

Initial Exploration of Factors Affecting University Students' Performance in First-Year Physical Chemistry

Eddia P. Copeland Solas

Mount Saint Vincent University

Abstract

This study, conducted with 70 science majors at a Caribbean university, explores factors affecting first-year chemistry performance, a concern for STEM degree requirements globally. Using an adapted version of the Chemistry Attitudes and Experiences Questionnaire (CAEQ), the research delves into the correlations among high school chemistry performance, attitudes-toward-chemistry, chemistry self-efficacy, university chemistry learning experiences, and students' performance on a physical chemistry module. The findings reveal consistently positive pre- and post-test attitudes and self-efficacy, with no statistically significant differences. While no significant relationship was found between students' attitudes and their academic performance, weak correlations emerged between the students' performance on the physical chemistry module and their self-efficacy and learning experiences. A moderately significant correlation was also identified between high school chemistry achievement and first-year physical chemistry module scores. These findings offer insights for refining matriculation criteria and designing targeted interventions to better support incoming students in science programs.

Keywords: attitudes-toward-chemistry, chemistry self-efficacy, first-year chemistry, university chemistry learning experience

Introduction

As the world strives for equitable educational opportunities, concerns arise over the academic underperformance of Black students in the UK, the Caribbean, and North America, particularly in the sciences (Dei, 1996; James & Turner, 2017; Jennings & Cook, 2019; Ladson-Billings & Henry, 1990; Moote et al., 2021). Reports highlight ongoing subpar performance in science subjects across all educational levels (Bloomfield & Soyibo, 2008; Hunter, 2014; Ministry of Education and Youth, 2017; Musengimana et al., 2021; Singh, 2016; Stockhausen & Soyibo, 2004), exacerbated

by learning disruptions caused by the COVID-19 pandemic (Organisation for Economic Co-operation and Development [OECD], 2023). To achieve developed status, Caribbean countries must enhance science literacy and academic performance, making quality science instruction crucial at all levels.

This study focuses on first-year chemistry performance at a Caribbean university on a physical chemistry module essential for health sciences, engineering, and science education degrees. Historically, low success rates in first-year chemistry modules have raised concerns about the understanding of foundational concepts

crucial for subsequent studies (Bridgeman-Maxwell & Garner-O'Neale, 2021; Casimir et al., 2023; Lewis et al., 2009).

The challenges in first-year chemistry performance are not unique to this university, and echo global concerns (Cooper, 2010; Hockings et al., 2008; Lewis et al., 2009; Pappalardo & Gunn, 2013; Villafañe et al., 2014). High attrition rates and failure percentages have been observed at various institutions, indicating potential gaps in students' learning experiences (Chambers, 2005).

Several factors have been implicated in low chemistry performance including lack of motivation, low self-efficacy, poor attitudes, and inadequate instruction (Behmke & Atwood, 2012; Hockings et al., 2008; Marais & Mji, 2009). Addressing these issues prompts questions about the effectiveness of creative formative assessment and the understanding of classroom dynamics. To explore these aspects, instruments like the Chemistry Attitudes and Experiences Questionnaire (CAEQ) are employed, offering insights into attitudes-toward-chemistry, chemistry self-efficacy, and learning experiences of first-year university chemistry students, potentially informing strategies to enhance student achievement.

This study is aimed at characterizing the factors that affect students' performance in first-year physical chemistry, and whether students' attitudes and self-efficacy regarding chemistry are altered by university chemistry learning experiences. The CAEQ, along with key demographic indicators, were used to harness the data to answer these questions. Understanding these classroom dynamics is likely to influence the teaching and learning of chemistry positively for students and instructors. The research questions are as follows:

1. Are the pre- and post-test attitudes-toward-chemistry and chemistry self-efficacy of first-year students positive or negative?
2. Are there significant differences in the students' pre- and post-test scores on attitudes-toward-chemistry and chemistry self-efficacy items?
3. What relationships are there among students' high school chemistry grades, attitudes, self-efficacy and learning experiences related to chemistry, and students' academic performance on a physical chemistry module in the first year of university?

Significance of the Study

The paucity of educational research on Caribbean science students' performance underscores the importance of documenting and analyzing information to guide future educational reforms in the region (Bridgeman-Maxwell & Garner-O'Neale, 2021).

The persistent low performance in chemistry remains a challenge for universities globally (Bridgeman-Maxwell & Garner-O'Neale, 2021; Casimir et al., 2023; Cooper, 2010; Fink et al., 2020; Marais & Mji, 2009), so this study, although focussed on one Caribbean tertiary institution, is crucial for understanding the factors influencing first-year chemistry performance. Insights from this research will equip chemistry educators with valuable tools for effective interventions to enhance learning experiences in this and other universities facing similar challenges. Given the centrality of chemistry in many science programmes, a strong grasp of the fundamentals enhances both teaching and learning, supporting students' academic success (Tai et al., 2005).

Literature Review

Chemistry instructors worldwide are seeking to determine the predictors of student success based on the observations of poor student performance in general chemistry (Bridgeman-Maxwell & Garner-O'Neale, 2021; Marais & Mji, 2009; Pappalardo & Gunn, 2013; Sirhan, 2007). This literature review explores the challenges faced by these instructors. It examines several factors implicated in influencing student success such as demographic characteristics, educational background, high school grades, learning experiences, learning styles, competence in mathematics, attitude, self-efficacy, and locus of control (Dalgety & Coll, 2006; Ellis-Hall &

Soyibo, 2004; Green & Celkan, 2011; Ogunkola & Garner-O'Neale, 2013; Simpson & Oliver, 1990; Tai et al., 2005; Zacharia, 2003).

Demographic Factors and Educational Background

Tai et al. (2005) suggest three major factors affecting student performance: demographic background, general educational background, and previous science learning experiences. Demographic characteristics of students and their effect on student performance have been the subject of much research (Ellis-Hall & Soyibo, 2004; Maple & Stage, 1991; Remali et al., 2013; Simpson & Oliver, 1990). The impact of high school GPA scores, ethnicity, and socio-economic background on student achievement have all been studied. Some researchers suggest that differences in attitudes and capabilities in science are key indicators of success, while others argue that social and environmental factors play more significant roles.

According to Tai et al. (2005), high school science and math scores and the general educational background of students serve as high predictors of college chemistry attainment. Tai et al. (2005) cited a 1994 study (Sadler & Tai, 2001) which showed that among college students studying physics, a strong positive correlation was found between having a background in calculus and performance on calculus-based and algebra-based physics courses. The same study also found that students who studied a few topics in depth in high school physics had better grades on college physics courses than those who studied more topics with less depth—indicating that the quality of the learning experience also made a difference. They explained that although repeating labs for understanding in high school was a key factor in good student performance in college chemistry courses, placing emphasis on following lab procedures did not translate to expertise during college chemistry courses. These findings support the idea that students' previous learning experiences are critical to their performance at the college level. In the Caribbean it has been observed that students who generally achieve high grades also do well in chemistry.

Noticeably, students who attend traditional high schools, having gained higher passes in Grade 6 achievement examinations (Jennings & Cook, 2019), display higher performances in all academic subjects (including chemistry) on standardized examinations at the end of Grade 11.

Self-Efficacy

According to some researchers (Kan & Akbaş, 2006; Moreno et al., 2021; Uzuntiryaki & Senay, 2015), student self-efficacy is a significant predictor of student achievement in chemistry. Bandura (1986) defines self-efficacy as an individual's judgment of their ability to organize and execute the actions required to achieve specific performance goals. Unlike self-esteem or general self-confidence, self-efficacy is task-specific, shaping a learner's belief in their capacity to succeed in particular tasks. Dalgety and Coll (2006) explain that low self-efficacy can result in students opting out of achievable tasks, thus impacting academic attainment.

Self-efficacy is a dynamic construct affected by factors such as learning experiences, prior academic performance, perceived difficulty, vicarious experiences, physiological state, and social persuasion. In fact, Harlen (2006) warns that even repeated failure, particularly in tasks perceived as easy, can lead to learned helplessness, hindering persistence and effort. Understanding students' self-efficacy therefore allows teachers to better support students, positively influencing their motivation and engagement.

Bandura (1986) states that students with high self-efficacy usually possess an internal locus of control — perceiving success as the result of effort and failure as insufficient effort; while those with an external locus of control perceive success and failure as the result of factors outside their control and have lower self-efficacy. He emphasizes the impact of self-misgivings on academic performance, noting that inefficacious individuals shy away from challenges, have lower aspirations, and are more anxious (Bandura, 1986).

Attitudes-toward-Chemistry

Attitudinal research is significant in science education (Casimir et al., 2023; Simpson & Oliver, 1990; Wahyudiati et al., 2019; Zacharia, 2003), with attitude defined as a mental state that influences responses to situations and objects (D. Cheung, 2009; Horowitz & Bordens, 1995; Oskamp & Schultz, 2014). Kan and Akbaş (2006) and Salta and Tzougraki (2003) state that attitudes can be assessed through cognitive, conative, and affective components, reflecting knowledge beliefs, actions toward the subject, and emotional response. Simpson and Oliver (1990) also suggest that attitudes, shaped by learning experiences, can predict academic achievement, possibly because students who exhibit positive attitudes generally work harder at achieving positive results (Heng & Karpudewan, 2015; Musengimana et al., 2021).

This literature review highlights the complex interplay of factors influencing student performance in chemistry. It underscores the importance of considering demographic, educational, and psychological elements (such as self-efficacy and attitudes) when addressing the challenges students face in general chemistry.

Methodology

Research Design

This research study investigated magnitude, differences, and correlations among first-year university students' performance in a physical chemistry module and their high school chemistry grades; pre- and post-test attitudes-toward-chemistry; chemistry self-efficacy; and university learning experiences. The research design included four independent variables and one dependent variable —performance on a module of physical chemistry taught in the first semester of the first year.

The first-year chemistry curriculum was delivered as 3 separate modules over two semesters, with Semester 1 focusing on

introductory physical and inorganic chemistry, and Semester 2 dedicated to organic chemistry. This study focusses on the physical chemistry module, which comprised three separate units delivered through lectures, tutorials, and mandatory laboratory sessions. This author conducted all lectures and served as one of two faculty members supervising the laboratory component. Student performance in the theoretical portion, delivered via lectures, was evaluated through three in-person, paper-based multiple-choice tests, and was used solely to determine students' performance on the module for the purpose of the study. No content from the laboratory sessions was used to determine students' performance on the module. Tutorial sessions were informal and responsive, addressing students' questions and difficulties through worksheet exercises or open class discussions, depending on student needs.

Sample

A convenience sample of 70 first-year chemistry students comprising 13 males and 57 females was used in the research. Participants all shared a lower middle-class background and were enrolled in one of three health-science programmes offered by the university – medical technology, dietetics and nutrition, and environmental health. All students, except one who had an equivalent matriculation, had passing grades (I–III) in chemistry at the Caribbean Secondary Education Certificate (CSEC). Equivalent to O'Level examinations in the UK, students sit CSEC exams at the end of Grade 11, and the results are used to matriculate for 4-year degree programmes in the English-speaking Caribbean.

The Chemistry Attitudes and Experiences Questionnaire (CAEQ)

Attitudes, self-efficacy, and learning experiences data were collected using the Chemistry Attitudes and Experiences Questionnaire (CAEQ) reported by Coll et al. (2002) and Dalgety et al. (2003). Although other instruments measure attitudes toward science (D. Cheung, 2009;

Fraser, 1981), and attitudes toward the subject of chemistry — ASCI and ASCIv2 (Brandriet et al., 2011; Bauer, 2008), the CAEQ is especially relevant to the Caribbean context owing to the similarity in university instructional formats between the Caribbean and New Zealand, where the instrument was developed. Both instructional contexts commonly include large lectures, smaller tutorials, and mandatory laboratory sessions.

The CAEQ combines use of the Likert scale, employed by the ASCI and ASCIv2, and the semantic differential, which is considered more discriminating for attitude measurement (Brandriet et al., 2011; Bauer, 2008; Coll et al., 2002). A slightly modified version of the CAEQ was used in this study, with adaptations made to better reflect the Caribbean context. These modifications included a demographic data section relevant to the research population and the removal of questions deemed less applicable, such as *"How confident do you feel in achieving a passing grade in a chemical hazards course?"* and *"My tutors encouraged me to take further chemistry papers"*. Aside from these adjustments, the instrument used largely followed the version presented in the appendix of Dalgety et al. (2003), with minor wording changes such as replacing *demonstrator* with *laboratory supervisor* in select items. In cases where questions from Dalgety et al. (2003) were removed, items were substituted with relevant questions from the CAEQ version supplied by Coll et al. (2002). The latter version included 22, 20, and 35 questions in Parts 2, 3, and 4, respectively, compared to 21, 17, and 31 questions in Dalgety et al. (2003). The final version of the questionnaire used in this study is provided in Appendix 1 of this manuscript.

The research questionnaire was comprised of 4 sections. In Part 1, demographic data and chemistry background information, students were asked to provide their grade in CSEC chemistry, which was used as the prerequisite in course matriculation.

Parts 2 and 3 of the questionnaire collected data on attitudes and self-efficacy. Due to the affective nature of the items in parts 2 and 3, a semantic differential format was used to elicit responses. Students' responses to stimuli were rated on a bipolar scale with contrasting adjectives at each end. The central position was considered neutral and the ends extreme. The other two positions from the centre moving outwards could be considered "slightly" and "quite" respectively. The items in parts 2 and 3 (attitudes and self-efficacy) were evaluated using numbers 1–7 where 1 represented the unfavourable extreme (negative attitude and low self-efficacy) and 7 the favourable extreme (positive attitude and high self-efficacy). Choices greater than 4 (midpoint of the scale) were considered positive, and those less than 4 were considered negative.

Part 2, consisting of 21 items, measured participants' attitudes-toward-chemistry, with a maximum possible score of 147. Since each item was rated on a 7-point scale, where a score of 7 represented the most favourable attitude, a total score of 147 (21 items $\times$ 7) reflected the most positive possible response. A total score above 84 indicated an overall positive attitude, while a score below 84 suggested a negative attitude. A score of 84 represented a neutral stance, based on a midpoint rating of 4 for each item (21 $\times$ 4 = 84). Part 2 was subdivided into five subscales: perception of chemists; skills of chemists via research; leisure interest (science documentaries, science fiction movies, and chemistry websites); career interest in chemistry; and attitudes-toward-chemistry in society. A sample item from the attitudes-toward-chemistry scale is provided in Figure 1.

Figure 1*Sample Item from the Attitudes-toward-Chemistry Scale*

Please indicate how you feel about chemists:

Athletic _ _ _ _ _ Unfit

Part 3 represented the self-efficacy scale and contained 17 items geared toward determining the confidence students possessed regarding particular aspects and tasks in chemistry. There was a maximum possible score of 119 (17×7). A total score greater than 68 (17×4) indicated an overall positive self-efficacy, while a score below 68 suggested a negative self-efficacy. A sample question from Part 3 is provided in Figure 2.

Figure 2*Sample Item from Part 3, the Chemistry Self-efficacy Scale*

Please indicate how CONFIDENT you feel about:

Designing and conducting a chemistry experiment

Totally confident _ _ _ _ _ Not confident

Part 4, the learning experiences scale, had 30 Likert-scale items and three subscales related to three aspects of learning experiences: lecture classes, tutorial classes, and laboratory classes. A sample item is shown in Figure 3.

Figure 3*Sample Item from Part 4, the Chemistry Learning Experiences Scale*

The lecture material was relevant to the objectives of the course	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
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Part 4 employed the 5-point Likert scale because the items collected perception data (Dalgety et al., 2003) chemistry self-efficacy, and learning experiences. The CAEQ instrument was developed as part of a larger study and sought to fulfill a need for an instrument to investigate factors that influence student enrollment choice. We set out to design the instrument in a manner that would maximize construct validity. The CAEQ was piloted with a cohort of science and technology students ($n = 129$) and pertained to specific contexts, which made the responses more likely to be discriminatory and definitive. For items in Part 4, it is much easier to agree or disagree than for items in Parts 2 and 3 where the concepts were less contextualized and beliefs therefore

likely to be less defined (Dalgety et al., 2003). The central position was considered neutral and the ends extreme. The two positions from the centre moving outwards were considered "agree/disagree" and "strongly agree/strongly disagree" respectively. They were evaluated using numbers 1–5. Choices greater than 3 (neutral) were considered positive, and less than 3 were considered negative.

Assessment of the reliability of the subscales of the CAEQ instrument using Cronbach's alpha resulted in a mean reliability coefficient of 0.76 for the pre-test and 0.84 for the post-test after one semester (n=669), which was within the acceptable range. Table 1 compares Cronbach's alpha for this study with the administration by Dalgety et al.

Table 1

Comparison of the Reliability (Cronbach's Alpha) Coefficients for the Scales of the CAEQ

Scales	Cronbach's α for developers of CAEQ (n = 669)	Cronbach's α for this study (n=70)
Pre-test attitudes-toward-chemistry	0.76	0.85
Pre-test chemistry self-efficacy	0.93	0.93
Post-test attitudes-toward-chemistry	0.80	0.86
Post-test chemistry self-efficacy	0.96	0.95
Post-test chemistry learning experiences	0.87	0.94

The CAEQ instrument underwent construct validity testing with pre- and post-test data from two introductory chemistry courses (pre-test: n=332; post-test: n=337) (Dalgety et al., 2003). Construct validity was assessed through predictive and concurrent validity. For predictive validity, the developers anticipated a correlation between positive learning experiences and favorable attitudes and self-efficacy. The results indicated a modest yet statistically significant correlation between students' assessment of their learning experiences, attitudes-toward-chemistry, and chemistry self-efficacy.

Factor Analyses were performed to validate CAEQ subscale measurements. The factor structures of CAEQ's Parts 2–4 (attitudes-toward-chemistry, chemistry self-efficacy, and chemistry learning experiences) were analyzed via principal component analysis and summarized in Table 2.

Table 2*Principal Component Analysis on the CAEQ Items by Subscales*

Component 1							
Attitudes-toward-chemistry			Chemistry self-efficacy		Chemistry learning experiences		
Perception of chemists	Skills of chemists	Chemistry careers			Lecture classes	Laboratory classes	Tutorial classes
0.371	0.779	0.690	0.717		0.685	0.744	0.769
0.563	0.885	0.910	0.677		0.787	0.768	0.611
0.636	0.761	0.826	0.832		0.590	0.531	0.685
0.688	0.730	0.786	0.716		0.675	0.767	0.742
0.737			0.745		0.724	0.681	0.755
0.620			0.712		0.624	0.623	0.736
0.526			0.765		0.647	0.621	0.562
0.184			0.859		0.829	0.493	0.590
			0.684		0.116	0.684	0.480
			0.677		0.070	0.748	0.521
			0.754				
			0.760				
			0.645				
			0.737				
			0.792				
			0.645				
			0.759				
% of variance	32.12%	62.53%	65.14%	54.19%	44.86%	45.22%	42.63%

Only the component with the highest percentage of variance explained (Component 1) was presented for each subscale, as it accounted for the greatest proportion of variance and displayed cohesive item loadings. The decision to focus on Component 1 was guided by its interpretability and the strength of the factor loadings across subscales. For Part 2 (Attitudes-toward-Chemistry), 3 subscales were analyzed, as the remaining 2 subscales (Attitudes to Chemistry in Society and Leisure interest in Chemistry) contained fewer than three items and were therefore excluded. The Perception

of Chemists subscale showed the highest percentage of variance explained by Component 1 at 32.12%; however, 2 items (0.184 and 0.371) fell below the commonly accepted threshold of 0.5, suggesting weak contributions to the underlying construct. These items were retained for the purposes of exploratory analysis and to maintain the theoretical structure of the instrument. Consistent with scale development practices, they were reviewed for possible revision or removal in future validation work. The Skills of Chemists subscale yielded a variance of 62.53%, with strong factor loadings

ranging from 0.730–0.885, while the Chemistry Careers subscale accounted for 65.14% of the variance, with loadings from 0.690 –0.910. For Part 3 (Chemistry Self-Efficacy), Component 1 explained 54.19% of the variance, and all items demonstrated strong loadings between 0.645 and 0.859. In Part 4 (Chemistry Learning Experiences), which included 3 subscales of 10 items each, the Lecture Classes subscale explained 44.86% of the variance. Most items loaded acceptably, but 2 items fell below the 0.5 threshold and were subsequently removed to enhance subscale reliability (G. W. Cheung et al., 2024; Kahveci, 2015; Kim et al., 2016). The Laboratory Classes subscale explained 45.22% of the variance, with loadings ranging from 0.493 –0.768; the lowest-loading item, though just below the threshold, was retained because of its conceptual relevance and acceptable proximity to the cutoff (Ryberg et al., 2020). This decision supported by Werner et al. (2021) who retained items in the Chemistry Self-Concept Inventory (CSCI) with loadings above 0.3, indicating that our inclusion of this item falls within acceptable practice in chemistry education research. The Tutorial Classes subscale accounted for 42.63% of the variance, with all items demonstrating strong loadings. Overall, the results support the structural validity of the CAEQ subscales, while also identifying specific items for further refinement in future confirmatory analyses.

The Physical Chemistry Assessment

A set of three multiple choice tests, covering each of the three units, and containing 79 items in total, was used to determine students' performance on the physical chemistry module. The tests were administered in person at the end of each unit, and at different points throughout the module. The first test consisted of 30 items, the second 25 items and the third 24 items. Each multiple-choice item was scored using 1 for each correct response and 0 for an incorrect response. Students had a choice of four possible answers for each item.

Assessment of the internal consistency of the overall multiple-choice test using Cronbach's alpha yielded a reliability coefficient of 0.78.

A comparison of this Alpha result with those reported by others (D. Cheung, 2009; Dalgety et al., 2003; Salta & Tzougraki, 2003) shows that the measurement has a satisfactory and acceptable reliability. The validity of the items on the physical chemistry tests was also satisfied, in that they were measuring students' knowledge on the tested theory. All items for the tests were selected from the test item file of the accompanying prescribed text, supplied by the publisher of the text for instructors only. Each item was first submitted to experts in the field by the publisher and properly checked before publishing and sending to instructors. The items were selected based on the topics taught in the units of the module. In addition, each test was checked for length and manageability by students, by administering it on two previous occasions to different sets of students, and modified where necessary to ensure language accessibility.

Data Collection

There were two 30-minute administrations of the CAEQ. The first administration (pre-test) included Parts 1–3, which addressed demographics, attitudes-toward-chemistry, and chemistry self-efficacy. The second administration (post-test) covered all four parts of the instrument, with Part 4 focusing on university chemistry learning experiences. Both administrations were conducted during in-person class time — the first (pre-test) during the opening week before lectures began, and the second (post-test) in the final week following the end of lectures. Of the 80 students enrolled in the physical chemistry module, 70 completed the questionnaire on both occasions, resulting in a response rate of 87.5%. Additionally, students were assessed on the module content using multiple-choice tests administered at three intervals during the semester (weeks 4, 8, and 12). Each test (related to each unit) lasted one hour, with a maximum combined test score of 79, assigning one mark per correct response.

Data Analysis

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS versions 12.0 and 14.0) and Microsoft Excel (1997–2003 Workbook). Scoring of the multiple-choice tests was done manually, assigning one mark for a correct response and zero for an incorrect response. To provide answers to research questions the following applications were employed.

RQ1: Are the pre- and post-test attitudes-toward-chemistry and chemistry self-efficacy of first-year students positive or negative?

In response to this question, frequency distributions, means, and standard deviations for pre- and post-test attitudes-toward-chemistry, and chemistry self-efficacy; and post-test first-year chemistry learning experiences, were computed and analyzed.

RQ2: Are there significant differences in the students' pre- and post-test scores on attitudes-toward-chemistry and chemistry self-efficacy items?

In response to this question, paired t-tests of differences in pre- and post-test results of attitudes-to-chemistry and chemistry self-efficacy were calculated and analyzed.

RQ3: What relationships are there among students' high school chemistry grades, attitudes, self-efficacy, and learning experiences related to chemistry, and their academic performance on a physical chemistry module in the first year of university?

Pearson correlation coefficients were used to examine relationships between students' high school grades, attitudes-toward-chemistry, self-efficacy, university learning experiences, and their academic performance in chemistry at university.

Ethical Considerations

This study analyzed data exploring relationships among high school chemistry performance, attitudes-toward-chemistry, chemistry self-efficacy, university chemistry learning experiences, and performance on a physical chemistry module. Ethical approval was obtained from the university's Research Ethics Board.

Informed consent was obtained from all participants after they were provided with detailed information about the study's purpose, procedures, and their rights (including the right to withdraw at any time), at the beginning of the questionnaire (see Appendix 1). Confidentiality was ensured by anonymizing all data—removing identifying information and storing the data securely with access restricted to the researcher. Only data directly related to the study's objectives were used. Survey items were carefully designed to minimize the risk of discomfort. No harm was anticipated, and none was reported. All procedures adhered to institutional ethical guidelines.

Results and Discussion

Research Question 1

Are the pre- and post-test attitudes-toward-chemistry and chemistry self-efficacy of first-year students positive or negative?

The pre- and post-test attitudes-toward-chemistry and chemistry self-efficacy of first-year university students were found to be positive.

Table 3*Statistics for the Pre-test and the Post-test Attitudes-toward-Chemistry and Chemistry Self-efficacy*

	n	Pre-test			Post-test			t*	p
		Mean	SD	%	Mean	SD	%		
Attitudes-toward-chemistry	70	113.43	14.89	77.16	113.46	14.59	77.18	0.01	p>0.05
Chemistry self-efficacy	70	85.06	17.22	71.48	88.59	16.46	74.45	1.24	p>0.05

*Paired t-test between pre- and post-test means; no significant differences in mean scores. Maximum possible score on attitudes-toward-chemistry = 147; maximum possible score on chemistry self-efficacy = 119

Part 2 of the CAEQ questionnaire, with 21 items, measured participants' attitudes-toward-chemistry, allowing for a maximum possible score of 147. A total score greater than 84 indicated an overall positive attitude, while a score below 84 suggested a negative attitude. As seen in Table 3, students scored an average of 113.43 on the pre-test (SD 14.89) and 113.46 (SD 14.59) on the post-test of the Attitudes-toward-Chemistry Scale, representing 77.16% and 77.18% of the maximum score respectively, for the sample (n=70).

The positive pre-test attitudes-toward-chemistry displayed by the students are in keeping with expectations of science majors with at least 3 years prior exposure to chemistry. These results are consistent with those of Dalgety et al. (2003) which indicate that students entering first-year chemistry classes at two tertiary institutions in New Zealand showed positive attitudes towards the subject. The fact that attitudes-toward-chemistry remained positive after one semester of university chemistry suggests that university learning experiences did not diminish students' interest in the subject; even though most students, while passing the physical chemistry tests, received low grades. University learning experiences reinforced the positive attitudes-toward-chemistry displayed by the students and were possibly influenced and maintained by the knowledge and expertise of the instructor; the positive relationships among students, their

peers, and instructor; and an overall positive classroom climate (Musengimana et al., 2021). Nevertheless, one semester of chemistry may not have been sufficient to produce meaningful or significant changes in students' attitudes-toward-chemistry as influenced by their university learning experiences.

Part 3 of the CAEQ represented the self-efficacy scale and contained 17 items. There was a maximum possible score of 119. A total score greater than 68 indicated an overall positive self-efficacy, while a score below 68 suggested a negative self-efficacy. As seen in Table 3, the students' mean scores were 85.06 (SD 17.22) and 88.59 (16.46) on the pre- and post-test chemistry self-efficacy items respectively. These means represent 71.48% and 74.45% respectively of the maximum score and indicate a positive chemistry self-efficacy by most students before and after their experience with the chemistry module. This finding is similar to that of Dalgety and Coll (2006) in their study conducted on the self-efficacy of students enrolled in a first-year chemistry course geared at both majors and non-majors. High pre-test scores were expected, as enrollment in health science programmes requires a passing grade (I-III) in Chemistry at the CSEC or equivalent level, and students' prior learning experiences are known to influence their self-efficacy (Cooper, 2010; Dalgety & Coll, 2006; Pappalardo & Gunn, 2013).

There was no decline in self-efficacy of students after a semester of physical chemistry. This was reassuring, since previous research suggests that the mathematical demands of physical chemistry often induce anxiety, particularly among female students. For example, Eriba and Ande (2006), Kousathana and Tsaparlis (2002), and Tai et al. (2005) reported that such demands can negatively impact students' confidence. Given that 57 of the 70 participants in this study were female, a potential decrease in self-efficacy scores was anticipated. It would be valuable for future research to examine whether a more gender-balanced sample would yield different results. Dalgety and Coll (2006) reported positive self-efficacy of students after 1 year of chemistry instruction, although they were uncertain if this was due to the dropout of less confident students. In this study, however, there were no dropouts during the one semester course, so we attribute the positive post-test chemistry self-efficacy scores (which showed a slightly higher mean than the pre-test), to positive learning experiences during the module. Question 2 explored the significance of the differences between pre- and post-test results.

Research Question 2

Are there significant differences in the students' pre- and post-test scores on attitudes-toward-chemistry and chemistry self-efficacy items?

As shown in Table 3, the mean attitudes-toward-chemistry scores of students was 113.43 on the pre-test (SD 14.89) and 113.46 (SD 14.59) on the post-test. When the t-test for paired samples was run, it revealed that there were no significant differences between the two means ($t=0.01$, $df=69$, $p>0.05$). The similar pre- and post-test results might be explained by the relatively short university chemistry learning experience (the students were taught the module of physical chemistry for one semester of 13 weeks) or the fact that all students were science majors.

Table 3 also showed that the mean chemistry self-efficacy scores of students was 85.06 on the pre-test (SD 17.22) and 88.59 (SD 16.46) on the post-test. When the t-test for paired samples was run it revealed that there were no significant differences between the two means ($t=1.24$, $df=69$, $p>0.05$). The similarity in pre- and post-test scores may be attributed to the relatively short duration of the university chemistry module (only 13 weeks), and that all participants were science majors. In addition, students entered university with already high levels of self-efficacy, leaving limited room for measurable improvement. This contrasts with the findings of Thalluri et al. (2021), who reported a significant increase in student self-efficacy following a short, pre-university science course. It is possible that a longer period of instruction could yield more substantial effects on both students' attitudes-toward-chemistry and their chemistry self-efficacy, potentially resulting in statistically significant differences between pre- and post-test scores. Further research is warranted, as students' perceptions of their university learning experiences (whether positive or negative) are likely to influence these outcomes (Harlen, 2006; Moreno et al., 2021; Simpson & Oliver, 1990).

Research Question 3

What relationships are there among students' high school chemistry grades, attitudes, self-efficacy and learning experiences related to chemistry, and their academic performance on a physical chemistry module in the first year of university?

Pearson correlation coefficients relating the independent and dependent variables were computed. The results are shown in Table 4.

Table 4*Pearson Correlation Coefficients Relating Independent and Chemistry Module Score*

Variables	Chemistry Module Score
High school chemistry grades	0.41**
Post-test attitudes-toward-chemistry	0.05
Post-test chemistry self-efficacy	0.32*
Post-test university first year learning experiences	0.29*

*pbir = 0.01; **pbir = 0.001

High school chemistry grades show the strongest and most statistically significant correlation with the Physical Chemistry Module Score ($r = 0.41$, $p < 0.001$). This suggests that prior academic performance in chemistry is a meaningful predictor of success in the module. Post-test Chemistry Self-efficacy ($r = 0.32$, $p < 0.01$) and First Year Learning Experiences ($r = 0.29$, $p < 0.01$) are also positively and significantly correlated with performance. This indicates that students' confidence in their chemistry abilities and their perceptions of their learning environment are moderately associated with better outcomes. The Post-test Attitudes-toward-Chemistry ($r = 0.05$) show a very weak, non-significant relationship with the Chemistry Module Score, suggesting that while students may like or appreciate chemistry, this alone does not predict their performance.

Close examination of test scores showed that students who earned an A in GCE O-Level or a Grade I in CSEC chemistry scored significantly higher in the theoretical content of the physical chemistry module than their peers with lower high school chemistry grades. While some researchers believe there is a link between positive attitudes-toward-chemistry and academic success (Casimir et al., 2023) and there are studies which link positive student attitudes to high chemistry attainment (Kan & Akbaş, 2006; Levin et al., 1991; Lewis et al., 2009; Musengimana et al., 2021), none of these

studies examine the extent of the attitudes or the impact of students' chemistry attainment in physical chemistry at the first year of university. In future studies, it would be interesting to discover the extent of the connections between high school chemistry grades and achievement in university chemistry for this population.

In summary, although no relationships were found between module performance and students' attitudes, there was a positive, statistically significant, but weak relationship with self-efficacy, learning experiences, and high school chemistry grades; the relationship with high school grades being the strongest.

Limitations

While important, this study provides only a preliminary exploration of Caribbean university students' chemistry learning experiences and performance. A more extensive year-long investigation could offer more conclusive insights into the impact of university learning experiences on attitudes-toward-chemistry and chemistry self-efficacy.

No pilot testing of the amended CAEQ was conducted with the sample population. Given potential differences in the characteristics of the current survey population compared to those in prior validations, these factors may have influenced the results.

The study focussed exclusively on physical chemistry, neglecting organic and inorganic chemistry. This limits the generalizability of the findings across other crucial areas of the chemistry curriculum. A more comprehensive examination encompassing all areas might have offered a more nuanced understanding of challenges encountered in first-year chemistry.

The relatively small convenience sample of 70 students from a single university (instead of a larger random sample) can affect the external validity of the results and limit their generalizability. Nevertheless, the study is an important first step in interrogating the issues.

Conducted over a single semester of 13 weeks, there was not enough time in this study to observe the possible changes resulting from university learning experiences. A longer-term study could provide deeper insights into how learning experiences influence attitudes, self-efficacy, and performance as well as the sustained impact of educational interventions.

Although the Cronbach's alpha for the multiple-choice items resulted in a reliability coefficient of 0.78 (which is within the acceptable range for studies of this type), test-retest reliability would have added to the reliability of the instrument. However, this was omitted because of time constraints.

Conclusion, Implications, and Future Work

This study found that students entered university with positive attitudes and strong self-efficacy toward chemistry, which remained stable after taking one semester of physical chemistry. Their learning experiences were also largely positive; however, performance in the CSEC Chemistry examination emerged as the strongest predictor of success in first-year university physical chemistry. These findings highlight the critical role of prior academic preparation (Tai et al., 2005) and suggest that universities may need to strengthen chemistry

matriculation requirements or implement targeted interventions for incoming students. Where stricter entry criteria are not feasible, alternative approaches such as concurrent support courses, culturally responsive instruction, and pre-university online tutorials (delivered through platforms like YouTube and Moodle) could help address gaps in foundational knowledge. Future research should expand to other Caribbean institutions for comparative insights and the adoption of mixed-methods designs, to better understand the factors influencing student performance. Ultimately, bridging the gap between high school and university chemistry teaching and learning is essential to improving outcomes and student readiness for the demands of tertiary-level chemistry.

Eddia P. Copeland Solas, PhD is currently an Associate Professor in the Faculty of Education at Mount Saint Vincent University. She has a Ph.D. in Chemistry, a Master of Science Education and a Master of Teaching. She previously taught in the Chemistry Department at the University of Technology, Jamaica. As a Science Educator, her research focuses on chemistry education, culturally responsive pedagogies in science, addressing common misconceptions in science, teaching science to English-as-an-additional-language learners, and identifying barriers to student learning in science.

Email: eddia.solas@msvu.ca

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Appendix 1

Adapted CAEQ – Chemistry Attitudes and Experiences Questionnaire (Coll et al. 2002; Dalgety et al., 2003).

Dear Student:

We invite you to participate in a survey aimed at evaluating your chemistry attitudes and experiences of first-year university chemistry. Please indicate your willingness to participate by completing the questionnaire below. All personal information obtained from this survey will be kept strictly confidential. Any report of the results obtained from this survey will be generalized to obscure the identity of any particular student. Refusal to participate will have no effect on your chemistry grade. Your thoughtful responses to the questions in this survey will enable us to improve the quality of chemistry education provided to first-year students. Thank you for participating.

This part of the questionnaire seeks to obtain demographic data as well as your chemistry background. Please respond by filling in the blanks. For example: If your highest level of chemistry studied is CAPE chemistry you would answer the following as shown:

Highest level of chemistry studied CAPE chemistry

Grade obtained IV

Name: _____

ID# _____

Age: _____

Gender: _____

Occupation of parent(s) or guardian _____

High School _____

Grade in CSEC/O'Level Chemistry or equivalent: _____

Highest level of Chemistry studied _____ Grade obtained _____

Programme _____

This part of the questionnaire investigates the perceptions **YOU HAVE ABOUT CHEMISTRY AND RELATED TOPICS**. For example: If you feel chemistry is mostly about the study of natural substances, and only a little bit about the study of synthetic substances then you would answer the following questions as shown:

Chemistry Natural Substances √ _____ Synthetic Substances

Please indicate what YOU think about the following			
Chemists			
1	Athletic	_____	Unfit
2	Socially aware	_____	Socially unaware
3	Environmentally aware	_____	Environmentally unaware
4	Flexible in their ideas	_____	Fixed on their ideas
5	Care about the effects of their results	_____	Only care about their results
6	Imaginative	_____	Unimaginative
7	Inquisitive	_____	Indifferent
8	Patient	_____	Impatient
Chemistry Research			
9	Helps people	_____	Harms people
10	Improves quality of life	_____	Decreases quality of life
11	Solves problems	_____	Creates problems
12	Advances society	_____	Causes society to decline
Science Documentaries			
13	Enjoyable	_____	Boring
Chemistry Websites			
14	Interesting	_____	Boring
Chemistry Jobs			
15	Challenging	_____	Easy
16	Varied	_____	Repetitive
17	Interesting	_____	Boring
18	Satisfying	_____	Unsatisfying
19	Exciting	_____	Tedious
Talking to my Friends about Chemistry			
20	Fascinating	_____	Dull
Science Fiction Movies			
21	Exciting	_____	Tedious

This part of the questionnaire investigates the confidence **YOU HAVE IN UNDERTAKING DIFFERENT TASKS**. For example: If you feel extremely confident about talking to a scientist about chemistry then you would answer the following questions as shown:

Please indicate how confident you feel about talking to a scientist about chemistry

Totally confident √ _ _ _ _ _ Not confident

Please indicate how CONFIDENT YOU feel about				
1	Applying a set of chemistry rules to different elements of the periodic table	Totally confident	_ _ _ _ _	Not confident
2	Tutoring another student in a first-year chemistry course	Totally confident	_ _ _ _ _	Not confident
3	Ensuring that data obtained from an experiment is accurate	Totally confident	_ _ _ _ _	Not confident
4	Proposing a meaningful question that could be answered experimentally	Totally confident	_ _ _ _ _	Not confident
5	Explaining something that you learnt in this chemistry course to another person	Totally confident	_ _ _ _ _	Not confident
6	Choosing an appropriate formula to solve a chemistry problem	Totally confident	_ _ _ _ _	Not confident
7	Knowing how to convert the data obtained in a chemistry experiment into a result	Totally confident	_ _ _ _ _	Not confident
8	After reading an article about a chemistry experiment, writing a summary of the main points	Totally confident	_ _ _ _ _	Not confident
9	Learning Chemistry theory	Totally confident	_ _ _ _ _	Not confident
10	Determining the appropriate units for a result determined using a formula	Totally confident	_ _ _ _ _	Not confident
11	Writing up the experimental procedures in a laboratory report	Totally confident	_ _ _ _ _	Not confident

	Please indicate how CONFIDENT YOU feel about			
12	After watching a television documentary dealing with some aspect of chemistry, writing a summary of its main points	Totally confident	— — — — —	Not confident
13	Applying theory learnt in a lecture for a laboratory experiment	Totally confident	— — — — —	Not confident
14	Writing up the results section in a laboratory report	Totally confident	— — — — —	Not confident
15	After listening to a public lecture regarding some chemistry topic, explaining its main ideas to another person	Totally confident	— — — — —	Not confident
16	Reading the procedure for an experiment and conducting it without supervision	Totally confident	— — — — —	Not confident
17	Designing and conducting a chemistry experiment	Totally confident	— — — — —	Not confident

This part of the questionnaire looks at **YOUR EXPERIENCES DURING YOUR MOST RECENT CHEMISTRY CLASSES**. Please answer these questions considering ALL your experiences during your most recent chemistry classes. For example if you thought that the concepts introduced in the lectures were explained very clearly, you would answer the following question.

The concepts introduced in the lecture material were explained clearly ☒ SA ☐ A ☐ N ☐ D ☐ SD

		Strongly agree	Agree	Neither	Disagree	Strongly disagree
	Please answer these questions about your lecture classes					
1	My lecturers were interested in my progress in Chemistry	SA	A	N	D	SD
2	The concepts introduced in the lecture material were explained clearly	SA	A	N	D	SD
3	The lecture material was relevant to the objectives of the course	SA	A	N	D	SD
4	The lecture notes were interesting	SA	A	N	D	SD
5	The chemistry lecturers have made me feel that I have the ability to continue in science	SA	A	N	D	SD
6	The lecture notes were clearly presented	SA	A	N	D	SD
7	The lectures were well organized and structured	SA	A	N	D	SD
8	The lectures were presented in an interesting manner	SA	A	N	D	SD
9	The lecturers explained problems clearly to me	SA	A	N	D	SD

	<i>Please answer these questions about your TUTORIAL classes</i>				
10	The tutorial problems covered all parts of the course	SA	A	N	D SD
11	The problems in the tutorial sheets were relevant to the course	SA	A	N	D SD
12	The tutor was interested in my progress in chemistry	SA	A	N	D SD
13	The tutorial sheets helped me understand the lectures	SA	A	N	D SD
14	The chemistry tutors made me feel I have the ability to continue in science	SA	A	N	D SD
15	The material presented in tutorials was useful	SA	A	N	D SD
16	The material covered in tutorials was presented in an interesting manner	SA	A	N	D SD
17	The tutor explained problems clearly to me	SA	A	N	D SD
	<i>Please answer these questions about your LABORATORY classes</i>				
18	The laboratory manual contained instructions that were easy to follow	SA	A	N	D SD
19	When writing-up experiments in my laboratory book, the relationship between the data and the results was clear	SA	A	N	D SD
20	My lab supervisor was interested in my progress in chemistry	SA	A	N	D SD
21	The practical experiments were related to lectures	SA	A	N	D SD
22	What is required in the write-up of an experiment is clear	SA	A	N	D SD
23	The theory behind the experiments was clearly presented	SA	A	N	D SD
24	The purpose of the calculations required for laboratory books write-up was clear	SA	A	N	D SD
25	The laboratory manual, experimental techniques and write-up were all interlinked	SA	A	N	D SD
26	What was required in the questions when writing up the laboratory book was clear	SA	A	N	D SD
27	It was easy to find a lab supervisor to discuss a problem with	SA	A	N	D SD
28	The experiments were interesting	SA	A	N	D SD
29	The amount of work required when writing up the laboratory report was appropriate for the amount of the assessment	SA	A	N	D SD
30	The laboratory supervisor explained problems clearly to me	SA	A	N	D SD