The Chemical Misconceptions of Pre-service Science Teachers at the University of Limerick: Do they change?

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Abstract

Science teachers in Ireland can enter the profession through two models of teacher training: through a concurrent science education degree programme, or by taking a Higher Diploma in Education after completing a degree in science. The University of Limerick offers a concurrent model of science teacher training. Like many other pre-service science teachers and students of science worldwide, these students have many misconceptions in chemistry (Mulford & Robinson 2002; Kruse & Roehrig 2005; Kind 2009). The presence of misconceptions has been well documented amongst students at all levels of education in numerous areas of the chemistry curriculum (Ben-Zvi *et al.* 1986; Peterson and Treagust 1989; Taber 2002; Kind 2004; Cakmakci 2010). It has been noted that this is, in the main, due to the abstract nature of the subject which requires learners to operate at a high cognitive level (Reddish 1994; Johnstone 2006; Childs and Sheehan 2009). The issue of chemical misconceptions is a significant issue for the quality of pre-service science teachers. Such students may leave their third level education without having ever had their misconceptions addressed. For an improvement in science education to occur teachers must be able to apply the findings of research into chemical misconceptions, yet many pre-service chemistry teachers have numerous misconceptions themselves (Haidar 1997; Nakiboglu 2003; Canpolat *et al.* 2006; Tan & Taber 2009; Pinarbasi *et al.* 2009), which they may transmit to their students in turn. Previous studies have also found gender and age to be factors affecting students' learning (Linn & Peterson 1985; Bunce & Gabel 2002; Kelly 2005). This study aims to investigate the number and type of chemical misconceptions pre-service science teachers possess and whether these misconceptions are altered as they progress through their degree programme. This study of pre-service science teachers chemical misconceptions showed a high level of misconceptions, which did not alter significantly through their four years of training. Gender and the course studied were significant factors in the level of misconceptions displayed.

Key Words:

Pre-service science teachers; Chemical misconceptions; Science education

Introduction

The quality of teachers has been found to have a significant impact on the success of educational systems (Barber & Mourshed 2007) and on the academic success of learners (Sanders and Rivers 1996). The production, therefore, of highly competent teachers with a solid understanding of the fundamental concepts of chemistry is required in order to produce an education system which serves the needs of its learners. The presence of chemical misconceptions in pupils in secondary education (Kind 2004; Peterson and Treagust 1989; Schmidt 1997; Sheehan 2010), undergraduate students (Cakmakci 2010; Kelly *et al.* 2010; Mulford and Robinson 2002), science graduates (Coll and Treagust 2003; Taber 2000), pre-service science teachers (Calik and Ayas 2005; Kerr *et al.* 2006; Tan and Taber 2011) and qualified teachers (Kruse and Roehrig 2005; Kikas 2004) have been widely reported in other countries. Learners operating at the formal operational stage of cognitive development, as described by Piaget, have been found to have more success at chemistry and a deeper understanding of the subject. (Bunce and Hutchinson 1993) Studies have linked development of cognitive ability with increases in mathematical ability and age. Gender has also been reported as a significant factor in these studies, with male learners showing increased cognitive development compared to female learners of the same age (Shayer and Adey 1981; Sheehan 2010). Misconceptions are known to be resistant to change through traditional means of teaching (Mulford and Robinson 2002; Peterson and Treagust 1989) and require direct targeting in order to be addressed (Thomaz *et al.* 1995; Wood and Breyfogle 2006).

Recent studies in Ireland (McCormack 2009; Sheehan 2010) found that chemical misconceptions are widespread among Junior Certificate and Leaving Certificate pupils. Typically Junior Certificate and Leaving Certificate pupils are aged 14-15 and 16-18 years of age, respectively. In order to address this problem, teachers must be prepared to turn the findings of research on chemical misconceptions into practice. Teachers must also have a sound understanding of fundamental chemistry concepts and possess relatively few misconceptions themselves.

Rationale

There are two models of teacher education in place in Ireland through which prospective science teachers may enter the profession: a concurrent model and a consecutive model. The concurrent model involves a four year degree programme in both science and education. In the consecutive model, graduates of science complete a Higher Diploma in Education. The University of Limerick offers a concurrent model of science teacher education. As is the case in many institutions, the mode of instruction in place in the University of Limerick is a traditional lecture style which has been found to emphasise lower order cognitive skills such as recall (Zoller 1993). The misconceptions of pre-service science teachers are, therefore, not directly addressed and may therefore persist throughout their four years of concurrent science and teacher education. An exploratory study was conducted in order to identify the problematic areas and the number of chemical misconceptions of a group of pre-service science teachers in their third year of study.

The research questions guiding this exploratory study were:

1. What chemical misconceptions do these pre-service science teachers hold?
2. Is there a link between these misconceptions and gender, age or course studied?
3. What effect do misconceptions have on students' feelings of confidence and preparedness in teaching chemistry?

Based on the findings of this exploratory study, a larger scale pilot study was then devised. Research Questions 1 and 2 were addressed in this study, in addition to the following:

4. Are the misconceptions present in the first year of pre-service teachers' chosen course of study altered over the course of four years of formal study?
5. Is there a link between the number of misconceptions and previous school experience of chemistry and mathematics?

Methodology

This study began with the hypothesis that, like students in other countries and institutions, our pre-service science teachers would have misconceptions in chemistry. The study consisted of two parts: an exploratory study which sought to identify if third year pre-service science teachers held misconceptions in the area of chemistry and a follow up pilot study to investigate whether these misconceptions varied as students progressed through their degree programme from first to fourth year.

a) Exploratory Study

The instrument utilised in the exploratory study was initially designed to provide one of the authors with information about the prior knowledge, misconceptions and feelings of preparedness towards teaching Leaving Certificate chemistry of pre-service teachers, undergoing a chemistry pedagogics module. Therefore, this phase was never designed with the larger scale study in mind. However, the results of this initial study were so poor that further investigation was required. The test consisted of 17 questions which encompassed the conceptual areas described in Table 1.

Table.1: Structure of Pre-service Science Teacher Chemical Misconceptions Test for Exploratory Study

Concept Area	Subtopic (where relevant)	Questions	Sources of Questions
Particulate Nature of Matter	Atomic Structure	Q13, Q16	Taber (2003); Tan and Taber (2009)
	Chemical Formulae & Equations	Q1	Mulford & Robinson (2002); Sheehan (2010)
	Phase Change	Q2, Q5, Q6	Yezierski & Birk (2006); Sheehan (2010)
	Gas Laws	Q3	National Institute for Science Education (NISE) (2008)
	Solution Chemistry	Q14, Q17	NISE (2008)
Chemical Bonding		Q6, Q7, Q8	Taagepera & Noori 2000; Yezierski & Birk 2006
Equilibrium		Q4	NISE (2007)

It was not possible to test the students for misconceptions in all areas of the Leaving Certificate chemistry syllabus due to time constraints. It was decided to test areas that previous studies had shown to be problematic and that the authors knew from their own experience with the students to be areas of difficulty. (Peterson & Treagust 1989; Mulford & Robinson 2002; Yezierski & Birk 2006; Tan & Taber 2009; Sheehan 2010) Students were given the test instrument during a 3rd year chemistry pedagogy lecture session (N = 55) and there was a response rate of 80% (n = 44). Students were also given a questionnaire examining their confidence for their upcoming 4th year teaching practice experience. Responses were coded as correct or incorrect and analysed using Predictive Analytics Software (PASW). Question 14 comprised of many parts (7) testing three different concept areas relating to solution chemistry. The decision was taken to treat Q14 as three different questions (with each concept area grouped as one question) and, therefore, Q14 was triple weighted. The results presented and discussed in this paper refer to the misconceptions that were tested in the exploratory instrument. The pre-service science teachers' responses to the prior knowledge questions are not discussed in this paper.

b) Pilot Study

The results of the exploratory study indicated the need for an examination on a wider scale of the chemical misconceptions held by pre-service science teachers across all years of study. Common chemical misconceptions were identified based on a review of the literature. It was decided that the Leaving Certificate syllabus should provide the basis for a framework which would allow the misconceptions to be categorised. A new instrument was designed to test what the authors considered to be the most fundamental concepts in the Leaving Certificate syllabus using appropriate conceptual questions from the literature. A number of questions developed by the authors were used in cases where no appropriate question could be obtained from the literature. The instrument was reviewed both internally and externally by experts. The instrument consisted of twenty-one questions and tested the conceptual areas shown in Table 2. Question 2 was broken up into three separate questions for the purposes of marking the instrument, as it assessed three different conceptual areas.

Table 2: List of Concepts & Questions included in Pilot Study Instrument (* indicates question also used in exploratory study)

Concept Area	Subtopic (where relevant)	Question No.	Concept(s) being tested	Source of Questions
Particulate Nature of Matter	Atomic Structure	Q7*	Factors influencing ionisation energies	Taber (2003); Tan & Taber 2009)
	Chemical Formulae & Equations	Q5, Q6*, Q11	Meaningful conversions from symbolic to microscopic	Mulford & Robinson (2002)
	Phase Change	Q3*	Understanding of phase change	Yezierski & Birk (2006); Sheehan (2010)
	Conservation	Q4	Conservation of matter	Mulford & Robinson (2002)
	Composition of Matter	Q1, Q2	Microscopic nature of atoms, elements, compounds and mixtures	Sanger (2000); Mulford & Robinson (2002)
Chemical Bonding		Q13, Q14, Q15, Q16, Q20	Process and energetics of bonding, effect of bond type and structure of ionic compounds	Developed by author; Peterson & Treagust (1989); Mulford & Robinson (2002); Jensen (unpublished)
Equilibrium		Q17, Q18	Dynamic nature of equilibrium and the equilibrium constant	Krause *et al*. (2004); Adapted for Journal of Chemical Education website

Pre-service teachers who will receive a qualification to teach chemistry at the end of their course of study were the target group for this study. Pre-service teachers were invited to come to a drop-in centre to complete the instrument. In order to improve the response rate, the instrument was later administered during lecture and laboratory slots in pre-service teachers' timetables for all four years of the courses. There were 274 such candidates identified in the University of Limerick and 212 of these took part in the study giving a response rate of 77%. No time limit was imposed on participants. Responses were analysed using PASW.

<u>Results & Analysis</u>

Exploratory Study

Table 3 below, indicates that the overall scores of the students in the exploratory study were low. The particulate nature of matter was clearly the most problematic area for the students, with a poor overall score.

Table 3: Breakdown of Mean Scores for Each Concept Area in Exploratory Study

Concept Area	Questions	Average Score (n= 44)	% of Sample not Attempting
Particulate Nature of Matter	Q1, Q2, Q3, Q5, Q6, Q13, Q14, Q16, Q17	25.8%	4.26% (n = 2)
Chemical Bonding	Q 6, Q7, Q8	46.9%	0.0% (n = 0)
Equilibrium	Q4	78.6%	4.26% (n = 2)
All Areas		32.8%	

The relationship between the pre-service science teachers' overall scores and their gender, age, course of study, previous school experience in chemistry and confidence to teach the subject at Leaving Certificate level were tested for significant differences. These results are presented in Table 4 below.

Table 4: Significance of Relationships in Exploratory Study

Relationship being Tested	Statistical Test(s)	Result	Meaning
Gender & Overall Score	Independent Samples T-Test	$t(42) = 4.598$, $p < 0.05$	On average, male (M = 44.8, SE = 3.6) participants achieved higher scores than female participants (M = 24.5, SE = 2.7).
Age & Overall Score	Bivariate Correlation	$r = 0.226$, $p > 0.05$	Older pre-service teachers were found to achieve higher scores, though not significantly so.
Course of Study & Overall Score	Independent Samples T-Test	$t(40)= 2.403$, $p<0.05$	The mean score for those studying '*Physical Sciences (ed)*' (M = 46.1, SE = 5.4) was significantly greater than for those studying '*Biological Sciences with Chemistry (ed)*'. (M = 30.9, SE = 2.8) and *'Physical Education with Chemistry (ed)'* (M = 12.5, SE = 12.5).
Leaving Certificate Chemistry and Overall Score	Independent Samples T-Test	$t(37)= 0.527$, $p>0.05$	Those that studied chemistry for the Leaving Certificate achieved higher scores than those that did not, though not significantly so.
Level of confidence in ability to teach Leaving Certificate Chemistry and Overall Score	One-Way ANOVA Hochberg Post-Hoc Test	$F(4, 36)=2.545$, $p>0.05$	A trend demonstrating an increase in the mean score for pre-service teachers as confidence increased was observed, but this combined effect was not significant. A significant linear trend ($F(1, 36) = 5.709$, $p<0.05$), was observed when examining the relationship between the pre-service teachers' confidence in their ability to teach chemistry at Leaving Certificate level and their overall scores. This indicated that the pre-service teachers' confidence levels increased linearly with their overall scores.

The results summarised in Table 4 indicate that there were significant differences among the students tested in the exploratory study. Initial analysis of the data indicated that there was a relationship between the students' gender and their overall performance on the instrument. Links between the students' age were also noted, with the older students performing better overall on the questions examined. Pre-service teachers of twenty-one years of age or older were found to achieve higher scores in the instrument though these differences were not considered to be significant. It was also noted that the pre-service teachers' chosen course of study had a significant effect on their performance in the overall score achieved on the questions examined. Students in the course '*Physical Education with Chemistry (ed)*' were not considered as there was a lack of confidence in test results due to the small sample size (n = 2) of the group. When the pre-service science teachers' confidence levels were examined it was found that despite a lack of significance in the overall combined effect, there was a proportional increase of the overall scores with confidence levels.

Pilot Study

The results grouped by concept area are shown in Table 5. The overall performance of pre-service science teachers was poor with an average score of 30.8%. Over 80% of the pre-service teachers taking part in the study achieved less than 40% on the overall instrument. The results are similar for each section of the instrument as shown in Table 5, with average scores < 50%.

Table 5: Breakdown of Mean Scores for Each Concept Area in Pilot Study

Concept Area	Questions	Average Score (n=212)	% of Sample not Attempting Section
Particulate Nature of Matter	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q11	28.2%	0
Stoichiometry	Q8, Q9, Q10, Q12	43.0%	0.5
Chemical Bonding	Q13, Q14, Q15, Q16, Q20	32.7%	1.4
Equilibrium	Q17, Q18	31.1%	0.9
All Areas		30.8%	0

A breakdown of the scores achieved in the Chemical Misconceptions Identification Instrument is displayed in Figure 1.

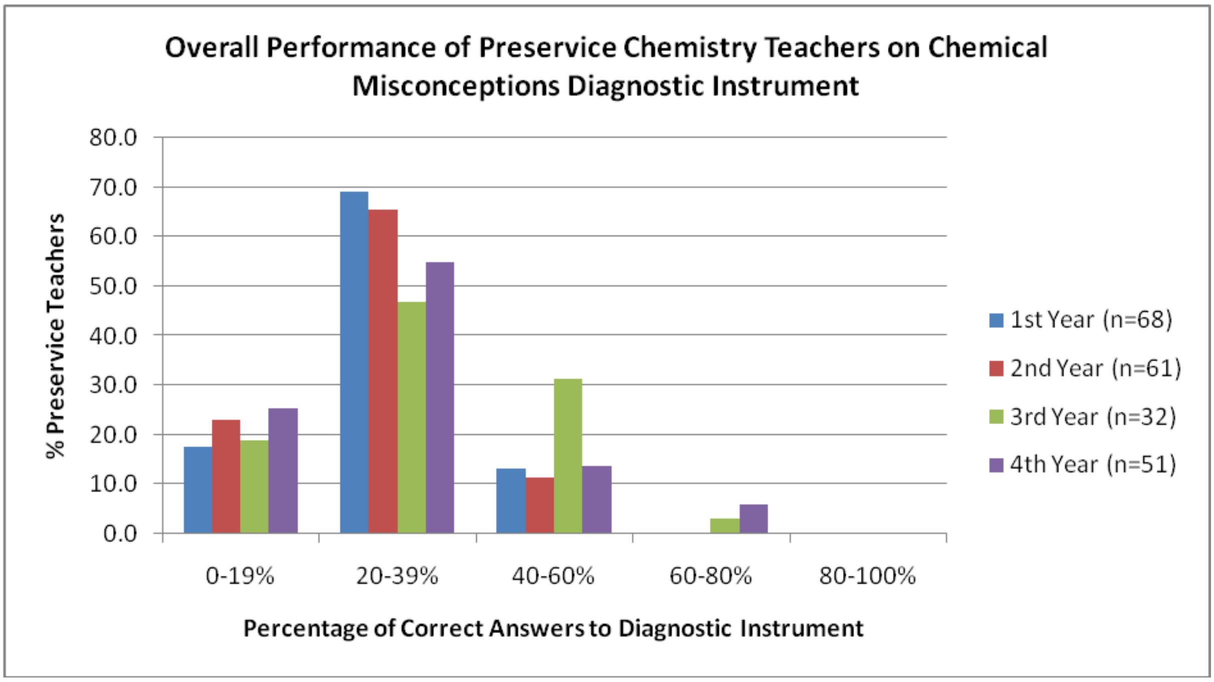

Figure 1: Breakdown of Performance of Preservice Teachers in Pilot Study Instrument

On analysis of the responses of pre-service chemistry teachers to the instrument, a number of significant factors emerged as having an effect on the percentage obtained by pre-service teachers. These factors were gender, age, course of study, background in Leaving Certificate chemistry, and background in Leaving Certificate mathematics. There was found to be no significant effect of year of study on the performance of pre-service chemistry teachers. A summary of these tests may be found in Table 6.

Table 6: Significance of Relationships in Exploratory Study

Relationship being Tested	Statistical Test(s)	Result	Meaning
Gender & Overall Score on CMII	Independent Samples T-Test	$t(210) = -4.43$, $p < 0.05$	On average, male participants (M = 35.7, SE = 1.5) achieved higher scores than female participants (M = 28.1, SE = 0.96).
Age & Overall Score on CMII	Bivariate Correlation	$r = 0.153$, $p < 0.05$	Older pre-service teachers were found to achieve significantly higher scores.
Course of Study & Overall Score	One-Way ANOVA Hochberg Post-Hoc Test	$F(5, 206)=8.29$, $p<0.05$	The mean score for those studying '*Physical Sciences (ed)* (M = 44.2, SE = 2.6)' was significantly greater than those studying '*Biological Sciences with Chemistry Elective (ed)*' (M = 29.4, SE = 1.8), '*Biological Sciences with Physics Elective (ed)*' (M = 25.8, SE = 2.2) and '*Biological Sciences (no elective) (ed)*' (M = 29.0, SE = 1.1), though not for ' *Physical Education with Chemistry (ed)*' (Insert M = , SE =).
Leaving Certificate Chemistry Level & Overall Score	One-Way ANOVA Hochberg Post-Hoc Test	$F(2, 171)=7.58$, $p<0.05$	Pre-service teachers with higher level chemistry for the Leaving Certificate (M = 33.5, SE = 1.1) achieved higher scores than those that did not study chemistry for the Leaving Certificate (M = 25.5, SE = 1.7).
Leaving Certificate Mathematics Level and Overall Score	Independent Samples T-Test	$t(204)= -3.30$, $p<0.05$	Those that studied higher level mathematics (M = 33.4, SE = 1.2) for the Leaving Certificate achieved higher scores than those that studied ordinary level mathematics (M = 27.8, SE = 1.2).
Year of Study & Overall Score	One-Way ANOVA Gabriel Post-Hoc Test	$F(3, 208)=1.79$, $p>0.05$	Those in their fourth year of study achieved the same scores as those in their first, second and third years of study

Figure 2 shows the performance of pre-service teachers in each year of study for each question in the Chemistry Misconceptions Identification Instrument. As can be seen in Figure 2, the most poorly answered questions on the instrument, with less 20% of the total cohort responding correctly, were Questions 2b, 2c, 6, 7, 9, 11, 15, 19 and 20. Five of these questions are concerned with concepts relating to the particulate nature of matter and two with chemical bonding. Misconceptions found in more than 10% of pre-service chemistry teachers have been listed in Table 7.

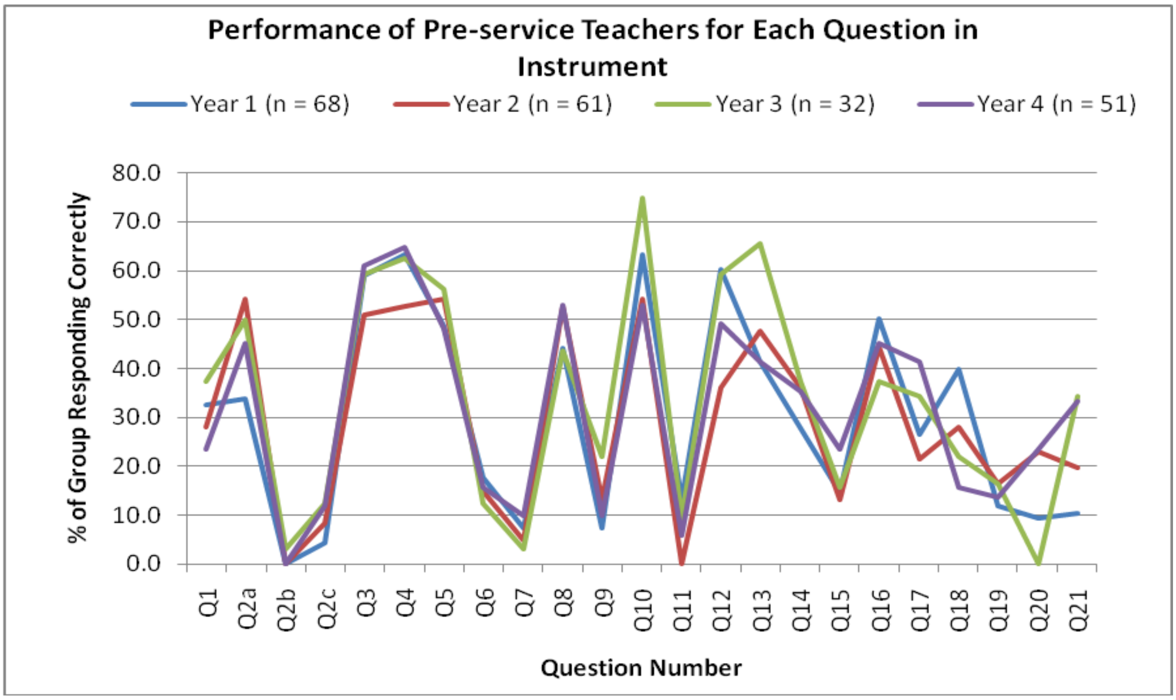

Figure 2: Breakdown of Performance of 1st, 2nd, 3rd & 4th Year Pre-service Teachers in each Question in the Pilot Study Instrument

Question 6, as shown in Figure 3, was one of the most poorly answered questions in the instrument and was used in both the exploratory and pilot studies. This question was designed to assess conceptual understanding of coefficients and subscripts in chemical formulae and equations and the role of a limiting reagent. A full list of the chemistry misconceptions identified from the instrument may be found in Table 7.

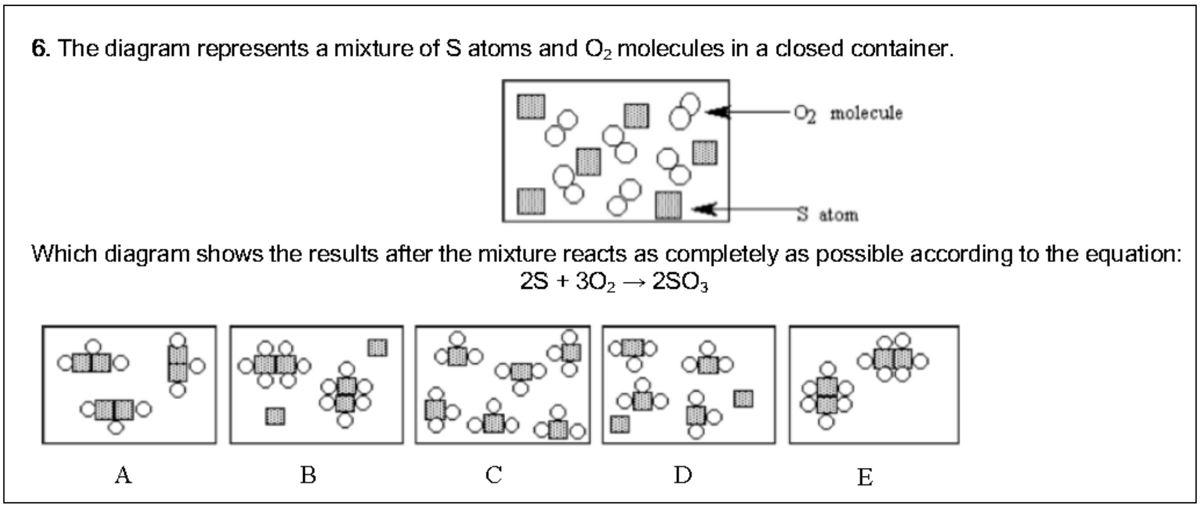

Figure 3: Conceptual Question Used in Both the Exploratory & Pilot Studies

Table 7: List of Specific Misconceptions found in more than 10% of Pre-service Teachers

Concept Area	Subtopic (where relevant)	Misconceptions Identified	% of Sample (N=212)
Particulate Nature of Matter	Atomic Structure	Use of Octet Rule analogy to explain differences in ionisation energies	42.0%
		Use of relation-based reasoning to explain differences in ionisation energies	34.4%
	Chemical Formulae & Equations	Confusing the meaning of coefficients and subscripts	56.5%
		A failure to conserve atoms or understand the role of a limiting reagent	74.9%
	Phase Change	A belief that a phase change from liquid to gas involves the breaking of covalent bonds	30.1%
	Conservation	Matter not conserved as gas weighs less or is less dense than solid	27.8%
	Composition of Matter	Attributing macroscopic properties such as density, melting point and structure to a single atom	52.4%
		Identifying all pure substances composed of elements as homogeneous mixtures	20.7%
		Identifying pure substances composed of compounds as heterogeneous mixtures	25.5%
		Identifying substances containing more than one element as compounds	30.2%
Stoichiometry	The Mole	The mass of a particle affects the number of particles in one mole of substance	31.1%
		The type of particles affects the number of particles in one mole of substance	10.4%
		12g of Carbon contains a mole of electrons	58.0%
		Unable to apply mole ratio to generic chemical equation	30.2%
	Volumetric Analysis	Belief that a solution of 1M contains molecular mass of substance in 1 L of water	19.8%
Chemical Bonding		Belief that an ionic bond involves the sharing of electrons	15.6%
		The electron pair is centrally located in a covalent bond	30.2%
		Breaking bonds releases energy	61.1%
		Ionic bonding is always stronger than covalent bonding	19.3%
		The presence of metallic bonds raises the boiling point of a substance	12.7%
		N_2H_4 is a resonance structure	15.6%
		Lone pairs can never exist on adjacent atoms	16.5%
		Nitrogen forms triple bonds when possible	26.9%
Equilibrium		Reactant concentration increases as equilibrium is established	28.8%
		Concentration fluctuates as equilibrium is established	20.3%
		Failure to understanding meaning of equilibrium constant	49.0%

Discussion

The number of misconceptions found among pre-service science teachers in the overall study was high with over 80% achieving less than 40% in the instrument used in the pilot study. The average score achieved in the overall instrument was 30.8%. Other studies which have looked at the conceptual understanding of general chemistry topics have found similar results. Mulford and Robinson (2002) found that the average score achieved by college students undertaking a traditional first semester general chemistry course was 45.5%. In Ireland, a study performed by Sheehan (2010) to investigate the chemical misconceptions held by Junior Certificate and Leaving Certificate pupils found that 67.2% and 63.8%, respectively, achieved less than 40% in a test designed to assess conceptual understanding of fundamental topics in chemistry. This suggests that the Irish education system is not dealing with the misconceptions of learners. While direct comparison cannot be made between this study and the study by Sheehan (2010), given the use of different instruments to identify misconceptions, one can infer that throughout secondary and tertiary level education in Ireland the number of misconceptions held by learners remains unacceptably high, and is little affected by additional years of study.

Pre-service science teachers demonstrated the poorest conceptual understanding in questions related to the particulate nature of matter in both the exploratory study (M=25.8%) and the pilot study (M=28.2%). Over 70% in the exploratory study and 60% in the pilot study achieved less than 40% in the conceptual area of particulate nature of matter. Yezierski and Birk (2006) note a similarly poor understanding of this conceptual area among college general chemistry students who achieved an average score of 51.5% on the authors' test. The number of misconceptions held by pre-service teachers about the particulate nature of matter appears to be much the same as the number of misconceptions held by Junior Certificate and Leaving Certificate pupils with 67.2% and 49.9%, respectively, achieving less than 40% in questions related to this topic (Sheehan 2010). The current study found misconceptions about the particulate nature of matter relating to the macroscopic and microscopic views of matter; compounds, elements and mixtures; phase change at particulate level, conservation of mass, chemical formulae and equations, ionisation energy and solution chemistry. These findings are in agreement with other international studies (Ben-Zvi *et al.* 1986; Mulford and Robinson 2002; Kruse and Roehrig 2005; Tan and Taber 2009).

Gender was found to have a significant impact on the number of misconceptions held by pre-service science teachers with female pre-service teachers holding a greater number of misconceptions. This may be the case due to the different learning strategies employed by female learners. Meece and Jones (1996) found that female learners were more likely to engage in rote learning. Furthermore, differences in the number of misconceptions held by the genders may be the result of differences in cognitive development, as male students at upper secondary and university level have been found to be more likely to operate at the formal operational level than female students (Sheehan 2010). Shayer and Adey (1981) also found a direct correlation between cognitive development and age which is likely to account for the lower number of misconceptions found in pre-service teachers over twenty-one years of age in this study.

The area of science that pre-service teachers were specialising in was found to be a significant factor when related to their overall performance in the concept test. Pre-service science teachers with subject specialism's in the Physical sciences did significantly better than their peers in the concept tests in both studies. One possible explanation for this is the higher mathematical ability of the pre-service teachers in the LM096: Physical Sciences (ed.) when compared to that of their counterparts in the Biological Sciences courses. Previous research has shown significant linkages between mathematical ability and cognitive levels, with students who display a higher mathematical ability being more likely to operate at the formal operational level of thinking (Sheehan 2010).

There was found to be no trends or significant relationships between the year of study and the number of misconceptions held by pre-service science teachers. In the vast majority of cases, there was also no relationship between the year of study and the responses selected for each of the individual questions. This suggests that neither the number nor type of misconceptions is significantly altered over the course of four years of university education for pre-service science teachers. Similar findings were noted by Sheehan (2010) in the number and type of misconceptions amongst Junior Certificate and Leaving Certificate. This suggests that the misconceptions found in the pre-service science teachers taking part in this study are likely to have persisted from their early study in secondary school if not possibly from their primary education (McCormack 2009).

The highly resistant nature of misconceptions to traditional forms of instruction has been well recorded (Holt-Reynolds 1992; Mulford and Robinson 2002; Peterson and Treagust 1989). This study suggests that the education system in Ireland, as has been found in other countries, does not encourage the reduction or alteration of chemistry misconceptions in learners. Misconceptions are known to interfere with new learning (Clement 1982; Smith *et al.* 1993). Thus, the Irish education system is producing learners with high numbers of misconceptions and low conceptual understanding of chemistry. However, a recent intervention project in Ireland (Sheehan and Childs, 2011) has demonstrated that it is possible to increase pupils cognitive level and reduce the number of chemical misconceptions using a carefully designed programme of study.

Conclusion & Reflections

Pre-service science teachers enrolled in science education courses at the University of Limerick have unacceptably high levels of chemical misconceptions across all years of study. These misconceptions are not reduced or altered in any significant way over the course of four years of study. Thus, it would appear that the concurrent science education programmes at the University of Limerick are not successful in addressing learners' misconceptions and deepening their understanding of chemistry concepts. Pre-service teachers that studied higher level chemistry and mathematics for the Leaving Certificate were found to hold fewer misconceptions than their peers. Male pre-service teachers also held fewer misconceptions than females of the same age, while those over twenty-one years of age were similarly found to hold fewer misconceptions. Those enrolled in courses with significant mathematical and physics content also demonstrated better conceptual understanding of fundamental chemistry topics. These differences in conceptual understanding are likely to be the result of differences in the cognitive level at which pre-service teachers in these group are operating.

The limitations of this study included the small sample size of the exploratory study, which led to a lack of homogeneity within this sample among the age, previous school experiences with chemistry and course area. The exploratory also only examined three conceptual areas of chemistry, allowing only a limited comparison between the two phases. The results of the pilot study merely provide a snapshot of the number and type of chemical misconceptions present in each of the four years of study which are not homogeneous in the areas of age, previous school experience in mathematics and chemistry and course of study.

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