondents have a negative attitude towards the subject chemistry though it seems that stem students have a higher level of negative attitude compared to non-stem.

3.1.3.3. Comparison on the Constructs of ASCI when Grouped by Senior High School Academic Standing

Constructs	SHS-AS	Mean	SD	p-value	Decision
Intellectual Accessibility	non honor	2.63	.930	.699	Accept Ho
	with honor	2.53	.901		
	with high honor	2.40	.547		
Interest and Utility	non honor	2.87	.718	.617	Accept Ho
	with honor	2.84	.720		
	with high honor	2.56	.456		
Fear	non honor	2.62	.870	.724	Accept Ho
	with honor	2.54	.919		
	with high honor	2.80	.447		
Emotional Satisfaction	non honor	2.80	.619	.322	Accept Ho
	with honor	2.69	.769		
	with high honor	2.40	.821		
Anxiety	non honor	2.61	.741	.757	Accept Ho
	with honor	2.67	.710		
	with high honor	2.48	.481		
Overall Attitude	non honor	2.71	.579	.703	Accept Ho
	with honor	2.65	.581		
	with high honor	2.52	.485		

Table 7. One-way ANOVA result on ASCI when grouped by senior high school academic standing

F-test result in Table 7 shows the result on the extent of attitude using the ASCI when grouped by senior high school academic standing. In the context of this study, no significant difference was exhibited in between and among the three groups..

3.1.4. Result of the Test for Rank as to the Most/Least Exhibited Attitude

Constructs of ASCI	(I)Factor1	(J)Factor1)	MD* (I-J)	Sig	Rank
1. Intellectual Accessibility	1(2.580)	2(2.853)	-.273*	.001	SECOND
		3(2.584)	-.003	1.00	
		4(2.744)	-.164	.317	
		5(2.639)	-.059	1.00	
2. Interest and Utility	2(2.853)	1(2.580)	.273*	.001	FIRST
		3(2.584)	.269*	.001	
		4(2.744)	.109*	.025	
		5(2.639)	.214*	.000	
3. Fear	3(2.584)	1(2.580)	.003	1.00	SECOND
		2(2.853)	-.269*	.001	
		4(2.744)	-.160	.127	
		5(2.639)	-.055	1.00	
4. Emotional Satisfaction	4(2.744)	1(2.580)	.164	.317	FIRST
		2(2.853)	-.109*	.025	
		3(2.584)	.160	.127	
		5(2.639)	.105	.114	
5. Anxiety	5(2.639)	1(2.580)	.059	1.00	FIRST
		2(2.853)	-.214*	.000	
		3(2.584)	.055	1.00	
		4(2.744)	-.105	.114	

Table 8. Repeated measures ANOVA result on the five constructs of ASCI

Table 8 presents the findings of a multiple comparison test conducted to assess the attitudes towards the five constructs of ASCI. The post hoc analysis using Bonferroni's method indicates that three constructs demonstrated significantly higher levels of negative attitude compared to the other two constructs. Descriptive statistics indicate that Interest and Utility were ranked as the constructs with the highest negative attitude, while Intellectual Accessibility exhibited the least negative attitude among the constructs. Three constructs emerged as having the highest negative attitude, while two constructs ranked the lowest in terms of negative attitude.

3.2. Result of the Test for Structural Model

3.2.1. Summary for the Parameter Estimates

There were twenty seven (27) hypotheses crafted from the eight (8) main constructs

The parameter estimates based from beta coefficient and p-value from the result of SEM analysis in Table 4 revealed that eleven out of the twenty-seven hypotheses had direct affect in between selected constructs from ASCI, profile variables and General Chemistry academic performance.

SHS strand directly affects the ASCI construct Intellectual Accessibility (p-value=0.010). In addition, SHS academic standing/rank directly affects the construct Anxiety (p-value=0.012) and Intellectual Accessibility. The results suggest that the senior high school (SHS) strand has a direct impact on students' perception of the intellectual accessibility of chemistry, while SHS academic standing influences their level of anxiety and intellectual accessibility towards the subject.

Hypotheses	Path	B	p-value	f2	Results
H1	SHS-S → GC_AP	-0.104	0.083	0.015	Not Supported
H2	SHS_AS → GC_AP	-0.085	0.129	0.008	Not Supported
H3	In_Acc → Fear	0.121	0.052	0.043	Not Supported
H4	In_Acc → GC_AP	0.046	0.271	0.005	Not Supported
H5	In_Acc → Anx	0.054	0.238	0.019	Not Supported
H6	In_Uti → In_Acc	0.587	<0.001	0.361	Supported**
H7	In_Uti → fear	0.283	<0.001	0.154	Supported**
H8	In_Uti → GC_AP	0.060	0.211	0.009	Not Supported
H9	In_Uti → Anx	0.175	0.009	0.108	Supported*
H10	E_Sat → In_Acc	-0.038	0.306	0.018	Not Supported
H11	E_Sat → In_Uti	0.782	<0.001	0.612	Supported**
H12	E_Sat → Fear	0.091	0.112	0.045	Not Supported
H13	E_Sat → GC_AP	0.147	0.024	0.010	Supported*
H14	E_Sat → Anx	0.605	<0.001	0.434	Supported**
H15	Fear → GC_AP	0.042	0.290	0.005	Not Supported
H16	Anx → Fear	0.235	<0.001	0.120	Supported**
H17	Anx → GC_AP	0.241	<0.001	0.044	Supported**
H18	SHS-S → In_Acc	0.172	0.010	0.034	Supported*
H19	SHS-S → In_Uti	0.056	0.230	0.001	Not Supported
H20	SHS-S → E_Sat	0.101	0.088	0.010	Not Supported
H21	SHS-S → Fear	0.046	0.272	0.005	Not Supported
H22	SHS- S → Anx	0.060	0.212	0.007	Not Supported
H23	SHS_AS → In_Acc	0.162	0.014	0.020	Supported*
H24	SHS_AS → In_Uti	-0.014	0.428	0.001	Not Supported
H25	SHS_AS → E_Sat	-0.118	0.057	0.013	Not Supported
H26	SHS_AS → Fear	0.019	0.402	0.001	Not Supported
H27	SHS_AS → Anx	0.166	0.012	0.013	Supported*

Table 9. Parameter estimates of the relationship of the three main variables of the study

In terms of the inter-relationship of the five constructs, six (6) significant direct effects were found based from the SEM analysis. Interest and Utility has a large (f^2=0.361) direct effect on Intellectual Accessibility (p-value=<0.001), Interest and Utility has a moderate (f^2=0.154) direct effect on fear (p-value=<0.001), Interest and Utility has a small (f^2=0.108) direct effect on Anxiety (p-value=0.009); Emotional Satisfaction has a large (f^2=0.612) direct effect on Interest and Utility (p-value=<0.001); Emotional Satisfaction has a large (f^2=0.434) direct effect on Anxiety (p-value=<0.001); and Anxiety has a small (f^2=0.120) direct effect on fear (p-value=<0.001).

SEM analysis was also conducted to test the inter-relationship of the five constructs with the general chemistry academic performance of the respondents. Two (2) constructs of the ASCI have a direct effect on the general chemistry academic performance of the respondents. Emotional Satisfaction has a small (f^2=0.010) direct effect on general academic performance (p-value=0.024), Anxiety also has a small (f^2=0.044) direct effect on the general chemistry academic performance (p-value=<0.001) of the respondents. The SEM analysis revealed that Emotional Satisfaction and Anxiety have direct effects on the general chemistry academic performance of the respondents..

3.2.2. Test for Model Fit and Quality Indices

Model fit and quality indices are crucial in Structural Equation Modeling (SEM) analysis for several reasons. These tests assess how well the proposed model aligns with the observed data, validate the model's theoretical relationships, detect misspecifications, compare alternative models, and provide evidence for generalizability (Hair, Black, Babin & Anderson, 2019);. Evaluating these indices ensures the validity and reliability of SEM analyses and aids in decision-making regarding model suitability (Schreiber, Nora, Stage, Barlow & King, 2006).

Model fit and quality indices results based from WarPLS

Average path coefficient (APC)=0.175, P=0.005
Average R-squared (ARS)=0.355, P<0.001
Average adjusted R-squared (AARS)=0.337, P<0.001
Average block VIF (AVIF)=1.624, acceptable if <= 5, ideally <= 3.3
Average full collinearity VIF (AFVIF)=2.003, acceptable if <= 5, ideally <= 3.3
Tenenhaus GoF (GoF)=0.559, small >= 0.1, medium >= 0.25, large >= 0.36
Simpson's paradox ratio (SPR)=0.889, acceptable if >= 0.7, ideally = 1
R-squared contribution ratio (RSCR)=0.989, acceptable if >= 0.9, ideally = 1
Statistical suppression ratio (SSR)=0.815, acceptable if >= 0.7
Nonlinear bivariate causality direction ratio (NLBCDR)=0.778, acceptable if >= 0.7

Overall, the fit and quality indices of the structural model in the present study fell within acceptable limits.

3.2.3. General Model Using Structural Equation Modeling (SEM)

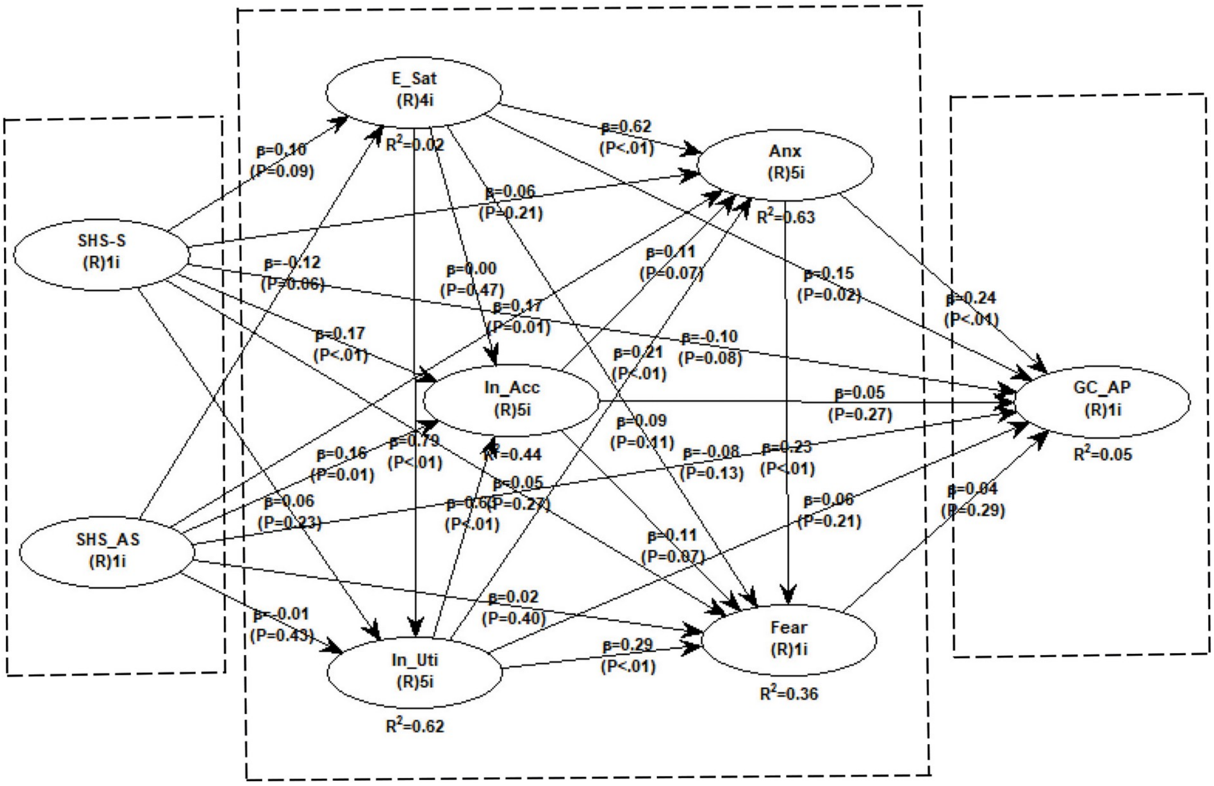

Figure 1. General model showing the relationship of selected constructs

The Figure 1 illustrates the structural model of the study, showing the directional relationships among selected profile variables, the five ASCI constructs: Intellectual Accessibility, Interest and Utility, Fear, Emotional Satisfaction, and Anxiety and their direct effects on Academic Performance in General Chemistry. Positive constructs such as Interest and Utility, and Emotional Satisfaction positively influence Intellectual Accessibility and academic outcomes, while negative constructs like Fear and Anxiety show detrimental effects. The model highlights how these attitudinal factors are interrelated and collectively shape students' academic performance.

4. Discussion

The assessment of reliability and validity for the constructs in this study indicates strong internal consistency and adequate convergent validity. Construct reliability, evaluated through Composite Reliability (CR) and Cronbach's Alpha (CA), showed values exceeding the 0.70 threshold for all constructs, with CR values ranging from 0.918 to 1.000 and CA values from 0.868 to 1.000, demonstrating high internal consistency (Hair, Hult, Ringle & Sarstedt, 2016). Convergent validity was confirmed as item loadings were statistically significant ($p < 0.001$) and ranged from 0.727 to 1.000, while Average Variance Extracted (AVE) values exceeded 0.50 for all constructs, indicating that the constructs explain more variance than measurement error (Fornell & Larcker, 1981). These results affirm that the measurement model is both reliable and valid, providing a robust foundation for further structural analysis.

The descriptive statistics for students' attitudes towards college general chemistry indicate an overall negative sentiment, with a mean score of 2.62 across various constructs. Students consistently disagreed with positive statements regarding Intellectual Accessibility, Interest and Utility, Fear, Emotional Satisfaction, and Anxiety, reflecting a somewhat negative attitude towards chemistry. This negativity can stem from several factors. The perception of chemistry as a difficult and challenging subject often leads to frustration and anxiety (Boe, Henriksen, Lyons & Schreiner, 2021). Also, past negative experiences in chemistry classes, such as ineffective teaching methods or lack of support, further may shape unfavorable attitudes (Hannover & Kessels, 2022). Cultural and societal influences, including stereotypes and gender biases, exacerbate these negative perceptions (Reid & Skryabina, 2020). Finally, individual differences in learning styles and preferences significantly impact students' engagement and attitudes towards chemistry (Tsai, Ho, Liang, & Lin, 2021).

The comparative statistics for students' attitudes towards chemistry, analyzed by sex, senior high school strand, and academic standing, reveal significant insights. The T-test results indicate that male students exhibit a significantly more negative attitude towards the constructs of Interest and Utility and Emotional Satisfaction compared to female students, suggesting that males find chemistry less engaging and emotionally satisfying (Hannover & Kessels, 2022). This highlights the importance of addressing gender-specific perceptions in chemistry education. However, no significant differences were found between male and female students in the other constructs, indicating a generally uniform negative attitude towards chemistry across both sexes. When comparing students based on their senior high school strand, the results show no significant differences between STEM and non-STEM students in their attitudes towards chemistry. Despite this, STEM students exhibited a slightly higher level of negative attitude, which may be attributed to the higher exposure and expectations associated with the subject in STEM curricula (Boe et al., 2021). This suggests that the perceived difficulty and relevance of chemistry might be influencing these attitudes. Similarly, the ANOVA results for academic standing indicate no significant differences in attitudes towards chemistry among students with different academic rankings. This implies that negative attitudes towards chemistry are pervasive across all academic standings, regardless of students' performance levels. Factors such as teaching quality, instructional methods, and individual interests likely play a more substantial role in shaping these attitudes than academic rank alone (Salta & Koulougliotis, 2020).

The multiple comparison test results reveal significant variations in students' attitudes towards the ASCI constructs. Interest and Utility exhibit the highest negative attitudes, suggesting that students perceive chemistry as uninteresting and lacking practical utility, which could impede their engagement and motivation (Osborne et al., 2003). Conversely, Intellectual Accessibility, related to understanding chemistry concepts, demonstrated the least negative attitude, indicating that students' primary concerns lie in the subject's perceived relevance rather than its difficulty (Boe et al., 2021).Addressing these issues requires making chemistry more relevant and engaging through hands-on, inquiry-based learning and highlighting real-world applications (Salta & Koulougliotis, 2020; Hannover & Kessels, 2022). Additionally, ensuring clear and accessible teaching of chemistry concepts can further reduce negative attitudes and enhance overall interest (Tsai et al., 2021). By focusing on these areas, educators can foster a more positive and engaging learning environment in chemistry.

The SEM analysis, as depicted in Table 9, illuminates significant relationships among constructs of the Attitudes towards Chemistry Survey Instrument (ASCI), profile variables, and general chemistry academic performance. Notably, eleven hypotheses demonstrated direct effects, elucidating the intricate interplay of factors impacting students' attitudes and performance in chemistry. Furthermore, significant direct effects among ASCI constructs, including Interest and Utility, Emotional Satisfaction, and Anxiety, underscore the need for holistic interventions considering emotional experiences and perceived usefulness to enhance engagement and academic success in chemistry education (Osborne et al., 2003; Salta & Koulougliotis, 2020). This implies the need for tailored instructional approaches and materials to enhance the intellectual accessibility of chemistry across different SHS strands. By considering these individual differences, educators can create a more inclusive learning environment, fostering positive attitudes and reducing anxiety in students' engagement with chemistry. These findings have implications for educators and policymakers, suggesting the need to develop targeted interventions that promote students' interest, perceived usefulness, emotional satisfaction, and address anxiety to enhance their attitudes and engagement with chemistry. Recent studies support the SEM findings on the inter-relationships among the five ASCI constructs interest, perceived usefulness, emotional satisfaction, and anxiety as key factors influencing students' attitudes and engagement with chemistry. Patacsil and Quimbo (2023) found that student interest, motivation, and supportive learning environments significantly affect satisfaction and performance in chemistry. Valenzuela-Peñuñuri, Tapia-Fonllem, Fraijo-Sing and Manríquez-Betanzos (2024) emphasized that academic motivation and self-efficacy positively impact emotional engagement in science, while Wilkes, Gamble and Rocabado (2024) reported that emotional costs and anxiety negatively influence student persistence and achievement. These findings highlight the importance of fostering positive emotional experiences, addressing anxiety, and enhancing perceived relevance to improve students' engagement and learning outcomes in chemistry.

Moreover, the SEM analysis reveals the direct influence of Emotional Satisfaction and Anxiety on general chemistry academic performance, emphasizing the importance of cultivating a supportive learning environment to improve student outcomes (Tsai et al., 2021). It also implies that students' emotional experiences and satisfaction with chemistry, as well as their levels of anxiety, can influence their performance in the subject. Creating a positive and supportive learning environment and addressing anxiety can potentially enhance students' academic performance in chemistry. Educators should consider these factors when designing interventions and support systems to promote better academic outcomes in the subject. However, it is important to recognize that other factors such as teaching quality and individual differences also play a role in academic performance and should be taken into account. These findings advocate for comprehensive approaches integrating pedagogical strategies, emotional support, and personalized interventions to optimize chemistry education outcomes (Hannover & Kessels, 2022; Osborne et al., 2003). It also highlights the significance of students' emotional experiences, satisfaction with chemistry, and levels of anxiety in relation to their performance in the subject. Recent studies support this finding. For example, Brown and Nedungadi (2024) found that positive emotions such as enjoyment and hope were significantly associated with higher grades in a General, Organic, and Biological Chemistry course, while anxiety and boredom negatively influenced performance. Similarly, Liu, Zhang, Chen and Wang (2025) reported that positive achievement emotions had a direct positive effect on chemistry performance, and that chemistry self-efficacy mediated the relationship between emotions and academic outcomes.

The fit and quality indices of the structural model, as assessed through WarPLS analysis, indicate satisfactory alignment between the proposed model and the observed data. The average path coefficient, R-squared values, and adjusted R-squared values demonstrate significant explanatory power of the model, while the average block VIF and average full collinearity VIF suggest acceptable levels of multicollinearity. Additionally, the Tenenhaus GoF value indicates a moderate level of goodness-of-fit, suggesting that the model adequately explains the observed variance in the data. These findings support the validity and reliability of the SEM analysis conducted in this study (Tenenhaus, Vinzi, Chatelin & Lauro, 2020).

The structural model developed in this study offers a novel theoretical framework in science education by highlighting how attitudinal constructs like Interest and Utility, Intellectual Accessibility, Emotional Satisfaction, Fear, and Anxiety interrelate and directly influence academic performance in general chemistry. Unlike earlier models that treated attitudes as static or isolated factors, this model presents a dynamic structure where positive emotions enhance understanding and performance, while negative emotions hinder them. This aligns with prior findings that emphasize the role of affect in science learning (e.g., Xu, Jiang & Lin, 2023; Toma, Jansen & Schüler, 2022), but extends them by mapping direct inter-construct pathways, offering clearer targets for intervention. As such, it provides science educators with a diagnostic and predictive tool to enhance student success through affective engagement.

5. Conclusion

For the measurement model component, descriptive results indicate that the respondents displayed a negative attitude towards college general chemistry. This negative attitude may stem from various factors such as perceived difficulty, lack of relevance, negative past experiences, cultural and societal influences, and individual differences in learning styles. To address this issue, it is recommended to enhance teaching methods, create a supportive learning environment, challenge stereotypes and biases, personalize instruction, and foster positive experiences with chemistry. By implementing these recommendations, educators and policymakers can work towards improving students' attitudes, promoting a positive learning experience, and increasing student engagement and success in chemistry.

Findings from inferential statistics highlight the varying levels of negative attitude among the constructs of ASCI. Interest and Utility were identified as having the highest negative attitude, while Intellectual Accessibility exhibited the least negative attitude. These results emphasize the importance of addressing negative attitudes towards chemistry, particularly in the areas of Interest and Utility. Educators and curriculum developers should focus on developing engaging teaching methods and highlighting the practical applications of chemistry to enhance students' attitudes and engagement with the subject. By implementing targeted interventions and creating a positive learning environment, educators can foster more positive attitudes towards chemistry and create a more engaging and meaningful learning experience for students.

For the structural model component, the selected profile variables, including the SHS strand and academic standing/rank, demonstrated significant effects on the constructs of Intellectual Accessibility and Anxiety within ASCI. The findings suggest that educators should tailor their instructional approaches and materials to enhance the intellectual accessibility of chemistry across different SHS strands. Additionally, it is important for educators to be aware of the anxiety levels among students with varying academic ranks and provide appropriate support to address this issue. By considering these individual differences and implementing targeted interventions, educators can create a more inclusive learning environment that fosters positive attitudes and reduces anxiety in students' engagement with chemistry. This can ultimately contribute to improved learning outcomes and a more positive experience with the subject.

The SEM analysis revealed significant direct effects among the five constructs of ASCI, highlighting the inter-relationships between these constructs. The findings emphasize the importance of addressing students' interest, perceived usefulness, and emotional satisfaction to enhance their attitudes and engagement with chemistry. Educators and policymakers should focus on developing interventions that promote students' interest and perceived usefulness in chemistry, as well as creating a supportive and emotionally satisfying learning environment. Additionally, efforts should be made to address students' anxiety and alleviate their feelings of fear related to the subject. By considering these inter-relationships and implementing targeted strategies, educators can enhance students' overall attitudes and engagement with chemistry, leading to improved learning outcomes and a more positive learning experience.

The SEM analysis also revealed that Emotional Satisfaction and Anxiety have direct effects on the general chemistry academic performance of the respondents. This highlights the significance of students' emotional experiences, satisfaction with chemistry, and levels of anxiety in relation to their performance in the subject. To improve academic performance in chemistry, educators should focus on creating a positive and supportive learning environment that fosters emotional satisfaction and addresses students' anxiety. Implementing strategies such as providing additional support, promoting stress management techniques, and tailoring instructional approaches can contribute to better academic outcomes. However, it is important to consider that academic performance is influenced by various factors, and therefore, a comprehensive approach that addresses multiple aspects of students' learning experiences should be adopted.

The model fit and quality indices indicate that the structural model has strong statistical adequacy and theoretical coherence. All key metrics such as APC, ARS, AVIF, GoF, and others fall within acceptable or ideal ranges, suggesting that the model is well-specified, free from major multicollinearity issues, and demonstrates good explanatory power. These results confirm the model's robustness in representing the underlying relationships among attitudinal constructs and academic performance. It is recommended that this validated model be utilized in further studies and educational assessments to inform targeted interventions in science education, and that future research replicate the findings across diverse contexts to strengthen its generalizability.

The generated or developed model highlights how positive attitudes foster learning, while negative emotions hinder academic success, aligning with and extending prior affective research in science education. It is recommended that educators incorporate strategies that enhance emotional satisfaction and perceived relevance while minimizing fear and anxiety in the classroom. Future research should explore longitudinal and experimental approaches to further validate and refine this emerging theoretical model.

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