Methodology

- **Stage 1 - Grounded Theory Approach**
  - Used to develop a set of interview questions
    - Concept Maps (67)
    - Academic Staff Interviews (n=18)
    - Examination Scripts (137)
    - Preliminary Student Interviews (17)

- **Stage 2 - Phenomenological Approach**
  - One-hour Student Interviews (n=48)
  - Tabulated Dataset
  - 5 Themes

Results – 5 Identified Themes

<table>
<thead>
<tr>
<th>Theme</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Types of Students</td>
<td>Profile of the student: What is the student's base skill set and attitude towards the subject?</td>
</tr>
<tr>
<td>2 Entity</td>
<td>Initial Viewpoint: What picture/idea is the starting point for that individual?</td>
</tr>
<tr>
<td>3 Potential Diagrams</td>
<td>Specific Understanding of an Operational Tool: What is the students understanding of these diagrams?</td>
</tr>
<tr>
<td>4 Contextualization</td>
<td>The Teaching/Learning Process: How do students make sense of the subject?</td>
</tr>
<tr>
<td>5 Difficulties</td>
<td>The Teaching/Learning Process: What are the difficulties students face when studying quantum mechanics?</td>
</tr>
</tbody>
</table>

Interview Questions

- Double Slit
- Duality - Ideas and Experiments
- Tunnelling - Barriers and Wells
- Instructor - Difficulties
- Linking - Shielding, Radioactivity, Real World
- Quantaroos - Quantum Kangaroos
- Epilogue

Wakeup Call #1

- 62% perceive that the course material in quantum mechanics is currently being delivered in compartmentalised chunks

Implication

- Students see no reason to integrate this material with other knowledge

Wakeup Call #2

- 30% of students discussed in detail that they were confused

Implication

- Students are not seeing a coherent ‘big picture’ for the discipline of quantum mechanics
  - "I was wandering, slightly confused, in the dark, for much of my undergraduate studies"
Wakeup Call #3

NAME 3 APPLICATIONS OF QUANTUM MECHANICS?

- Only 25% were able to provide three.
- Post interview - all students commented that it was either ‘scary’ or ‘outrageous’ that the courses they had taken had not adequately prepared them to answer such a ‘simple’ question.

Wakeup Call #4

DESCRIBE RADIOACTIVITY IN TERMS OF QUANTUM MECHANICS?

- 50% of third years and 57% of fourth years did not provide an answer, despite being prompted with the terms ‘tunnelling’, ‘probability’ and ‘wave function’.

Wakeup Call #5

AN UNFAMILIAR POTENTIAL DIAGRAM

Discuss the likely behaviour of a quantum entity entering from the left.

- 70% were able to identify the features and provided a likely behaviour scenario.
- Only 10% could describe how they would setup the problem to analytically solve it.

Wakeup Call #6

QUANTUM ENTITY

A common assumption held by the lecturers is that, as the students progress they move to a probabilistic viewpoint.

- Over 50% believe that a quantum entity sometimes behaves like a (classical) wave and at other times like a (classical) particle.
- 20% wave packet.
- The ‘wave vs particle’ view is persistent over time.
- No indication this is a stepping stone towards a more sophisticated viewpoint.

Wakeup Call #7

MATH RULES

- 100% of students and lecturers said that good mathematical skills will get you a good mark.

Implication

- Little incentive for students with good math skills to make complex changes to their schemata in order to gain a deeper conceptual appreciation.

Wakeup Call #8

VISUALIZATION OF MATH

- 50% said they cannot visualize the mathematics, it simply serves as a tool or a black box process.

Implication

- There are two sides to this coin...
Good Morning Class...

"Honestly, if a student handed in a graph like that in any other subject they would be failed outright. Especially if it had a probability distribution drawn too... And we wonder why they get confused..."