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Attitude and Achievement of First-Year Chemistry Undergraduate Students at The University of the South Pacific

Joel Johnson[1], Pritika Reddy[2], Sushita Sharma[2], Lara Wakeling[3], Janice Mani[1], Tessa Benveniste[1], Mani Naiker[1] and Stephen Brown[4]*

[1] School of Health, Medical and Applied Sciences, Central Queensland University, Rockhampton, QLD, Australia, [2] School of Information Technology, Engineering, Mathematics, and Physics, The University of the South Pacific, Suva, Fiji, [3] School of Science, Psychology and Sport, Federation University Australia, Ballarat, VIC, Australia, [4] Department of Interprofessional Health Studies, Auckland University of Technology, Auckland, New Zealand

Student attitude toward chemistry may influence engagement and achievement in chemistry-related courses, however, equivocal results in studies conducted in Western countries to date indicate this relationship requires further investigation. In this study, we investigated the correlation between attitude toward chemistry and achievement amongst a cohort of first-year undergraduate students from The University of the South Pacific (USP). A cluster analysis was used to identify low- and high-achieving groups of students to further explore potential correlations. There was a positive correlation between the cognitive and affective components of attitude among low-achieving students, but not among high-achieving students. The cognitive component of attitude did not appear to be strongly correlated with achievement in students from either group, although the affective component was positively correlated with achievement. The single item most strongly correlated with student achievement was their response on the Worthless-Beneficial scale. One of the notable findings was the differences in the attitude-achievement relationship between low-achieving and high-achieving students, suggesting that combining these clusters of students into a single group for analysis may obscure underlying correlations. Chemistry educators should continue to target their teaching styles to cater to different learning styles and achievement levels of students, including cognitive and non-cognitive learning styles.

Keywords: first-year undergraduates, chemistry education, attitude, achievement, cluster analysis

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Muhammet Usak,
Kazan Federal University, Russia

Reviewed by:
Muharrem Duran,
Yozgat Bozok University, Turkey
Abraham Flanigan,
Georgia Southern University,
United States

Correspondence:
Stephen Brown
stbrown@aut.ac.nz

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INTRODUCTION

Current trends in Higher Education, ranging from governance issues and policies right through to academic integrity, primarily revolve around one central focus: student success (Denisova-Schmidt, 2017). The concept of student success has multi-dimensional definitions throughout the literature; however, York et al. (2015, p. 4) defined student success as comprising six aspects; (1) academic achievement, (2) satisfaction, (3) acquisition of skills and competencies, (4) persistence, (5) attainment of learning objectives, and (6) career success. Given the importance of student success, it is not surprising that many universities invest millions of dollars in retaining students and helping them achieve success in their studies (Simpson, 2005; Cuseo, 2010).

For universities, one of the most used metrics of student success is academic achievement due to the ease of measuring this parameter, and therefore research into factors affecting student academic achievement has become a seminal area of interest for researchers, academics, and Higher Education institutions. These factors can be broadly divided into teaching and learning perspectives. Generally, university instructors only have control over teaching methods; however, it is also important to understand the impact of various internal factors in determining achievement. In a university setting, achievement is dependent upon the student acquiring relevant skills, which in many cases necessitates a significant investment of effort and perseverance in the pursuit of learning objectives; a concept known as "grit" (Hodge et al., 2018). Furthermore, the amount of effort expended by a student is also dependent upon their attitude toward the subject, with more positive attitude typically leading to improved achievement in university programs (Osborne et al., 2003; Xu et al., 2012).

One discipline which may be particularly difficult for new students to learn is the study of chemistry (Zoller, 1990; Wood and Donnelly-Hermosillo, 2019; Naiker et al., 2021). Chemistry – often referred to as "the central science" – enables students to better understand natural phenomena and the world they live in Majid and Rohaeti (2018). It is a foundational science and thus often a core requirement for first year students studying a wide range of topics. As noted by Kousa et al. (2018) and Wahyudiati and Rohaeti (2020), there is a need to promote chemistry education so that individuals are prepared to solve future scientific challenges and contribute to the collective development of society.

Attitude and Student Achievement in the South Pacific Context

This current research project was conducted at The University of the South Pacific (USP), a regional higher education provider in the Pacific Oceanic region. The university is jointly operated by 12 member nations and services an area of 30 million square kilometers across the Pacific Ocean, with more than 30,000 students enrolled in total. Ongoing studies continue to provide deeper insight into the learning styles and patterns of Pacific students, with courses and content delivery being modified accordingly (Sharma et al., 2018, 2020). For example, educators often incorporate the "Pacific way of learning" into their courses, which is any informal education that does not include classroom-based or curriculum-based learning. The uniqueness of Pacific Oceanic geography and multi-national governance structure of USP provides a novel student experience which is currently understudied. The continued diaspora of Pacific peoples away from the region, particularly those obtaining higher education in the region's Universities, also necessitates more investigation into undergraduate student experience.

There have been previous studies on student attitude toward science (including several studies looking at chemistry specifically) in this regional population, for example, Naiker et al. (2020a) used Test Of Science Related Attitudes (TOSRA) to evaluate the attitude of secondary Fijian students toward science, finding a generally positive attitude, although differences were observed based on gender and ethnicity. Also, Sharma et al. (2021) found slightly poorer attitudes among secondary Tongan students, although there was no difference between genders in this population. Others (Brown et al., 2014a) used the Attitude to the Study of Chemistry Inventory (ASCI) instrument to quantify attitude toward chemistry in cohorts of first-year undergraduate and foundation chemistry students. Students' attitudes were generally positive, with Brown et al. (2014a) identifying three constructs of attitude measured by the instrument (affective, cognitive and value). However, no correlation between attitude and achievement was conducted.

Previous studies have reported a moderately positive correlation between student attitude and their achievement in university-level courses (Osborne et al., 2003; Xu and Lewis, 2011; Xu et al., 2012). However, data correlating the attitude and achievement of students studying chemistry is quite limited (Bauer, 2008). Among the major branches of science, chemistry stands as a unique topic, generally requiring more theoretical principles and mathematical knowledge compared to biology, but also more hands-on laboratory skills compared to fields such as physics. Hence there may not be a strong correlation between student attitude and their achievement in chemistry, as other internal factors influencing student achievement, such as mathematical knowledge, also affect student achievement to a considerable degree. Indeed, previous studies looking specifically at the relationship between attitude and achievement in chemistry students have only found a weak positive correlation (Bauer, 2008; Xu and Lewis, 2011; Brown et al., 2015). Hence in this study we sought to clarify the relationship between student attitude and achievement amongst undergraduate chemistry major students at a regional university in the South Pacific region.

Student Attitude

Difficulties arise when investigating student attitude toward a given topic, as the concept of "attitude" is not well understood and remains a "somewhat nebulous" idea (Brown et al., 2014a). Part of the confusion stems from the fact that attitude is not a unidimensional construct (Reid, 2006). Rosenberg et al. (1960) proposed a tripartite model of attitude, comprising cognitive, affective, and behavioral elements. In this model, the cognitive component encompasses the student's knowledge and belief surrounding the topic in question; the affective component includes their individual preferences about the topic; while the behavior component incorporates how the student tends to act regarding the topic. Bagozzi and Burnkrant (1979) later proposed a two-component model of attitude, comprising only the cognitive and affective elements, arguing that student behavior was largely derived from their cognitive and affective attitude toward the topic, rather than being a distinct entity of student attitude. In other words, student attitude toward the subject of chemistry could be thought of as how the students think (cognitive element) and feel (affective element) toward chemistry.

There is a growing body of research on student attitude, achievement, and the relationship between these two variables. Work by Majid and Rohaeti (2018) demonstrated that a positive attitude toward learning improved motivation and learning outcomes for students. Similarly, Kahu and Nelson (2018) concluded that student attitude is a critical factor that determines student achievement. They argue that although other factors are related to student achievement, students are responsible for their learning and play a central part in the teaching and learning process.

Student Attitude Toward Science Subjects

The attitude of students toward science is the determining factor of emotions such as "liking" or "disliking" science subjects, affecting their learning outcomes and performance (Kurniawan et al., 2019). Such attitudinal constructs can either guide students to study the subjects in related fields or subjects they like, or they can push students away from careers that require even moderate competencies in the subject (Recber et al., 2018). There is generally a positive attitude toward science amongst secondary students; however, a smaller number of students still have a negative attitude (Naiker et al., 2020a). In such cases, teacher motivation and learning design play important roles in garnering student attention and improving students' attitude toward science subjects. Although there has been a sustained level of research into general attitudes toward science using instruments such as the Science Attitude Scale (SAS; Bajaj and Devi, 2021) and the TOSRA (Sharma et al., 2021), there is a recent trend to consider more specific science disciplines, such as chemistry (Montes et al., 2018; Rüschenpöhler and Markic, 2020). This follows from studies demonstrating a visible decrease in student interest and achievement in specific science disciplines (Vilia et al., 2017) and subsequent impaired progress to related undergraduate programs in Higher Education institutes (Sharma et al., 2018). Studies on the effect of student attitude toward achievement have been conducted across a range of subjects such as mathematics, English, physics, and chemistry (Vilia et al., 2017; Dimosthenous et al., 2020; Kaur and Vadhera, 2021; Sharma et al., 2021). However, we focus specifically on studies from the chemistry discipline in the remainder of this section.

Studies investigating student achievement and success in chemistry have demonstrated negative impacts of various issues including unappealing teaching methods (Najid et al., 2021), lack of enjoyment in the subject (Majid and Rohaeti, 2018), and disinterest of students toward the subject (Duangsri et al., 2017). However, there is evidence that positive student attitudes toward the subject of chemistry can correlate with student achievement (Brown et al., 2015; Vilia et al., 2017; Kousa et al., 2018; Montes et al., 2018; Kenni, 2019; Wahyudiati and Rohaeti, 2020). Other work by Fraser and Lee (2015) has indicated that student attitude is partially responsible for student achievement, while other factors such as self-efficacy, motivation and the learning environment were also significant contributors. To explore the potential impact of these additional factors, a range of studies have been conducted to evaluate the attitude of students and/or their achievement in chemistry from different perspectives and dimensions such as gender-based differences (Steegh et al., 2021), the influence of teacher practices (Mwangi et al., 2020), the self-efficacy of students (Kadioglu-Akbulut and Uzuntiryaki-Kondakci, 2021) and their experiences in learning chemistry (Kaur and Vadhera, 2021; Naiker et al., 2021). Most notably, Celik (2018) showed that providing students with an interactive and engaging learning environment only enhance their achievement if they had a positive attitude toward the topic, otherwise no improvement in achievement was observed. This highlights the importance of Higher Education providers assessing and understanding the attitude toward chemistry amongst their student cohorts.

The current research will attempt to identify any possible relations between student attitude and achievement in undergraduate introductory chemistry at USP. The internal structure of the instrument used to quantify attitude will also be explored (factor analysis), and a grouping technique (cluster analysis) will be applied to student achievement scores to identify different levels of academic ability. Relations between attitude and academic performance will then be explored in any groups identified, using correlation.

MATERIALS AND METHODS

Instrument Choice

For the assessment of student attitudes toward the study of chemistry, this study utilized the ASCI instrument, as developed by Bauer (2008). Several instruments have been developed specifically for measuring student attitude and experiences in the study of chemistry, including the Chemistry Attitudes and Experiences Questionnaire (CAEQ; Wahyudiati and Rohaeti, 2020; Naiker et al., 2021), the ASCI (Bauer, 2008), its refined version, the ASCIv2 (Xu et al., 2012), amongst others (Salta and Tzougraki, 2004; Cheung, 2009). The ASCI and ASCIv2 have been used by numerous researchers for quantifying student attitudes toward chemistry (Xu and Lewis, 2011; Brown et al., 2014a, 2015; Kahveci, 2015; Mooring et al., 2016; Sen et al., 2016; Sen and Oskay, 2017), making them among the most widely used and validated instruments for this purpose. Both instruments display two distinct subscales consistent with the two elements of attitude proposed by Bagozzi and Burnkrant (1979) (i.e., cognitive and affective). The instrument utilizes a semantic differential response, with students asked to position their response on a 7-point scale (between two opposing adjectives, e.g., good-bad, valuable-worthless). The use of this approach avoids students "reading" social desirability or directionality into the item, hence maximizing the focus of the instrument upon students' individual attitudes toward chemistry. To minimize response bias, the positive adjective is presented first for some of the items, while the negative adjective is presented first for the remaining items.

Ethical approval for this study was obtained from the Human Research Ethics Committee of the host university (The University of the South Pacific). The study population was the 2013 cohort of undergraduate chemistry major students at USP who were enrolled in a first-year chemistry unit (CH102; Principles and Reactions of Organic Chemistry). This unit is compulsory for students enrolled in the Bachelor of Science degree, with either a major or minor in chemistry (Wakeling et al., 2014). All students enrolled in this course must have previously passed chemistry in high school or completed a foundational chemistry unit at university. The unit content was delivered in a face-to-face format *via* standard 4 × 50-min lectures per week throughout the 14-week semester and included a weekly 1 h tutorial session and 12 × 3 h practical laboratory classes throughout the semester. It was also supported by teaching material and other resources uploaded to the online learning platform (Moodle). Half of the overall grade for the unit is derived from student performance on continuous assessment items throughout the term (two short tests and laboratory-based assessment), while the final exam provides the other half of their grade. The laboratory assessment component included lab reports, as well as a final lab skills-based assessment. To pass the unit, students must achieve at least 40% on the final exam and 50% overall for the unit, as well as at least 60% tutorial attendance and 75% laboratory attendance (Gopalan, 2014).

To measure student achievement in the unit, the scores for each student on the continuous assessment items and final exam were utilized. To obtain the overall grade for the unit, these scores were summed. Grades data were available for a total of 235 students. In addition, the attendance rates of individual students at the laboratory and tutorial classes were also recorded. It should be noted that marks for individual assignments were not available for all students; hence only the results of 221 students are included in analysis relating to grades achieved on individual assessment items. All students were invited to complete the ASCI instrument, with 97 students opting to provide informed consent and allow their grade data to be anonymously linked to their ASCI survey responses. A total of 95 valid responses were provided; only these responses were used in subsequent analyses correlating student attitudes with their grades. The cognitive sub-scale for each student was calculated by summing the scores for questions 1, 4, 5, and 10, while the affective sub-scale was calculated by summing responses to questions 7, 11, 14, and 17; following the methods of Brown et al. (2015). For all items, a higher rating indicates a more positive attitude toward chemistry. Exploratory factor analysis using principal component analysis with varimax rotation was performed in SPSS (v26), to confirm if the subscales identified in the present dataset matched those subscales identified by previous researchers. All other statistical analyses were performed in R Studio, running R 4.0.2 (R Core Team, 2020). Cluster analysis using the K-means method was performed on students' academic achievement scores. K-means clustering is defined as a method having an iterative process in which the dataset is grouped into a number (K) of pre-defined non-overlapping clusters, making the inner points of the cluster as similar as possible while trying to keep the clusters at distinct space. The method allocates the data points to a cluster so that the sum of the squared distance between the clusters centroid and the data point is at a minimum, at this position the centroid of the cluster is the arithmetic mean of the data points that are in the clusters (Rosenberg et al., 2020).

RESULTS

Class Attendance and Grades

The average attendance throughout the semester was 89.1% for the laboratory classes and 81.6% for the tutorials. Attendance at lecture sessions was not monitored. The average overall mark for the unit was 49.7%, with most students achieving a passing grade (**Figure 1**).

Exploratory Factor Analysis

Initially, exploratory factor analysis (principal component analysis with varimax rotation) was conducted on the 95 responses to the ASCI instrument. The Kaiser-Meyer-Olkin measure was 0.790, indicating an adequate sample size for this analysis, while Bartlett's test of sphericity was $P < 0.001$, indicating that responses to the 20 variables (statements) were inter-related. Examination of the scree plot from the initial analysis suggested an optimum solution of three factors with eigenvalues >1, which together accounted for 45.6% of the variance. The exploratory factor analysis was then optimized for a three-factor solution, which provided the factor loadings shown in **Table 1** (explaining 51.3% of variance). These differed slightly from previous research on similar student populations (Brown et al., 2014a), principally for item numbers 1, 8, 13, and 19 (**Table 1**). The majority of items loaded onto the first factor, which appeared to be predominantly related to student interest and the level of mental challenge (e.g., Interesting – Dull, Comfortable – Uncomfortable, Satisfying – Frustrating). The second factor contained items relating to workload management and subject worth (e.g., Chaotic – Organized, Tense – Relaxed, Worthless – Beneficial). All three items loading onto the final factor were related to topic clarity and understanding (Confusing – Clear, Complicated – Simple, Easy – Hard).

Cluster Analysis

To investigate any natural "grouping" or "clustering" of students with differing achievement levels, cluster analysis was performed on the students' continuous assessment, final exam and overall scores. This revealed the presence of a low-achieving (LA) cluster comprising 38% of the cohort, with a high-achieving (HA) cluster comprising the remaining 62% of students, with the cluster ratio being 1:1.64.

As shown in **Table 2**, the LA cluster did not show any significantly lower attendance rates in the tutorial classes but did have significantly lower marks on the continuous assessment items and final exam, leading to lower overall grades for the unit ($P < 0.001$). In addition, the attendance at laboratory classes was much lower in the LA cluster ($P < 0.001$). However, although the LA cluster had slightly lower scores on both the cognitive and affective components of the survey instrument, this difference was not significant ($P > 0.05$).

Correlation of Attitude and Achievement

Among the entire student cohort, the rate of tutorial attendance was positively correlated with the marks achieved on the continuous assessment items ($r_{95} = 0.152$, $P < 0.05$) but

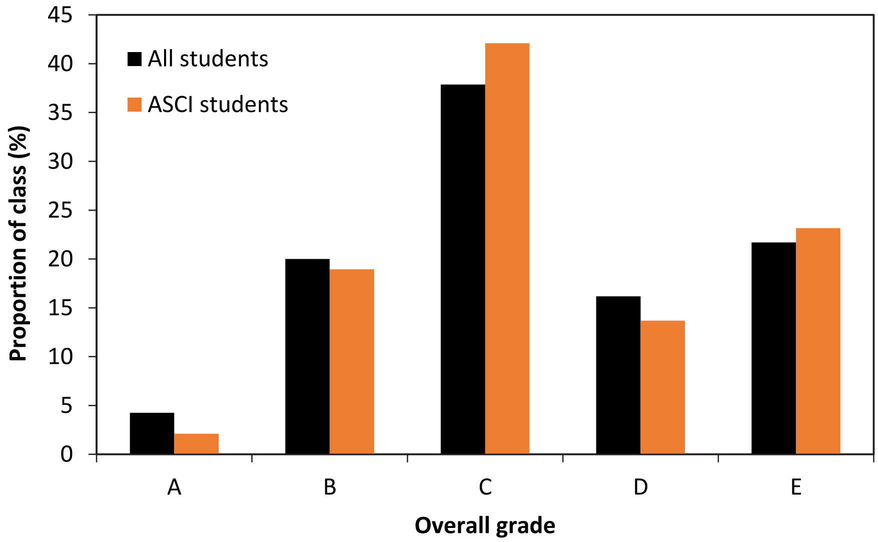

FIGURE 1 | Overall grade achieved by the entire class ($n = 235$ students) and students who completed the ASCI instrument ($n = 95$). Grades were calculated from students' total marks for the unit, as follows: (A) ≥77.5%, (B) 63.5–77.4%, (C) 49.5–63.4%, (D) 39.5–49.4%, and (E) <39.5%.

TABLE 1 | Factor loadings for the exploratory factor analysis.

Item	Word pair	Factor 1	Factor 2	Factor 3	Category from Brown et al., 2014a
12	Interesting – Dull	0.848			1
15	Worthwhile – Useless	0.790			1
11	Pleasant – Unpleasant	0.660			1
3	Exciting – Boring	0.644			1
14	Comfortable – Uncomfortable	0.627			1
13	Disgusting – Attractive	0.593			3
6	Good – Bad	0.584			1
18	Safe – Dangerous	0.561			1
7	Satisfying – Frustrating	0.515	0.514		1
9	Comprehensible – Incomprehensible	0.501			1
10	Challenging – Not Challenging	−0.533			2
16	Work – Play	−0.581			1
17	Chaotic – Organized		0.710		3
19	Tense – Relaxed		0.692		2
20	Insecure – Secure		0.631		3
8	Scary – Fun		0.512		2
2	Worthless – Beneficial		0.476		3
5	Confusing – Clear			0.733	2
4	Complicated – Simple			0.688	2
1	Easy – Hard			0.627	1

Note that loading values below 0.45 are not shown.

negatively correlated with the affective component of attitude ($r_{95} = -0.219$, $P < 0.05$). Attendance at laboratory classes was strongly positively correlated with the marks on the continuous assessment items ($r_{95} = 0.594$, $P < 0.01$), the final exam ($r_{95} = 0.388$, $P < 0.01$), and the overall grade for the unit ($r_{95} = 0.510$, $P < 0.01$). There was a positive correlation between the cognitive and affective components of attitude among students in the LA cluster ($r_{35} = 0.412$, $P < 0.05$), but not in the HA cluster ($r_{60} = 0.105$, $P > 0.05$).

As shown in **Table 3**, the affective component of student attitude toward chemistry was positively correlated with all assessment items (continuous assessment, final exam, and overall grade). However, it was negatively correlated with tutorial attendance. In contrast, the cognitive component was not significantly correlated with any assessment item or class attendance. In other words, the way students "felt" about the subject took precedence over what they "thought" about it.

TABLE 2 | Mean scores for the assessment items, attendance scores, and ASCI subscales.

	All students ($n = 221$)	Low-achieving (LA) cluster ($n = 87$)	High achieving (HA) cluster ($n = 134$)	*T*-Test between LA and HA clusters
Continuous assessment (out of 50%)	25.2 ± 8.8%	20.3 ± 5.8%	32.2 ± 4.2%	***
Final exam (out of 50%)	24.5 ± 9.1%	15.3 ± 5.0%	31.3 ± 6.2%	***
Overall marks (out of 100%)	49.7 ± 17.9%	35.6 ± 8.8%	63.6 ± 9.2%	***
Tutorial attendance (out of 100%)	81.6 ± 14.2%	81.8 ± 12.8%	82.5 ± 12.5%	NS
Laboratory attendance (out of 100%)	89.0 ± 17.9%	83.9 ± 19.2%	95.9 ± 7.4%	***
	($n = 95$)	**($n = 35$)**	**($n = 60$)**	
Cognitive subscale (out of 28)	13.5 ± 3.8/28	12.6 ± 3.8/28	14.1 ± 3.7/28	NS
Affective subscale (out of 28)	19.8 ± 3.8/28	18.7 ± 3.8/28	20.3 ± 3.7/28	NS

*NS, not significant ($P > 0.05$), ***$P < 0.001$.*

TABLE 3 | Correlation of attitude with attendance and achievement in the student cohort.

	Attitude component	Continuous assessment	Final exam	Overall grade	Tutorial attendance	Laboratory attendance
All students ($n = 95$)	Cognitive	0.180	0.151	0.176	−0.115	−0.015
	Affective	0.206*	0.372**	0.324**	−0.219*	−0.023
LA cluster ($n = 35$)	Cognitive	−0.061	−0.018	−0.052	−0.152	−0.106
	Affective	−0.030	0.512**	0.304	−0.294	−0.116
HA cluster ($n = 60$)	Cognitive	0.178	0.029	0.097	−0.097	−0.182
	Affective	0.189	0.273*	0.284*	−0.173	−0.284*

The results show Pearson correlation coefficients for all students, the low achieving (LA) cluster and the high achieving (HA) cluster.
*$P < 0.05$, **$P < 0.01$.*

For students in the LA cluster, the affective component was significantly correlated with their score on the final exam ($r_{35} = 0.512$, $P < 0.01$) but not the continuous assessment items. In the HA cluster, the affective component was positively correlated with the final exam and overall unit grade, but negatively correlated with laboratory attendance rates ($r_{60} = 0.284$, $P < 0.05$). This differed somewhat from the results of Brown et al. (2015), who found a positive correlation between the affective component and final exam score for both "all students" and "low achieving students," but not for "high achieving students."

Correlation Between Attitude and Individual Attitude to the Study of Chemistry Inventory Items

The EFA showed that 34.2% of the variability in overall grades could be predicted from student responses to the ASCI instrument (results not shown). Upon closer examination of the items important to the model, items 2 (Worthless – Beneficial) and 15 (Worthwhile – Useless) were found to be the most important contributors, and the only statistically significant variables. This suggests that students' opinion of the worth of chemistry may be significantly correlated with their performance in chemistry-related units.

Furthermore, correlation coefficients between the individual ASCI items and student achievement data revealed that item 2 (Worthless – Beneficial) had the strongest correlation coefficients with student scores on the final exam and their overall grades **Table 4**. Several other significant items were related to the understandability of chemistry (e.g., items 5, 9, 14) and student enjoyment (e.g., items 7, 8, 12).

DISCUSSION

Overall, the attitude toward chemistry among the student cohort was positive. This was generally expected, as all students were studying chemistry as either a major or minor of their degree. This also concurred with previous research findings that showed broadly positive attitudes toward chemistry amongst Fijian undergraduate students (Brown et al., 2014a). Additionally, senior secondary students from Fiji have been found to have a higher level of enjoyment of science lessons, compared to students from other Oceanic countries such as Australia (Naiker et al., 2020a). This may be translated to increased enjoyment of science-related topics, such as chemistry, in their university studies. The lower scores on the cognitive subscale compared to the affective subscale (**Table 2**) indicated that students had a higher level of affection for chemistry-related topics but did not show similarly high levels of cognitive engagement with the topic material. It is possible that students from this cohort were focused on learning to pass the assessments, rather than aiming to gain a solid understanding of the unit content.

One of the most important indicators of the effectiveness of teaching is the academic achievement of learners. This can be influenced by the learning approaches of the student (Brown et al., 2014b; Everaert et al., 2017); however, it also depends on

TABLE 4 | Pearson correlation coefficients (r) between individual items on the ASCI and student achievement and attendance rates ($n = 95$ students).

Item	Word pair	Continuous assessment	Final exam	Overall grade	Tutorial attendance	Laboratory attendance
1	Easy – Hard	0.263*	0.140	0.207*	−0.048	−0.002
2	Worthless – Beneficial	0.262*	0.402**	0.368**	−0.079	0.101
3	Exciting – Boring	0.152	0.153	0.164	−0.120	0.089
4	Complicated – Simple	−0.028	0.062	0.026	−0.149	−0.127
5	Confusing – Clear	0.229*	0.212*	0.235*	−0.167	0.068
6	Good – Bad	0.057	0.186	0.141	−0.184	0.029
7	Satisfying – Frustrating	0.158	0.335**	0.280**	−0.190	−0.01
8	Scary – Fun	0.231*	0.237*	0.252*	0.41	0.147
9	Comprehensible – Incomprehensible	0.188	0.347**	0.301**	−0.149	−0.031
10	Challenging – Not Challenging	0.021	−0.005	0.006	0.052	0.020
11	Pleasant – Unpleasant	0.102	0.224*	0.185	−0.081	−0.031
12	Interesting – Dull	0.122	0.264**	0.219*	−0.121	−0.057
13	Disgusting – Attractive	0.050	0.143	0.112	−0.167	−0.072
14	Comfortable – Uncomfortable	0.191	0.298**	0.272**	−0.186	0.020
15	Worthwhile – Useless	−0.016	0.710	0.098	−0.263*	−0.018
16	Work – Play	−0.152	−0.196	−0.191	−0.019	0.091
17	Chaotic – Organized	0.117	0.170	0.159	−0.141	−0.042
18	Safe – Dangerous	0.147	0.246*	0.219*	0.014	0.003
19	Tense – Relaxed	−0.049	0.041	0.003	−0.024	0.053
20	Insecure – Secure	0.11	0.228*	0.191	−0.199	−0.06

$^*P < 0.05$, $^{**}P < 0.01$.

individual motivation (Nabizadeh et al., 2019) and grit (Hodge et al., 2018). Based on the results presented here, it appears that cognitive learning – typically perceived as the knowledge-gathering aspect of learning – appears to have little impact on overall student academic performance. Cognitive learning is an active and immersive learning process through which students aim to internalize new information and connect it with previously learned topics and concepts. This method of learning can be seen as a deep learning process, with less emphasis on memorization and/or rote learning compared to more surface-based learning approaches (Brown et al., 2014b). Nevertheless, there was no significant correlation found between the cognitive subscale of student attitudes toward chemistry and their achievement in this study. In contrast, a moderate but significant correlation was found between the affective subscale of student attitudes and their achievement on both the continuous assessment items and the final exam. Notably, this correlation was only significant for the final exam among low-achieving students, suggesting that their higher affection for chemistry only improved their academic performance under the high-pressure invigilated exam situation. In contrast, a higher affection for chemistry did not improve their grades on the continuous assessment items, which comprised a mixture of theoretical and practical components. To continue engaging chemistry students in active and independent learning, we suggest that it is necessary for educators to consider interactive and student-oriented modes of delivering learning resources to further enhance student engagement with the topic contents, particularly in their continuous assessment tasks. In addition, we further suggest that students should be encouraged and alerted to become familiar with self-regulating learning skills to better understand newly learned information.

Another notable finding from this study was that high-achieving students with greater "affection" for chemistry tended to have a lower attendance rate at laboratory classes. This could be attributed to the fact that students are only required to attend 75% of the laboratory classes to be able to pass this unit, in line with the standard learning and teaching policies at USP. Furthermore, the laboratory assessment components were not held every week, but at several different weeks throughout the term. As many educators would be well aware, students are savvy enough to dedicate their efforts to areas where they will get the best outcomes. Hence it is possible that high-achieving students who perceived that they were sufficiently well versed with the required laboratory skills attended the laboratory classes in the weeks where their performance was assessed, but skipped some of the classes that did not contribute to their overall unit grade.

This highlights the need for chemistry educators and laboratory instructors to ensure that they are providing a positive and interactive experience for students in laboratory classes. The use of more engaging laboratory methods, such as Inquiry Oriented Learning (IOL) or Process-Oriented Guided-Inquiry Learning (POGIL) approaches could help improve student enjoyment and learning outcomes (Naiker and Wakeling, 2015; Naiker et al., 2020b). Given the number of laboratory classes conducted throughout the term, possibly two or three of these classes could be dedicated to an IOL/POGIL approach. Other options to increase engagement in laboratory classes could be to incorporate assessment items into the practical sessions, or to assess student laboratory skills.

In view of improving students' affection toward chemistry, which may in turn improve their academic performance in associated units, a concerted effort should be made by teaching staff to ensure that their teaching styles are conducive to the cognitive and non-cognitive learning styles of different students. As proposed by Karagiannopoulou and Entwistle (2019), there are three main styles of teaching which may cater for students with different learning identities: (1) Didactic: Explaining concepts and providing sufficient concepts and theories to cover the syllabus, (2) Explanatory: Encouraging and supporting students' understanding, and (3) Dialogic: Providing a "meeting of minds" and freedom to explore understandings. Educators should ensure that they are providing an adequate mix of learning styles and delivery modes to ensure that all students feel included and are able to learn in a supportive environment, while keeping in mind cultural contexts such as the "Pacific way" of learning.

Although online learning did not form a significant part of the learning and assessment items in this study, it is of increasing importance both in the Pacific and worldwide. In recent years, chemistry courses have been offered at USP *via* distance and flexible learning, due to increasing adoption of digital technology and the use of ICT tools as drivers of teaching and learning (Chandra and Sharma, 2018). Although the notion of distance and flexible learning is evident at the USP, some challenges of digital literacy and access to suitable speed internet connections still exist amongst the student cohort (Reddy et al., 2020a,b; Reid, 2006). Work by Reddy et al. (2020c) has identified student attitude as one of the contributors to acceptance of technology-enabled learning. Recently, Johnson et al. (2021) found a positive attitude toward technology and generally adequate levels of digital literacy amongst commencing USP students, highlighting the ongoing potential for e-learning in the post-COVID era. However, further work is required to determine the impact of an online-based delivery mode on student attitudes toward chemistry.

CONCLUSION

This study demonstrated a generally positive attitude toward chemistry amongst first-year chemistry students from USP. Cluster analysis revealed the presence of a high-achieving and low-achieving groups of students, with significantly lower scores for the low-achieving groups across all assessment parameters except for tutorial attendance. There was a positive correlation between the cognitive and affective components of attitude among low-achieving students, but not among high-achieving students. The cognitive component of attitude did not appear to be strongly correlated with achievement, although the affective component was correlated.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Human Research Ethics Committee (The University of the South Pacific). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

PR and SS performed the data collection. JJ, JM, TB, and MN performed the data analyses. LW, MN, and SB performed the data interpretation. JJ, MN, and SB prepared the manuscript. All authors carried out the manuscript preliminary review and participated in study design and concept development.

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