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Quantifying attitude to chemistry in students at the University of the South Pacific

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Abstract:

The attitude towards the study of chemistry for new entrant chemistry students from a multi-national, regional, tertiary educational institution in the South Pacific were investigated using a purpose-designed diagnostic instrument. The Attitude toward the Study of Chemistry Inventory (ASCI) was used to quantify attitude in a cohort of first year undergraduate (n=144) and foundation (n=108) chemistry students. A similar, generally positive attitude to the study of chemistry was shown by both groups of students. Exploratory factor analysis using principle axis factoring and direct oblimin rotation was used to identify factors within the pooled data. Three factors accounted for more than 50% of the total variance, while Cronbach's alpha values for the factors 1, 2 and 3 were 0.92, 0.68 and 0.78, respectively. Factors 1 and 2 were consistent with known constructs of attitude, namely affective (factor 1) and cognitive (factor 2). However, the other factor (3) identified in this study was designated "Value", which may reflect the students choice of chemistry as a career path. ASCI may be a suitable tool for monitoring students' attitude throughout a degree and also to monitor the impact of novel approaches for teaching chemistry and engaging students.

Introduction:

Undergraduates are required to develop an understanding of subject specific content, and both the delivery and assessment of this content knowledge is supported by an extensive body of teaching and learning pedagogy. However, students' attitude to this content is rarely measured, yet a positive attitude may be congruent with higher achievement (Osborne et al., 2003; Xu and Lewis, 2011; Xu et al., 2012). Thus, it would seem appropriate to quantify attitude to chemistry during an undergraduate chemistry degree (Berg, 2005; Bauer, 2008), as this would complement the regular assessment of content specific knowledge.

The promotion of positive attitudes towards chemistry is an important component of an undergraduate chemistry degree, yet the concept of an attitude towards chemistry is somewhat nebulous, often poorly articulated and not well understood. Attitude can be considered as a tendency to respond to a certain stimulus (in this instance, chemistry), where the response has cognitive, affective, and behavioural elements, thus forming a tripartite theoretical model of attitude (Rosenberg and Hovland, 1960). The 'affective' reflects emotional responses through individual preferences to the stimulus, the 'cognitive' reflects an individual's beliefs and knowledge about the stimulus (Xu et al., 2013), and the 'behavioural' reflects an individual's tendency to act in a particular manner regarding the stimulus. Others (Bagozzi and Burnkrant, 1979) proposed that attitude could be viewed as a two component construct comprised of a cognitive and an affective component. These two attitudinal dimensions may simultaneously account for behavioural predispositions, although they may also have a differential impact on them.

The tripartite view of attitude (Rosenberg and Hovland, 1960), suggests that there is a clear distinction between thoughts, emotions, and behavioural intentions associated with a particular attitude. Thus, attitude to chemistry (or to science in general) may be identified and quantified within this tripartite structure, but only if appropriate instruments are used which identify these constructs. However, the tripartite view of attitudes requires cognitive, affective, and behavioural responses which are consistent (Fazio and Williams, 1986), suggesting that a single instrument may be inadequate for quantifying such a multi-dimensional phenomenon. Somewhat simplistically, attitude can be summarised as being positive or negative. However, attitude also has characteristics such as importance, certainty, and accessibility (Visser et al., 2006) – this inter-attitudinal structure may connect different sub-constructs of attitudes to one another, and/or to more underlying psychological constructs, for example values. Therefore, an instrument to quantify attitude to the

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3 study of chemistry may potentially have factors within it which align to this inter-attitudinal
4 structure.
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7 Teaching pedagogy aimed at developing a positive attitude toward science can be implemented
8 within a curriculum. For example, debate (Shaw, 2012), educational games (Akl, 2013), role play
9 (Koponen et al., 2012), and practical experience (Freedman, 1997; Abdullah et al., 2009) have all
10 been used to develop positive attitudes toward the study of chemistry. However, in order to
11 quantify the possible influence these pedagogies have on attitude toward chemistry in an
12 undergraduate curriculum, appropriate and valid instruments which measure attitude are required.
13 The Chemistry Expectations Survey (CHEMX; Grove and Bretz, 2007), Chemistry Attitudes and
14 Experiences Questionnaire (CAEQ; Coll et al., 2002), and the Colorado Learning Attitudes about
15 Science Survey (CLASS; Barbera et al., 2008; Heredia and Lewis, 2012) are validated tools that have
16 been used to quantify attitude to chemistry in undergraduate students. Also, the Attitudes to the
17 Study of Chemistry Inventory (ASCI; Bauer, 2008; Xu and Lewis, 2011), and its more recent shortened
18 version ASCIv2 (Xu et al., 2012) may also be suitable tools to quantify attitudes to chemistry in
19 undergraduate students.
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31 The University of the South Pacific (USP) is a regional university operating since 1968. Owned by 12
32 member countries, it is supported through 14 campuses spread over an area of 30 million square
33 kilometers of the Pacific Ocean, with 20,000 students enrolled (Jokhan and Sharma, 2010; Sharma et
34 al., 2011). The smaller centers are part of the larger campuses spread in remote locations or on the
35 smaller islands in some countries. This geographical spread, student diversity, shoestring budgets,
36 varying teaching resources and inherent limitations necessitate the adoption and adaptation of
37 efficient, cost effective learning and teaching tools and technologies, and a culture-inclusive
38 curriculum for the region (Chandra, 2012). While the University has students coming directly from
39 secondary school, there is a growing percentage (>30%) of mature students joining or rejoining USP
40 in recent years.
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50 The College of Foundation Studies at USP offers two programmes at the pre-degree level: the
51 Preliminary Programme and the Foundation Programme in Science and Social Science. The
52 Foundation Science Program aims to enhance students' theoretical, problem solving,
53 practical/experimental skills, and research and teamwork skills and equip students for studies in
54 degree level at USP or at any other tertiary institute. Students entering the Foundation Programme
55 will normally have passed an approved Form 6 examination (or equivalent), or have completed a
56 USP Preliminary Programme. Students enrol in either the Foundation Science Programme or the
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Foundation Social Science Programme, depending on the subjects they studied at secondary school (or in the Preliminary Programme) and also the degree programme they want to pursue once they complete their foundation studies. A total of 8 courses are required for admission to first year undergraduate studies at USP from the full Foundation Science Programme. To complete the Foundation Science Programme over two semesters, students must pass two English language courses, plus a further six foundation science courses related to agriculture, biology, chemistry, computing, geography, mathematics, physics, and technology.

The ASCI has not been used to quantify attitude to chemistry in a mixed cohort of both first year undergraduate chemistry majoring students, and Foundation science students studying chemistry at university. Also, the unique geography, demography, and language diversity of the Pacific Islands region, and the key role of USP as a regional provider of science education at a tertiary level has in this region, provides a unique cohort in which to quantify attitude to chemistry. Therefore, the aim of the current study was to quantify the attitude toward the study of chemistry, using the ASCI instrument, in a cohort of first year undergraduate and foundation chemistry students at the University of the South Pacific.

Methods:

With ethics committee approval, the Attitude toward the Study of Chemistry Inventory (ASCI, see figure 1) was given to two groups of students enrolled at the University of the South Pacific in 2013. First year undergraduate students studying chemistry at USP were recruited into the study during their first semester of study. ASCI was administered on-line using Survey Monkey®, and completed by 144 students. ASCI was also administered (in paper format) to 108 foundation year chemistry students in their first semester of study. Respondents in both groups were given clear instruction about completing the inventory, and given approx. 20 min to complete it. All data were collected anonymously and without individual identification. Data were transferred to both Excel and SPSS (IBM SPSS Statistics 19).

Exploratory factor analysis was carried out on the combined data from both groups. The internal structure of all data (total number of responses = 252) was assessed using the principal axis factoring method with the direct oblimin rotation method. Internal consistencies of items loading onto each identified sub-scale were estimated using Cronbach's α .

Results:

Responses to ASCI:

Each group of students' responses to the ASCI are summarised in box-and-whisker plots, shown in figure 2. For both foundation students and first year undergraduate students, a generally positive attitude toward the study of chemistry was measured. Highest positive scoring items were for 'beneficial', 'good', 'interesting', and 'worthwhile', whereas items which suggested a 'negative attitude' in both groups were: complicated – simple; challenging – not challenging; work – play; tense – relaxed. For the Foundation year students (n=108), the mean (SD) scores for factor 1, 2 and 3 were 31.4 (11.6), 19.8 (4.8), and 25.4 (5.3) respectively. For the first year undergraduates (n=144), the mean (SD) scores for factor 1, 2, and 3 were 29.0 (12.9), 18.7 (5.8), and 25.7 (5.8). For each factor, a two sample equal variance Student's *t*-test was used to compare these values between the two populations, with no significant differences being recorded (all $P > 0.1$).

Exploratory Factor Analysis (EFA):

Both groups' responses to ASCI were pooled for the exploratory factor analysis – this decision was based on the similarity of the mean responses to each item for both groups. The Kaiser-Meyer-Olkin (KMO, a measure of sampling adequacy) was 0.895, and Bartlett's test of sphericity was < 0.001 . An initial three factor solution, based on Eigenvalues > 1 , was suggested, where factors 1, 2, and 3, had Eigenvalues of 7.635, 2.327, and 1.296, respectively. These 3 factors accounted for 56.3% of the total variance. Cronbach's α was used as a statistic to indicate the internal consistency of the items which contribute to the factor (Cronbach, 1951; Cortina, 1993) for factors 1, 2, and 3 was 0.92, 0.68, and 0.78, respectively. The pattern matrix for items and extracted factors is shown in table 1, and the structure matrix is shown in table 2. A correlation between factor 1 and 3 was -0.607, suggesting some inter-dependence between these factors.

Discussion:

This is the first study to quantify the attitude to the subject of chemistry in students of chemistry at a university in the Pacific Islands. This study attempts to quantify the attitude to the study of chemistry using an established instrument (ASCI), and its uniqueness is that the population of interest is from a diverse, multi-lingual region, unified by enrolment at the dominant higher education provider within the region (USP). We also used the EFA statistical procedure to indicate a three factor internal data structure – a different finding to previous reports using the same ASCI instrument. The present study is exploratory only, and doesn't attempt to validate the instrument.

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3 Further work, to include confirmatory factor analysis, is proposed to examine the ‘fit’ of the three
4 factor solution to this cohort.
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9 The ASCI was originally validated in the United States on undergraduates majoring in chemistry
10 (Bauer, 2008). Using exploratory factor analysis, Bauer (2008) reported a four factor solution, with
11 items aligning to factors described as: Interest / Utility (5 items); Emotional Satisfaction (4 items);
12 Anxiety (4 items); and Intellectual Accessibility (5 items). A single item (safe – dangerous) was
13 independent of the other four factors, and was described with the term ‘Fear’. In the current study,
14 factor one contained 4 items previously identified as Interest /Utility, 3 items as Emotional
15 Satisfaction, 2 items previously identified as Intellectual Accessibility, and two further items
16 previously identified as Anxiety and Fear, respectively. Thus, the current study indicated that this
17 collection of items represented a common factor, and we suggest that a suitable descriptor for this
18 factor could be “Interest, Utility, and Emotional Satisfaction”. Cronbach’s α for this factor was 0.92,
19 suggesting good internal consistency (Bland and Altman, 1997; Sijtsma, 2009). The ASCI items which
20 are collected under this heading may quantify the affective responses to the study of chemistry (i.e.
21 How do I feel about studying chemistry?), as well as the feelings of studying something which
22 represents an academic challenge. This may be a factor which identifies with the student who
23 chooses to study a challenging course at a higher academic level, and enjoys the intellectual
24 demands of a scientific discipline.
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38 In the current study, factor two contained 3 items previously identified as Intellectual Accessibility,
39 and 2 items previously identified as Anxiety. We suggest that a suitable descriptor for factor two
40 could be “Intellectual Accessibility and Anxiety”. In the current study, factor three contained two
41 items previously identified as Anxiety, with additional items from the Interest / Utility and the
42 Emotional Satisfaction sub-scales. The alignment of items in these three factors with the descriptive
43 terms allocated to the items by Bauer (2008), are shown in table 1. Cronbach’s α for factors two and
44 three were 0.68 and 0.78, respectively – thus indicating that the internal consistency of the items in
45 these two factors is at the limit of acceptance (Cortina, 1993). However, it is likely that within the
46 components of attitude (commonly summarised as affective, cognitive, and behavioural), items in
47 the ASCI which form a common factor are likely to reflect different aspects of the same construct
48 (Tesser and Shaffer, 1990), thus reducing the consistency of responses to those items.
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58 A shorter version of the original ASCI was developed by Xu and Lewis (2011). This shortened version
59 (ASCIv2) contained eight of the original items in two sub-scales – each of which shared a common
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3 descriptor with that proposed by Bauer (2008). However, further refinement by Xu and Lewis
4 considered that Intellectual Accessibility aligned to the cognitive component of attitude, and
5 Emotional Satisfaction aligned to the affective component of attitude. The terms Affective and
6 Cognitive, when used as descriptors for the two factor solution, were consistent with the
7 components of attitude previously suggested (Rosenberg and Hovland, 1960). Using confirmatory
8 factor analysis, Xu et al (2012) showed that 4 ASCIv2 items (Easy – Hard, Complicated – Simple,
9 Confusing – Clear, Challenging – Unchallenging) could be included in the cognitive sub-scale, and
10 that 4 items (Uncomfortable – Comfortable, Frustrating – Satisfying, Unpleasant – Pleasant, and
11 Chaotic – Organised) could be included in the affective sub-scale. In the current study, factor one
12 contained 3 of the Affective items, and factor three contained all 4 of the Cognitive items identified
13 by Xu et al., (2012).
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24 Although affective and cognitive sub-scales form part of the structure of the current data, aligning
25 strongly with factor 1 and factor 2, respectively, other items in the original ASCI may describe
26 another dimension within the construct of attitude (Panter et al., 1997). In the current study, factor
27 three contained 5 items in a sub-scale with good internal consistency ($\alpha = 0.78$). The “positive
28 attitude” terms for these 5 items were simple, beneficial, attractive, secure, and organised – we
29 suggest that a suitable descriptor for this sub-scale is “Value”. We suggest that this may reflect a
30 student’s perception that studying chemistry has an intrinsic value, through both academic pursuit
31 (questionnaire items: complicated / simple, organised / chaotic, and beneficial / worthless) and a
32 career choice (questionnaire items: attractive / disgusting, and secure / insecure). This is
33 complementary to the behaviour component of attitude such that students may choose to study
34 chemistry as a behavioural response, where this response is directed by the desire to pursue a
35 valued career in chemistry. Consistent with the multi-dimensional structure of attitude, items within
36 factor 3 may quantify the notion of studying a difficult course that will bring both emotional and
37 cognitive satisfaction. It may also reflect a student’s desire to be challenged by the academic rigor of
38 a university course in chemistry, and through achievement, gain social status.
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52 To further analyse the internal structure of the data, the EFA was re-run using a selection of terms
53 identified by the initial 3 factor solution. Items were selected based on their interpretability with the
54 scale descriptors used previously (Affective, Cognitive, Value), and on their loadings. From the initial
55 solution, 5 items were chosen from factor 1 (loadings >0.7), 3 items were chosen from factor 2
56 (loadings >0.5), and 3 items were chosen from factor 3 (loadings >0.6). Using the principle axis
57 factoring extraction method with direct oblimin rotation (KMO = 0.847), 3 factors were identified
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which accounted for 65.58% of the total variance. The pattern and structure matrices are shown in table 3. Factor correlations were 0.00 between factors 1 and 2, -0.63 between factors 1 and 3, and 0.153 between factors 2 and 3. This analysis suggests that the ASCI can be presented as an 11 item inventory with three sub-scales, however, a confirmatory factor analysis is required to endorse this suggestion.

Individual items within each factor may lack an obvious interpretation with respect to that factor, and may appear irrelevant when isolated. However, values for Cronbach's alpha for each identified factor was maximised when the composition of the three factors was as reported. Also, it is likely that the factors identified with the current exploratory factor analysis have some overlap, and this is supported by the correlation between factor 1 and 3 (-0.607). The multidimensional structure of attitude is consistent with inter-connected sub-scales, and the factors identified in the current study have been interpreted within the tripartite structure proposed by Rosenberg and Hovland (1960). Our interpretation of the third factor as representing 'value' is based on the descriptors of the items by Bauer (2008), and the exploration of components of attitude by Visser et al. (2006). In the current study, we chose to use the original ASCI and not the shortened ASCIv2. We speculate that using the ASCI in its complete original form may allow "value" to be elicited whereas the shortened ASCIv2 survey may not. Upon commencement of studies at USP, students choose to enrol in specific science discipline based courses, meaning they have already decided on pursuing a career in chemistry. This may be the reason why a "positive attitude" towards "Value" has been identified in this cohort of students. In previous studies the cohort of students investigated had not necessarily made discipline specific career decisions at the time the survey was conducted, which may be why this descriptor has not been previously identified. Another key factor here is that the complete survey originally proposed by Bauer (2008) was used, whereas if the shortened version (ASCIv2) is used then this factor would not be able to be identified.

All participants were studying either foundation science or first year chemistry, in the English language. However, the culture-inclusive curriculum and diversity of the region pre-disposes the student cohort to be multi-lingual (Chandra, 2012). Local Indigenous Fijian dialects, Polynesian and Melanesian languages (for example, Samoan, Tongan, Pidgin English, Kiribati) and languages prevalent on the Indian sub-continent (for example, Hindi, Tamil/Telegu, Gujarati, and Punjabi) would be the common first languages for the students in the cohort surveyed in this research project. Thus, it is possible that participants in this study assigned different meaning to some of the terms used in the ASCI, and this may restrict the use of a semantic differential instrument in such a

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3 multi-lingual population. Also, the internal structure with three factors identified in our study was
4 different to the two factor solution identified by Xu and Lewis (2011), and this may reflect the
5 interpretation of individual terms used on the ASCI by the Fijian cohort. To our knowledge, different
6 language versions of the ASCI have not been subjected to any analyses.
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11 The decision to pool the responses from the Foundation year and the First year undergraduate
12 students was initially based on the similarity of the responses to individual items within the
13 inventory. Evidence to support this decision comes from the lack of differences recorded when
14 individual item scores were compared between the two student groups, and further post-hoc
15 comparisons between the mean scores for each identified factor. No differences were recorded
16 between the two student groups. Data collected from the original ASCI and the shortened ASCIv2
17 were pooled for analysis by Brandriet et al. (2011), and data collected from two separate classes
18 (n=61 and n=53) were pooled by Xu et al. (2012). The administrators of ASCI in the current study
19 were required to give the same instruction to each student group, and we achieved a >75% return
20 rate for completed questionnaires. Thus we are confident that the decision to pool the data from the
21 two student populations was correct and increased our level of confidence with the results of the
22 EFA. Also in the current study, both on-line and hard copy formats were used to administer ASCI. The
23 simplicity of the semantic differential and Likert scale format of the ASCI lends itself to both on-line
24 and paper formats, and we are confident that using both types of delivery did not alter the
25 responses. Changing the physical form of the instrument may introduce noise, however, when ASCI
26 and another questionnaire were co-administered (Bauer 2008), no order effects were reported
27 suggesting that the instrument was robust.
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43 In summary, the ASCI tool was shown to be effective in quantifying attitude to chemistry in this
44 cohort. This study uniquely showed a similar attitude to chemistry in both foundation and first year
45 students. It is the first application of the original ASCI in a cohort of foundation studies students, and
46 the first application of the ASCI to a demographically unique cohort of BSc chemistry students in the
47 Pacific Island region. Our exploratory factor analysis has described an internal data structure with
48 three sub-scales. Two of these sub-scales were consistent with the established constructs of
49 attitude, namely affective and cognitive; however, a third sub-scale possibly reflected a student's
50 choice of chemistry as a career path. We suggest that the ASCI may be a suitable tool to quantify
51 attitude at regular intervals throughout a degree pathway, thus complementing the routine
52 assessment of content specific knowledge. We also suggest that it may be a suitable instrument to
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quantify the impact of novel approaches to teach chemistry and further engage students in the scholarship of chemistry.

References:

Abdullah M., Mohamed N. and Ismail Z.H., (2009), The effect of an individualized laboratory approach through micro-scale chemistry experimentation on students' understanding of chemistry concepts, motivation, and attitudes, *Chemistry Education Research and Practice*, **10**, 53-61.

Adams W.K., Wieman C.E., (2010). Development and validation of instruments to measure learning of expert-like thinking. *International Journal of Science Education*, **33**, 1289–1312.

Ajzen I, Fishbein M. 1980. *Understanding Attitudes and Predicting Social Behavior*. Englewood-Cliffs, NJ: Prentice-Hall

Akl E.A., Sackett K.M., Erdley W.S., Mustafa R.A., Fiander M., Gabriel C. and Schünemann H., (2013), Educational games for health professionals. *Cochrane Database of Systematic Reviews*, Issue 1. Art.No.:CD006411.DOI: 10.1002/14651858.CD006411.pub3

Barbera J., Adams W.K., Wieman C.E. and Perkins K.K., (2008), Modifying and validating the Colorado Learning Attitudes about Science Survey for use in chemistry, *Journal of Chemical Education*, **85(10)**, 1435-1439.

Bauer C., (2008), Attitude towards chemistry: A semantic differential instrument for assessing curriculum impacts, *Journal of Chemical Education*, **85 (10)**, 1440-1445.

Bagozzi R.P. and Burnkrant R.E., (1979), Attitude Measurement and Behaviour Change: a Reconsideration of Attitude Organization and Its Relationship to Behaviour, *Advances in Consumer Research*, **6**, 295-302.

Bland J.M. and Altman D.G., (1997), Cronbach's alpha, *British Medical Journal*, **314**, 572.

Brandriet A.R., Xu X., Bretz S.L. and Lewis J.E., (2011), Diagnosing changes in attitude in first-year college chemistry students with a shortened version of Bauer's semantic differential, *Chemistry Education Research and Practice*, **12**, 271-278.

Chandra S., (2012), Conquering the Oceanic Divide: 12 Centers One Link – ICT. In: International Conference on ICT Culture in Education, New Delhi, page 25.

Coll R.K., Dalgety J. and Salter D., (2002), The development of the chemistry attitudes and experiences questionnaire (CAEQ), *Chemistry Education Research and Practice in Europe*, **3(1)**, 19-32.

Cortina J.M., (1993), What Is Coefficient Alpha? An Examination of Theory and Applications, *Journal Applied of Psychology*, **78(1)**, 98-104.

Cronbach L.J., (1951), Coefficient alpha and the internal structure of tests. *Psychometrika*, **16**, 297-333.

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3 Fazio R., and Williams C. (1986), Attitude accessibility as a moderator of attitude-perception and
4 attitude-behavior relation: An investigation of the 1984 presidential election. *Journal of Personality*
5 *and Social Psychology*, **51**, 505-514.

7
8 Freedman M. P., (1997), Relationships among laboratory instruction, attitude toward science, and
9 achievement in science knowledge, *Journal of Research in Science Teaching*, **34(4)**, 343-357.

11 Grove N.P. and Bretz S.L., (2007), CHEMX: Assessing Students' Cognitive Expectations in Learning
12 Chemistry, *Journal of Chemical Education*, **84(9)**, 1416-1424.

14 Heredia K. and Lewis J.E., (2012), A Psychometric Evaluation of The Colorado Learning Attitudes
15 about Science Survey (CLASS) for Use in Chemistry, *Journal of Chemical Education*, **89(4)**, 436-441.

17 Jokhan A. and Sharma B., (2010), Teaching Science at a Distance, In: D. Kennepohl and L. Shaw,
18 *Accessible Elements: Teaching Science Online and at a Distance*, pages 235-246, Athabasca University
19 Press, Canada, 2010.

21 Koponen J., Pyorala E. and Isotalus P., (2012), Comparing three experiential learning methods and
22 their effect on medical students' attitudes to learning communication skills, *Medical Teacher*, **34**,
23 e198-e207.

25 Osborne J., Simon S. and Collins S., (2003), Attitudes towards science: A review of the literature and
26 its implications, *International Journal of Science Education*, **25(9)**, 1049-1079.

28 Panter A.T., Swyger KA., Dahlstrom W.G., Tanaka J.S., (1997), Factor analytic approaches to
29 personality item-level data. *Journal of Personality Assessment*, **68**, 561-589.

31 Rosenberg M.J. and Hovland C.I. (1960) "Cognitive, Affective and Behavioural Components of
32 Attitudes." In M. J. Rosenberg, C. I. Hovland (eds.), *Attitude Organization and Change: An Analysis of*
33 *Consistency Among Attitude Components*. New Haven: Yale University Press.

35 Sharma B., Jokhan A. and Prasad A., (2011), Online Learning Environment in Mathematics via a
36 Pedagogical Progression Model of Moodle. In *Proceedings of Global Learn Asia Pacific 2011* (pp.
37 2241-2251). AACE, Melbourne, 2011.

39 Shaw J., (2012), Using small group debates to actively engage students in an introductory
40 microbiology course, *Journal of Microbiology and Biology Education*, **13(2)**, 155-160.

42 Sijtsma K., (2009), On the use, the misuse, and the very limited usefulness of Cronbach's alpha,
43 *Psychometrika*, **74(1)**, 107-120.

45 Tesser A., Shaffer D.R. (1990), Attitudes and Attitude Change. *Annual Review of Psychology*, **41**, 479-
46 523.

48 Visser P.S., Bizer G.Y., and Krosnick, J.A., (2006), Exploring the Latent Structure of Strength-Related
49 Attitude Attributes. *Advances in Experimental Social Psychology*, **38**, 1-67.

51 Xu X. and Lewis J., (2011), Refinement of a chemistry attitude measure for college students, *Journal*
52 *of Chemical Education*, **88**, 561-568.

Xu X., Southam D. and Lewis J., (2012), Attitude toward the subject of chemistry in Australia: An ALIUS and POGIL collaboration to promote cross-national comparisons, *Australian Journal of Education in Chemistry*, **72**, 32-36.

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Figure 1: Items in the Attitude to the Study of Chemistry Inventory (ASCI).

CHEMISTRY IS:

1.	easy	1 2 3 4 5 6 7	hard
2.	worthless	1 2 3 4 5 6 7	beneficial
3.	exciting	1 2 3 4 5 6 7	boring
4.	complicated	1 2 3 4 5 6 7	simple
5.	confusing	1 2 3 4 5 6 7	clear
6.	good	1 2 3 4 5 6 7	bad
7.	satisfying	1 2 3 4 5 6 7	frustrating
8.	scary	1 2 3 4 5 6 7	fun
9.	comprehensible	1 2 3 4 5 6 7	incomprehensible
10.	challenging	1 2 3 4 5 6 7	not challenging
11.	pleasant	1 2 3 4 5 6 7	unpleasant
12.	interesting	1 2 3 4 5 6 7	dull
13.	disgusting	1 2 3 4 5 6 7	attractive
14.	comfortable	1 2 3 4 5 6 7	uncomfortable
15.	worthwhile	1 2 3 4 5 6 7	useless
16.	work	1 2 3 4 5 6 7	play
17.	chaotic	1 2 3 4 5 6 7	organized
18.	safe	1 2 3 4 5 6 7	dangerous
19.	tense	1 2 3 4 5 6 7	relaxed
20.	insecure	1 2 3 4 5 6 7	secure

Figure 2: Responses to the Attitude to the Study of Chemistry Inventory (ASCI) in first year (upper figure) and foundation year (lower figure) students at the University of The South Pacific. The figure shows box-and-whisker plots for each ASCI item, where the upper and lower limits to the box are the values for the 1st and 3rd quartiles, respectively, the line in the box indicates the 2nd quartile, and the limits of the whiskers are the minimum and maximum values. Outliers are shown with 'o' and 'x'.

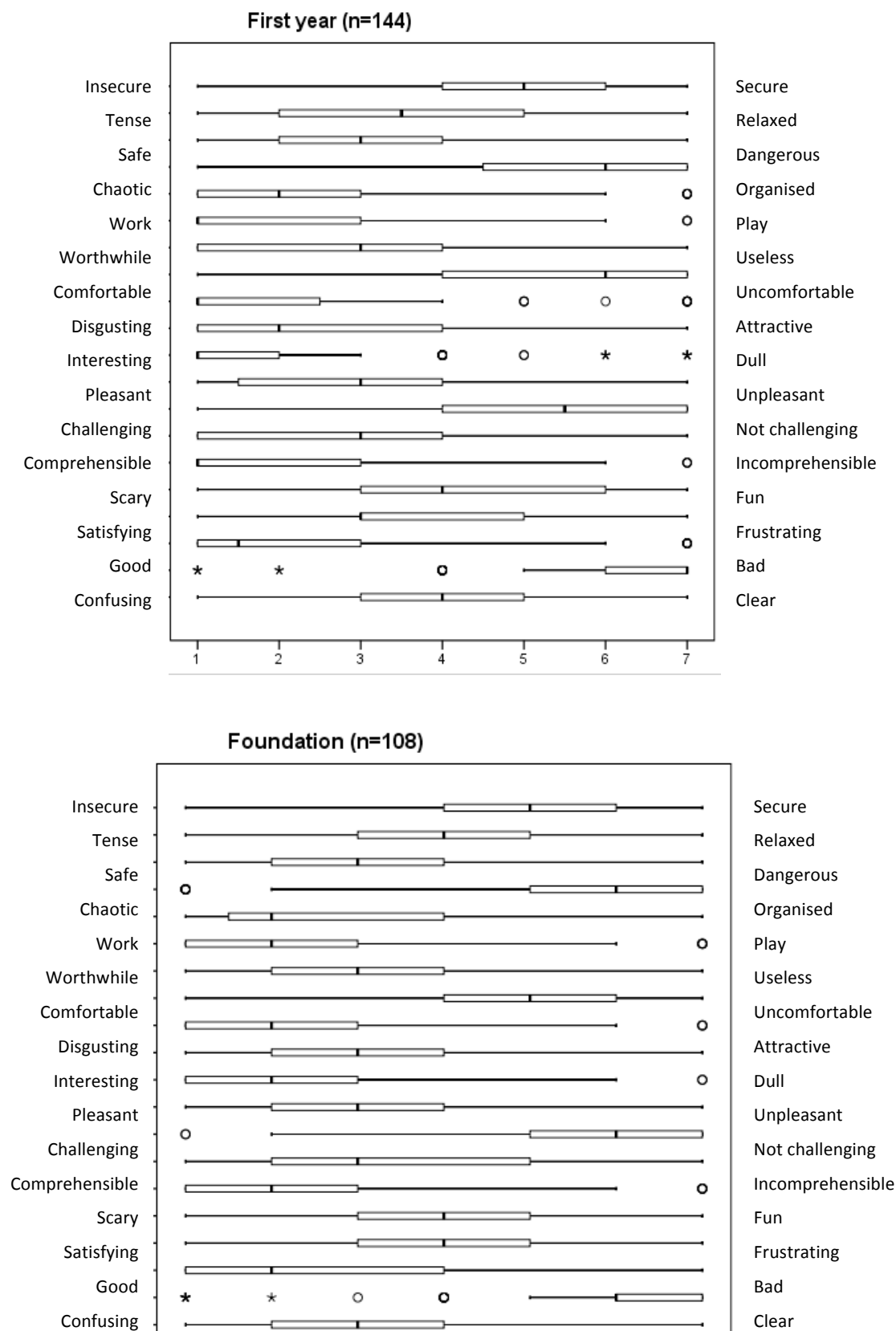


Table 1: Pattern matrix for Attitude to the Subject of Chemistry Inventory (ASCI) for data obtained from 252 chemistry students at The University of the South Pacific. Extraction Method: Principal Axis Factoring; Rotation Method: Direct oblimin with Kaiser Normalization (Rotation converged in 9 iterations). Key: IU: Interest / Utility; ES: Emotional Satisfaction; IA: Intellectual Accessibility; A: Anxiety; F: Fear. Factor correlations were -0.052 between factors 1 and 2, -0.607 between factors 1 and 3, and 0.166 between factors 2 and 3.

	Factor			Xu & Lewis (2011)	Bauer (2008)
	1 $\alpha = 0.92$	2 $\alpha = 0.68$	3 $\alpha = 0.78$		
comfortable - uncomfortable	.804			Affective	ES
pleasant - unpleasant	.770			Affective	ES
satisfying - frustrating	.716			Affective	ES
exciting - boring	.708				IU
worthwhile - useless	.700				IU
interesting - dull	.691				IU
good - bad	.690				IU
comprehensible - incomprehensible	.678				IA
easy - hard	.536			Cognitive	IA
work - play	.465				A
safe - dangerous	.339				F
tense - relaxed		.549			A
complicated - simple		.538	.330	Cognitive	IA
challenging - not challenging		.537		Cognitive	IA
confusing - clear		.352		Cognitive	IA
scary - fun		.324			A
worthless - beneficial			.748		IU
disgusting - attractive			.692		A
insecure - secure			.610		A
chaotic - organised			.568	Affective	ES

Table 2: Structure matrix for Attitude to the Subject of Chemistry Inventory (ASCI) for data obtained from 252 chemistry students at The University of the South Pacific. Extraction Method: Principal Axis Factoring, Rotation Method: Direct oblimin with Kaiser Normalization.

	Factor		
	1	2	3
interesting - dull	.811		-.598
pleasant - unpleasant	.808		-.529
comfortable - uncomfortable	.801		-.489
worthwhile - useless	.766		-.515
satisfying - frustrating	.745		-.492
good - bad	.736		-.482
exciting - boring	.733		-.466
comprehensible - incomprehensible	.685		-.423
easy - hard	.492		
work - play	.469		
safe - dangerous	.361		
complicated - simple	-.378	.600	.510
tense - relaxed		.577	
challenging - not challenging		.511	
worthless - beneficial	-.439		.714
disgusting - attractive	-.430		.708
chaotic - organised	-.514		.676
insecure - secure	-.354		.616
confusing - clear	-.473	.418	.534
scary - fun	-.476	.391	.533

Table 3: Pattern and structure matrix for 11 selected items from the Attitude to the Subject of Chemistry Inventory (ASCI). Data was obtained from 252 chemistry students at The University of the South Pacific. Extraction Method: Principal Axis Factoring, Rotation Method: Dirct oblimin with Kaiser Normalization.

	Pattern Matrix			Structure Matrix		
	Factor			Factor		
	1	2	3	1	2	3
Variance explained	40.49%	15.58%	9.51%			
comfortable - uncomfortable	.886			.832		-.488
pleasant - unpleasant	.726			.791		-.550
satisfying - frustrating	.758			.743		-.473
exciting - boring	.731			.729		-.444
worthwhile - useless	.705			.758		-.497
tense - relaxed		.580			.605	
complicated -simple		.427		-.385	.473	.488
challenging - not challenging		.637			.610	
worthless - beneficial			.736	-.454		.706
disgusting - attractive			.723	-.450		.733
insecure - secure			.500	-.399		.573

All loadings < 0.3 have been omitted.