The Quality of an Educational System cannot Exceed the Quality of its Teachers

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Overview of Presentation

- Background
- Focus of Study
- Research Questions
- Methodology
- Results
- Key Findings
- Conclusions
- Implications and Future Work
Background
Irish Education System

• Producing students with average reading and scientific literacy (Perkins *et al.*, 2011).
• Producing students with below average mathematical skills (Perkins *et al.*, 2011).
• Those entering third-level education often lack critical thinking and independent learning skills (Department of Education & Skills, 2010).
• Misconceptions about basic chemistry concepts are widespread among Junior & Leaving Certificate students (Sheehan, 2010).
School Systems

• The quality of an educational system cannot exceed the quality of its teachers (Barber & Mourshed, 2007).

• Raising the calibre of pre-service and in-service teachers is a successful strategy for improving educational systems like Ireland’s (Mourshed et al., 2010).
Subject Matter Knowledge

• The presence of misconceptions in the subject matter knowledge of teachers has been found to affect their
  – lesson plans, and
  – ability to detect and correct misconceptions amongst students.

• They can also lead to teachers
  – reinforcing misconceptions,
  – incorrectly criticising student answers, and
  – accepting faulty lab results.

(Abell, 2007; Hashweh, 1987)
Focus of Study

• To gain insight into the chemistry subject matter knowledge of pre-service science teachers in Ireland by investigating the prevalence of misconceptions among this group.
Research Questions

• What number and type of misconceptions in chemistry are held by Irish pre-service teachers?
• Does the number of years of science and science pedagogy study have an effect on the number or type of misconceptions?
• Is there a link between the number of misconceptions and gender, age or previous school experience?
• Does mode of entry to teaching (concurrent or consecutive) have an effect on the number or type of misconceptions?
Modes of Entry to The Teaching Profession in Ireland

5 Years (Consecutive Model)

Science Teacher

Higher Diploma in Education

B.Sc.

4 Years (Concurrent model)

Science Teacher

B.Sc. (Ed.)

Third level education
Methodology
Overview of Study

Phase 1
- Development of Instrument
- **Pilot Study**
- Revision of Diagnostic Instrument
- Administration of Instrument in Institution across Ireland
- Analysis of Results

Phase 2
- Design of Intervention Programme for Pre-service Science Teachers
- Design of Programme for In-service Teachers

Phase 3
- Implementation & Evaluation of Intervention Programme
- Revision of Related Materials
Phase 1

Misconceptions categorised
- Leaving Certificate chemistry syllabus was used as a framework.

Questions selected
- Suitable questions identified from the literature or developed by the authors.

Piloting of Instrument
- 212 pre-service science teachers across 4 years of a concurrent course. (Response Rate 77%)

Revision of the instrument
- Based on the results of the pilot study and interviews with participants.

Institutions recruited
- Course directors and science pedagogy lecturers contacted

Administration of instrument
- 467 pre-service science teachers in concurrent and consecutive courses across Ireland

Analysis of results
- Statistical Package for Social Sciences (SPSS v19)
Sample Group

• 467 pre-service science teachers (PSSTs) were involved in the study.

• They were spread across consecutive (144 PSSTs) and concurrent models of teacher training (323 PSSTs).

• There were 10 institutions involved, 2 of which were in Northern Ireland.

• 31% had a chemistry specialism, 66% had a biology specialism and 17% had a specialism in physics.
# Diagnostic Instrument (20 Questions)

<table>
<thead>
<tr>
<th>Concept Area</th>
<th>No. Qns</th>
<th>Concept(s) being tested</th>
<th>Source of Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Nature of Matter</td>
<td>4</td>
<td>Microscopic nature of atoms, elements, compounds and mixtures</td>
<td>Mulford &amp; Robinson (2002); Adapted from Sanger (2000)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Conservation of Matter</td>
<td>Adapted from Mulford &amp; Robinson (2002)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Understanding of phase change</td>
<td>Yezierski &amp; Birk (2006)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Meaningful conversions from symbolic to microscopic</td>
<td>Author developed; Nurrenbern &amp; Pickering (1987)</td>
</tr>
<tr>
<td>Stoichiometry &amp; the Mole Concept</td>
<td>4</td>
<td>The mole as a counting unit, using the mole concept in stoichiometry and understanding of molar volumes</td>
<td>Gower et al. (1977); Developed by author</td>
</tr>
<tr>
<td>Chemical Bonding</td>
<td>5</td>
<td>Process and energetics of bonding, effect of bond type and structure of Ionic Compounds</td>
<td>Peterson &amp; Treagust (1989); adapted from Mulford &amp; Robinson (2002); Author developed; Adapted from Jensen (unpublished)</td>
</tr>
</tbody>
</table>
Results
Pilot Study

- Over 80% of the 212 PSSTs involved in the pilot study achieved less than 40% in the instrument (M=30.8%).
- All areas of the diagnostic instrument were poorly understood.
- Particulate Nature of Matter was the most poorly understood area (M=28.2%).
- Those with Higher Level Leaving Certificate chemistry achieved significantly higher scores in the instrument.
- A number of factors had a significant impact on performance:
  - gender,
  - age,
  - specialism.
- There was no significant difference associated with year of study.
Results of Wide-scale Study
Overall Performance in Diagnostic Instrument

• 50% of those involved in the study achieved less than 40% in the instrument.
• A further 14% achieved exactly 40%.
Performance in Instrument: Mode of Entry

- No significant difference between modes of entry to the teaching profession and pre-service teachers overall performance on the instrument.
Performance in Instrument: Year of Study (n = 323)

- No significant difference between concurrent pre-service teachers in each year of study
### Breakdown of Scores in each Conceptual Area for all PSSTs (n = 467)

<table>
<thead>
<tr>
<th>Concept Area</th>
<th>Mean Percentage</th>
<th>% Not Attempting Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Nature of Matter</td>
<td>44.4%</td>
<td>0</td>
</tr>
<tr>
<td>Stoichiometry &amp; Mole</td>
<td>40.4%</td>
<td>0.9</td>
</tr>
<tr>
<td>Chemical Bonding</td>
<td>36.4%</td>
<td>0.4</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>17.6%</td>
<td>3.2</td>
</tr>
<tr>
<td><strong>Overall Score</strong></td>
<td><strong>37.4%</strong></td>
<td><strong>0</strong></td>
</tr>
</tbody>
</table>

- All areas were poorly understood.
- Equilibrium was the most poorly understood conceptual area.
Phase Change

4. A sample of liquid ammonia \((\text{NH}_3)\) is **completely evaporated** (changed to a gas) in a closed container as shown:

(Liquid) \hspace{1cm} (Gas)

Which of the following diagrams A, B, C, D, or E best represents what you would ‘see’ in the same area of the magnified view of the vapour? (Circle the correct answer)

- A
- B
- C
- D
- E

- 20.3% selected responses which indicate that bonds break on boiling.
Chemical Formulae

6. The diagram represents a mixture of S atoms and O₂ molecules in a closed container.

Which diagram shows the results after the mixture reacts as completely as possible according to the equation:

\[ 2S + 3O_2 \rightarrow 2SO_3 \]

A  B  C  D  E

- 46.2% are confusing subscripts and coefficients.
- 73.8% are failing to conserve atoms.
Energetics of Bonding

13. Hydrogen burns in air according to the equation:

\[ 2H_2 + O_2 \rightarrow 2H_2O \]

Which of the following is mainly responsible for releasing energy? (Circle the correct answer)

A) Breaking hydrogen-hydrogen bonds.
B) Breaking oxygen-oxygen bonds.
C) Forming hydrogen-oxygen bonds.
D) Both (A) and (B) are responsible
E) (A), (B) and (C) are responsible.

- 64.3% selected answers indicating that the breaking of bonds releases energy.

Results of Pre-service Teachers Understanding of Energetics of Bonding (n = 467)
# Relationships of Significance

<table>
<thead>
<tr>
<th>Relationship being Tested</th>
<th>Significance</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specialism &amp; Overall Score</td>
<td>✓</td>
<td>Those with a chemistry specialism (M=40.9%) did significantly better overall, while those with a biology specialism achieved significantly lower scores (M=35.5%).</td>
</tr>
<tr>
<td>Leaving Certificate Chemistry Level or A level Chemistry &amp; Overall Score</td>
<td>✓</td>
<td>Those with higher level chemistry for the Leaving Certificate (M=41.2%) or A level chemistry (M=46.2%) achieved higher scores than those that did not study chemistry.</td>
</tr>
<tr>
<td>Mode of Entry to Teaching Profession</td>
<td>✗</td>
<td>No significant difference in overall score was associated with entry through either the consecutive or concurrent models of teacher education.</td>
</tr>
<tr>
<td>Year of Study &amp; Overall Score</td>
<td>✗</td>
<td>Those in their fourth year of study achieved the same scores as those in their first, second and third years of study.</td>
</tr>
</tbody>
</table>
Conclusion
Key Findings

• Chemistry misconceptions are widespread among Irish pre-service science teachers.
• **Mode of entry** to the teaching profession has no significant impact on the number of misconceptions.
• These misconceptions are **not reduced or altered significantly** over the course of a **four-year concurrent programme**.
• PSSTs chosen specialism and their previous second-level chemistry experience were found to have significant impact on the number of misconceptions.
• Limitations include:
  – semi-longitudinal nature of study, and
  – the lack of homogeneity e.g. entry standards.
Conclusions

• Science teacher education programmes appear to have little effect on the chemistry misconceptions of pre-service science teachers.

• The programmes do not appear to produce pre-service teachers with sufficient subject matter knowledge to effectively address the misconceptions of their future students.

• Possible reasons for this include:
  – the manner in which university chemistry modules are taught,
  – how these chemistry modules are assessed,
  – lack of time to address these issues in science pedagogy modules, and
  – lack of integration between science courses and science pedagogy.

• This study highlights the need to address the chemistry misconceptions of pre-service science teachers early and often.
Implications & Future Work

• Why do the pre-service science teachers’ chemistry misconceptions remain unchanged over the course of their studies?
  – textbooks, lecture style, cognitive level, science pedagogy

• What are appropriate strategies & teaching materials for reducing these misconceptions
  – for pre-service science teachers and
  – for in-service science teachers?
Acknowledgements

This project has been funded by the Irish Research Council for Science, Engineering and Technology.

All institutions for allowing their student teachers to be surveyed.

Experts who reviewed the test and kindly offered advice over the last 2 years: Dr. Vanessa Kind, Prof. Dr. David DiFuccia, Dr. Rob Toplis, Dr. Jane Essex, and Stephen Krause.

This project has been supported by
The Department of Chemical and Environmental Sciences, University of Limerick
&
The National Centre for Excellence in Mathematics and Science Teaching and Learning, University of Limerick
References


Appendix
Results

- Over 80% of those involved in the study achieved less than 40% on the instrument.
- No significant difference between the pre-service teachers in each year of study.
Results: Pilot Study

<table>
<thead>
<tr>
<th>Concept Area</th>
<th>Mean Percentage</th>
<th>% Not Attempting Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Nature of Matter</td>
<td>28.2%</td>
<td>0</td>
</tr>
<tr>
<td>Stoichiometry &amp; Mole</td>
<td>43.0%</td>
<td>0.5</td>
</tr>
<tr>
<td>Chemical Bonding</td>
<td>32.7%</td>
<td>1.4</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>31.1%</td>
<td>0.9</td>
</tr>
<tr>
<td>Total</td>
<td>30.8%</td>
<td>0</td>
</tr>
</tbody>
</table>

- All areas poorly understood
- PNM most poorly understood conceptual area
The following drawings contain representations of atoms and molecules. Classify each of these drawings (labelled A, B, C, D and E) according to the three characteristics listed below. You should classify all five drawings for each category.

Characteristics:

**Characteristic A: State of Matter**
- solid
- liquid
- gas

**Characteristic B: Physical composition of matter**
- pure substance
- heterogeneous mixture
- homogeneous mixture

**Characteristic C: Chemical composition of matter**
- elements
- compounds
- element and compound
Wide-scale Study Pre-service Teachers Understanding of States of Matter

Diagram Labels

- Solid
- Liquid
- Gas

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Solid</th>
<th>Liquid</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>79.9%</td>
<td>18.4%</td>
<td>16%</td>
</tr>
<tr>
<td>2</td>
<td>90.6%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>94.2%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>94.0%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>97.0%</td>
<td>6%</td>
<td></td>
</tr>
</tbody>
</table>
PNM Question

Wide-scale Study Pre-service Teachers Understanding of Chemical Composition of Matter

Diagram Labels

Elements
Compounds
Elements & Compounds

<table>
<thead>
<tr>
<th>Diagram Labels</th>
<th>Pre-service Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90.1</td>
</tr>
<tr>
<td>2</td>
<td>83.7</td>
</tr>
<tr>
<td>3</td>
<td>71.9</td>
</tr>
<tr>
<td>4</td>
<td>61.2</td>
</tr>
<tr>
<td>5</td>
<td>83.7</td>
</tr>
</tbody>
</table>