Students' learning styles and academic performance in first year chemistry

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Introduction

Many factors influence students' learning – such factors include (but are not limited to) students' learning style preferences, their interest in the material under study, and the learning environment. A student's learning style preference refers to the way they respond to stimuli in a learning context, and to their characteristic way of acquiring and using information. These learning styles recognise that individuals learn in different ways, and thus that the students in any course will place a variety of different interpretations onto their lessons (Bailey and Garratt 2002). Felder (1993) reported that alignment between students' learning styles and an instructor's teaching style leads to better recall and understanding, as well as to more positive post-course attitudes. Since learning style preferences vary between students, the most effective mode of instruction will also vary. Furthermore, it has been reported that teaching is most effective when it caters for a range of learning styles, in part because occasionally having to learn in a less preferred style helps to broaden students' range of skills (Felder Felder and Dietz 2002). If any consideration is to be given to accommodating students' learning style preferences when considering the design of instructional or assessment materials, then it is necessary to know firstly whether the academic performance of students is dependent upon their preferred learning style, and secondly the distribution of learning style preferences within a student cohort must be known. This paper reports the distribution of learning styles amongst first year chemistry students at the University of Sydney, and investigates the relationship between academic performance in the end-of-semester examination and these styles. Some of the implications of these findings for teaching and learning are also discussed.

Determination of learning styles using the Paragon of Learning Styles Inventory
Several different instruments have been developed which allow students' learning styles to be investigated, such as the instruments developed by Shindler and Yang (2002) and Kolb (1984). Some such instruments are derived from different psychological bases, whilst others differ in that they were designed for different groups of students (allowing for different age ranges, for example) and for use in different domains. For valid results to be obtained, it is important that the instrument used be appropriate for the student cohort being investigated. The Paragon of Learning Styles Inventory (PLSI) has been chosen for this work, principally because its successful use with university level chemistry students has been previously reported (Tasker, Miller, Kemmett and Bedgood Jnr, 2003).

The PLSI is based on the personality test called the Myers-Briggs Type Indicator (MBTI), which in turn is based on Jung's theories of personality (Jung 1923). The MBTI was developed by Briggs-Myers in 1962 (Briggs-Myers and McCaulley 1985; Lawrence 1993) to classify people along the four Jungian psychological learning dimensions, giving a measure of cognitive and perceptual preferences (Shindler and Yang 2002). The MBTI is a reliable and validated inventory that assesses a person's personality type. The PLSI is a 48 item learning style inventory, developed by Shindler and Yang (2002) specifically for use in educational settings with students aged eight or older. It has shown excellent stability and reliability for people aged over 20.

The learning style preferences of a person, as identified by the PLSI, consist of four preferences, one each from the extrovert/introvert (EI), sensing/intuitive (SN), feeling/thinking (FT) and judging/perceiving (JP) dimensions. Characteristics of each style are summarised in Table 1. There

are 16 possible psychological types, covering every possible combination using one style from each dimension, and all possible types are found in society (Lawrence 1993).

Table 1: Characteristics of learning styles for each dimension

Learning Style	Function	Characteristics
Extrovert	Concerns the way people deal with other people and ideas	Learn through the outer world of people, things and actions
Introvert		Learn through the inner world of ideas, reflection and impressions
Sensing	Deals with how people take in information	Uses senses to draw on what is real
Intuitive		Use imagination to envision what is possible
Thinking	Concerns how people make decisions	Make decisions based on logic
Feeling		Make decisions based on people and their actions
Judging	Concerns the lifestyle a person prefers	Have preference for living a planned life
Perceiving		Spontaneous and flexible

Methodology

Participants

Three different groups of first year chemistry students participated in this study at the University of Sydney in 2004. All students were enrolled in one of the semester one chemistry units of study (UOS) available to students undertaking mainstream science qualifications. These UOS were CHEM1001 (Fundamentals of Chemistry 1A), CHEM1101 (Chemistry 1A) and CHEM1901 (Chemistry 1A – Advanced). All three units cover similar material, but differ in the level of assumed prior knowledge and the level at which material is presented. CHEM1001 students have either not completed chemistry for the Higher School Certificate (HSC), i.e., university entry level, or achieved comparatively poor results. CHEM1101 students have satisfactorily completed HSC chemistry, whilst CHEM1901 students have achieved a HSC chemistry mark above 80.

The survey instrument and scoring the instrument

The PLSI was distributed to 1143 first year chemistry students during a laboratory session. Each item of the PLSI relates to only one of the four dimensions and is scored according to which learning style is preferred. The score for each dimension is then obtained by summing the individual scores for all questions for that dimension. For any student with a balanced score on a dimension – that is, a score of 5 to 7, inclusive – it is usual to administer an additional survey called the *dimensions pairs list* to clarify a preference (Shindler and Yang 2002). However, since this is practically difficult to achieve unless conducting surveys one-on-one, and since we were more interested in dimension scores than in types, this was omitted. Instead, any student who scored 6 on a dimension was classified as balanced (X), and separated in data analyses involving types. Students with scores of 5 or 7 were assumed to have an (albeit weak) preference for the style to which they were inclined.

Results and discussion

Sample representivity

The PLSI was completed by 914 (77.3%) students. Figure 1 shows the distribution of examination grade bands for the CHEM1901 students, where it was found that there was no statistically significant difference between the distributions for respondents and non-respondents (χ^2=4.17, df=3, p=0.243). It follows that the responding advanced students were representative of all advanced students in first year chemistry. For the other two UOS the same tests showed that surveyed students were representative of all students who at least passed the UOS. However, students from the fail category are systematically under-represented in the respondent group for these UOS.
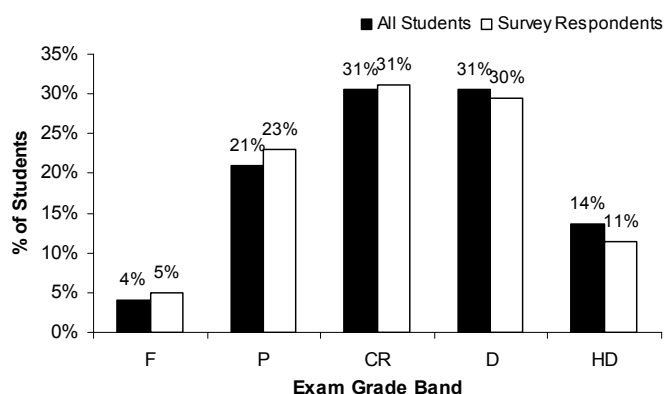
Figure 1: Distribution of examination grade bands for survey respondents and all students in CHEM1901

Distribution of learning styles amongst first year chemistry students

The distributions of learning styles of the surveyed first year chemistry students at the University of Sydney are shown in Figure 2. Data on the general population, derived from the Shindler and Yang (2002) study of Americans, is included for comparison, as statistics for Australians could not be located. A student's learning style preference was determined only for dimensions with responses to the full set of items. Gender distribution was determined using a survey distributed in semester two, and the proportions given for these distributions are based on those responses. Data from the FT dimension were separated by gender following similar analyses in the literature (Shindler and Yang 2002).
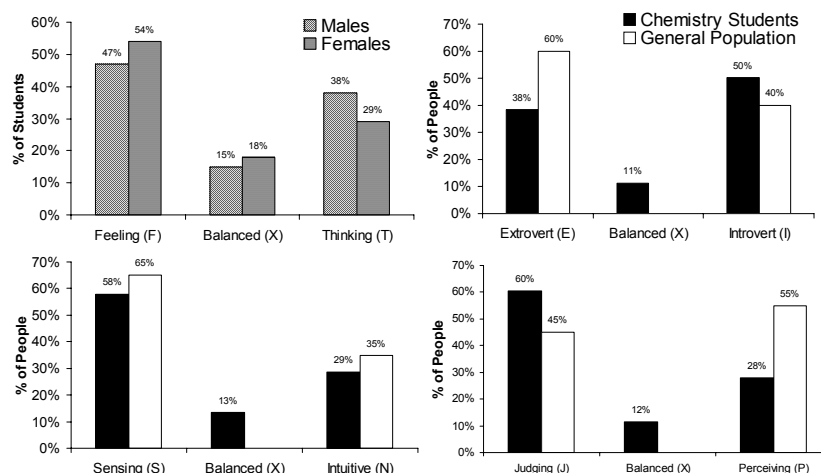

Figure 2: Distribution of learning styles of first year chemistry students

The distribution of learning style preferences amongst our first year chemistry students was not typical of the general population. A significantly higher proportion of chemistry students are *introverts*, compared to *extroverts*, perhaps because study of chemistry mainly involves individual work, which appeals to introverts. Chemistry also has more *judgers* than *perceivers*, possibly reflecting the logical, systematic and formal way that it is taught, which appeals to judgers. The distributions for these two dimensions do not vary between the different UOS.

There is no major variation for the FT dimension between the UOS; however, consistent with the general population, females predominate as feelers and males predominate as thinkers. The distribution for the SN dimension is consistent with the general population and independent of gender. The CHEM1901 cohort on its own, however, tends to have more intuitors (48%) than are found in other UOS (≈ 30%). A reason for this may be that intuitors take in information by seeing the 'big picture'. They are able to deal with abstract and complex concepts and are oriented towards theories, and are therefore able to grasp such ideas, commonly found in chemistry, more easily.

Relationship between learning styles and academic performance

The MBTI categorises personality characteristics by dichotomous types, which should lead to bimodal score distributions along each Jungian dimension. However, recent literature (Harvey and Murray 2002) has reported centre-weighted, unimodal dimension score distributions, and previous reports of bimodal distributions have been attributed to analysis artefacts (Bess and Harvey 2002). Figure 3 shows the distribution of scores along the EI and FT dimensions for University of Sydney chemistry students, which are clearly centre-weighted and unimodal. Such unimodal distributions are inconsistent with the existence of dichotomous types (which would be expected to produce bimodal distributions, with comparatively few people positioned near the centre). Rather, these data support the notion of personality traits, which vary in strength along each dimension. For this reason, each student's dimension score, derived from the PLSI, will be treated as indicative of the strength of their preference for a trait, rather than simply being used to categorise them into types. As such, the strength of the relationship between learning style preferences and academic performance can be investigated along the dimension, rather than merely for three discrete categories of students.
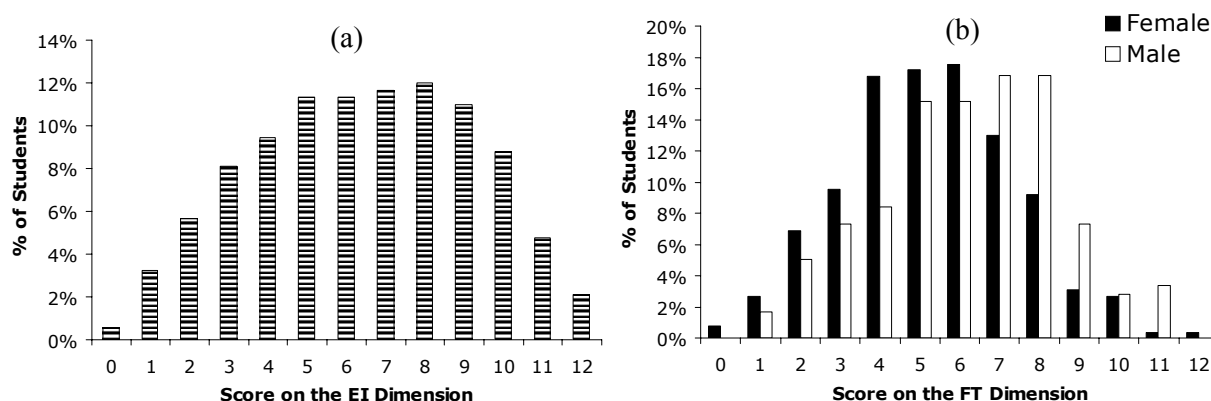
Figure 3: Distributions of students along the (a) EI dimension and (b) FT dimension

The examination marks for each of the scores on the EI dimension were averaged and a 95% confidence interval for the mean of the examination performance was constructed. Figure 4(a) shows the correlation between EI score and average final examination mark for CHEM1101, the largest of the UOS involved in this study. Similar correlations were found for all UOS examined. This correlation shows that introverts tend to perform better than extroverts with an average difference of up to ten marks across the dimension. It should be noted that students scoring zero or twelve were not used in the calculation of the regression line, as these groups are comparatively small, and including them introduces an inappropriate distortion into a calculation which does not take account of group size.

Academic achievement requires the capacity to deal intensively with concepts and ideas, which should favour people with introvert characteristics. On this basis, it has been predicted that introverts should outperform extroverts on tests of academic aptitude (Briggs-Myers and McCaulley 1985). This prediction has been independently verified in the domain of engineering by the studies of O'Brien, Bernold and Akroyd (1998) and Felder et al. (2002). The present study extends this finding to the domain of chemistry, where academic performance is again higher amongst introverts. Given the, at times, abstract and theoretical nature of chemistry, this finding is consistent with expectations.

Figure 4(a) also shows a performance decrease for students at the extreme introverted end of the EI dimension. The skill set of a successful chemistry student would be expected to include some skills based on typical extrovert characteristics – such as communication skills. Furthermore, since learning involves social interaction (Palincsar 1998), it seems reasonable that the near complete lack of extrovert characteristics is likely to impede learning. However, it is recognised that further work is needed if this plausible explanation is to be verified.

The examination marks for each score on the FT dimension were analysed in a similar fashion to that used for the EI dimension. Figure 4(b) shows the moderate correlation between FT dimension

score and average final examination mark, with thinkers tending to perform better than feelers, and with an average difference of up to eight marks between the extreme scores. Students scoring zero, one and eleven were not used in the calculation of the regression line, as these groups are extremely small, and would cause the same distortions to the regression line that were previously mentioned.
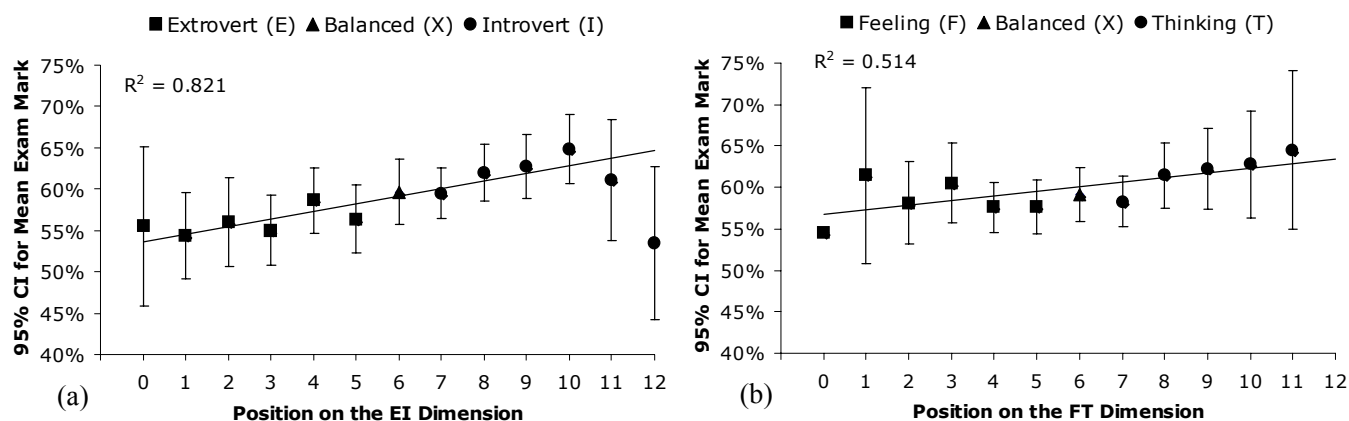

Figure 4. Correlation between examination performance and learning style for CHEM1101 grouped by position on (a) EI dimension and (b) FT dimension

It has been suggested that the FT dimension should have a minor influence on academic performance in the field of engineering (Briggs-Myers and McCaulley 1985). In the field of science, it has been assumed that thinkers would have an advantage over feelers; however, prior to this work there has been no research to support this assumption. The present study has shown unambiguously that the FT dimension does have an influence on academic achievement of chemistry students and in particular that thinkers do outperform feelers. It should also be noted that, despite what might be expected from the characteristics of the styles involved, no significant relationship was found between academic performance and score on either the SN or JP dimensions.

As there is evidence to suggest a difference in academic performance associated with differences in learning styles for both the EI and FT dimensions, with introverts and thinkers being favoured, consideration could be given to making changes to current teaching and assessment strategies to improve the performance of extroverts and feelers. At present, first year chemistry assessment incorporates very little group related activities, despite laboratory exercises often being done in pairs. One possible way to better accommodate the learning style of extroverts would be to introduce assignments for which students work in groups, as extroverts prefer to actively engage with the subject by interacting with others. Group work will also benefit feelers, who enjoy social interaction in harmonious groups. Such group work could be assessed via a poster presentation and oral report, providing the opportunity for extroverts to showcase their chemistry ability. This modification of assessment might help to redress the imbalance in assessment practices, as first year chemistry is currently almost exclusively assessed in written form, which strongly favours introverts. Huddle (2000) has reported that the inclusion of a poster session as part of the assessment in organic chemistry enhances student learning, and thus this assessment modification has benefits beyond those associated with assisting the extroverts and feelers in the student cohort. Methods of assessing poster sessions have also been described (Mills, Sweeney, DeMeo, Marino and Clarkson 2000).

Peer assisted study sessions (PASS) have been reported to improve the performance of students who attend them (Miller, Oldfield and Bulmer 2004). PASS offer a collaborative learning environment in which students can integrate traditional methods of teaching with learning from student centred discussions in a relaxed yet intellectually stimulating environment. The introduction of a similar program in first year chemistry at the University of Sydney would be of particular benefit to extroverts and feelers, as they learn best when socially interacting, whether with their teachers or their peers. Such a program might help to even the imbalance which has been identified.

Conclusion

Comparing individuals' learning styles and end-of-semester examination performance clearly showed that introverts performed better than extroverts and thinkers performed better than feelers. This finding strongly suggests that consideration does need to be given to learning styles when considering both questions of instructional practice and questions of assessment design. This paper has shown that knowledge of the learning style preferences of students could be used to develop targeted improvements in teaching, and some suggestions concerning how the learning styles of extroverts and feelers might be better accommodated have been made. It has also been suggested that the diversification of teaching strategies would address a wider variety of learning styles, thereby helping to minimise mismatches between learning and teaching styles, whilst ensuring that less preferred learning styles of students are accommodated. This will not only improve teaching and learning but might also increase retention rates for chemistry students in the future. Further research into the alignment of learning and teaching styles will be needed before implementing such a change.

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