CHAPTER 6

PHASE III – THE REFINED SEQUENCE

6.1 INTRODUCTION

This chapter describes how the results of the analysis of data collected during Phases I and II were brought together to refine the teaching sequence applied during this phase (Phase III).

Additional recommendations made by the experts interviewed during Phase I, discussions with the research team and Phase II-derived feedback on the effectiveness of the sequence led to the modification of some strategies and to the incorporation of additional activities in the final sequence. To explore the incorporation of formative assessment strategies as a formal component, each activity was reviewed and, where necessary, redesigned with a recursive element. The administration of the refined instrument, the analysis processes as well as results of the sequence evaluation, is also detailed. The chapter concludes with aspects of the explored concepts identified for the conduct of peer-teaching episodes during the final stage of the project.

6.2 ADDRESSING THE RESEARCH QUESTIONS

The previous two phases were brought together to: refine a sequence of teaching activities and formative assessment strategies; validate and consolidate answers to research questions 3 and 4; and develop a considered response to question 5.

Phase II sought to identify the level of knowledge, and variation in that knowledge, of identified fundamental electric and magnetic concepts held by a cohort of second year pre-service K-6 teachers. It also explored the relationship between a quantitatively assessed level of knowledge and the personally-held perception of the confidence of the participants to teach the identified concepts to Year 4 students.

The application of the Phase III-refined instrument facilitated the additional data collection and analysis necessary to address Research Question 5:

> *Does the integration of Predict-Observe-Explain-Share strategies into the 5Es pedagogical model provide an effective means to support and enhance K-6 pre-service teachers' learning of fundamental concepts?*

by redirecting participant responses to their perceptions of personal understanding, and their confidence to teach the identified concepts.

6.3 REFINED PHASE II INSTRUMENT

The application of the Phase II research instrument, as a sequence of teaching strategies, was effective at both increasing conceptual knowledge and understanding and at building confidence to teach the concepts. However, feedback from observers and participants indicated that some elements of the sequence did not build the understanding to the desired level anticipated, nor did it empower the participants to confidently teach the fundamental concepts. Hence, the research team identified specific components of the initial sequence for further development as an iterative cycle.

6.3.1 Methodological Considerations

To better refine particular elements of the sequence, I revisited data relevant to those elements collected during Phases I and II. Discussion with the research team about Research Questions 1 to 4 resulted in the preparation of the following summary.

Phase I

Chapter 4 detailed the collegial discussions and subsequent expert interviews that identified four concepts deemed fundamental to a foundation level of understanding of electric and magnetic phenomena for graduates of K-6 schooling. The Phase I interviews also pointed to possible barriers to the effective teaching of these concepts in K-6 classes including:

- the perceived boring, irrelevant and transmissive way the concepts are often taught;
- the lack of perceived support provided by syllabus documents;
- often difficult-to-procure equipment deemed necessary to explore and build conceptual understanding;
- time constraints to teach the concepts due to pressure of literacy and numeracy emphases; and
- a lack of knowledge and understanding of the concepts by K-6 teachers, impacting directly on a lack of confidence to teach about them.

These findings led to the identification of teaching strategies and learning activities to establish and consolidate understanding of the identified concepts:

- safety with electricity – at home and in the work-place;
- efficient use of electricity;
- efficient generation of electricity; and
- the motor effect.

The strategies and activities were further developed by incorporating recommendations made during feedback interviews with members of the research team, additional collegial discussions with members of the UNE Science Education Team and informal discussions with practicing school teachers. The resulting sequence elements developed for implementation was applied during Phase II, the results of which are presented in Chapter 5.

Phase II

The second year UNE EDSE213 cohort participated in the Phase II sequence in Semester I, 2009. Analysis (Colaizzi 1978; Marton 1981, 1986 – see Chapter 3.5.1) of the collected responses to the pre-intervention survey component of the instrument, revealed a significant range in understanding of the identified fundamental concepts from extremely limited (47% of participants scored less than 40% in the survey) to adequate for teaching basic electricity and magnetism concepts (29% scored greater than 60%). The remaining 24% demonstrated what may be regarded as an elementary understanding of fundamental concepts, of either electricity or magnetism, but not both.

As described in Chapter 5, most participants attributed this limitation to a dislike for the study of science during their school career. Reasons listed included the transmissive nature of the teaching (cited by 67% of those that identified a dislike for science), and the lack of discernable relevance to their everyday experience (cited by 54% of all participants). Analysis of the responses recorded in the interactive workbooks also revealed a causal link between participants' personally identified level of knowledge about the fundamental concepts, and their self-professed level of confidence to teach those concepts. Although this link could be generally regarded as linear (higher level knowledge equated with higher confidence), there was an expression by some with a greater level of assessed knowledge of a need to know more before they could feel confident to teach the concepts. This linked to a personally-held belief that their limited knowledge constrained their ability to prepare and present the necessary activities to their students and significantly inhibited their ability to answer questions likely to be posed by their students about the phenomena being explored.

These findings led to the identification of changes to the sequence that may better prepare pre-service teachers to facilitate the exploration of activities perceived as relevant by the students in their classes. It was also found that some of the activities required a degree of manipulative skill lacking in some of the pre-service teachers necessary to successfully complete the assigned tasks. Consequently, some activities were modified and additional activities incorporated into the Phase III instrument.

The refined activities concentrated on investigating what may be regarded as familiar aspects of the identified concepts and how they relate to everyday observations and experience. The designed activities also utilized readily available resources that required only elementary psychomotor skills for setup and implementation.

6.3.2 Recommendations from Phases I and II.

When re-analysing data collected in Phases I and II it became clear that a further set of practical teaching ideas were worth of incorporation into the final instrument. These ideas related to structural and pedagogical improvements. The structural considerations focussed on:

- the time required to prepare and deliver the activities;
- the nature of the activities in terms of safe, ease preparation and conduct; and
- access to equipment requiring an appropriate level of manipulative skill.

The pedagogical considerations included the incorporation of a suite of formative assessment strategies mapped against desired outcomes of the learning activities. This was presented in a format that contained elements that built upon, or reiterated and reinforced the desired understanding at a deeper level, and this exemplified by a change in cognition (Anderson and Krathwohl's (2001) modified Bloom's Taxonomy (see Table 3.3)).

Structural Considerations

Time

Cornish and Dukette (2009) quantified the attention span of 10–12 year-old children as typically being between 10 and 15 minutes. Considering that the defined sequence was to be modelled for delivery to Year 4 students (9–10 years of age), it was agreed that each of the sequence activities should be able to be completed in this time-frame.

The acceptable time for preparation of the sequence elements was agreed to be no more that it should have taken the students to complete: hence, each of the activities needed to be prepared in less than 15 minutes. This preparation included the design of appropriate formative assessment strategies that matched syllabus outcome statements, the gathering of the necessary equipment and the duplication of any necessary paperwork for the students to use. To test the preparation time required, each of the Predict-Observe-Explain-Share and hands-on activities were constructed from scratch by three fourth-year undergraduates enrolled in the Bachelor of Teaching (K-6) program.

Equipment

In considering the need to ensure that the learners would be able to successfully manipulate the equipment required for the activities, the scale was maximised where possible, as was the nature of the desired observations deemed necessary to build on existing understanding of the phenomena being observed. The incorporation of relatively inexpensive, large-scale digital read-out multimeters, large alligator clips on the wires and large bar magnets for the activities was considered appropriate by the research team.

Pedagogical Considerations

Formative Assessment

The small group informal interviews conducted during Phase II highlighted the need to further develop the formative assessment component of the peer-learning environment in the refined instrument. This was recommended as a mechanism to:

- enhance the teacher's understanding of the need to fully prepare and trial activities/sequences in terms of the knowledge and psychomotor skill level of their students;
- facilitate consideration of the form and function of the integrated formative assessment strategies;
- promote anticipation of what typical responses to the integrated formative assessment strategies
- encourage discussion concerning the availability of resources (material/personnel); and
- explore the kinds of questions that students may have after having participated in the activities (and where the answers may be found).

Acknowledging the need to validate formative assessment (Pellegrino, Chudowsky & Glaser 2001) strategies, defined behaviours that identify the level of participant understanding and what additional experiences could consolidate their understanding were incorporated.

Predict-Observe-Explain-Share (P-O-E-S)

The taxonomy of explanation in the *Share* component of the Predict-Observe-Explain-Share (an extension of the P-O-E pedagogy espoused by Palmer (1995)) is described in Table 6.1 below.

In this context, *sharing* is a form of collaboration and may be defined as a group of people negotiating a common belief as an explanation for an observed phenomenon.

Sharing Category	Key Descriptors
Disinterested	Either has not completed the task or has no interest in the concept. Easily and often distracted. Does not actively participate in discussion. May attempt to distract others and disrupt negotiation and discussion.
Shy	Offers personal explanation as observations with limited evidence. Offers explanation without confidence. May perceive opinion as having no worth or being wrong. Does not participate in debate. Unable to answer questions about opinion.
Observer	Communicates explanation without or with limited evidence or justification. Does not or is unwilling to defend explanation by avoiding questions.
Receptive	Offers explanation and listens to others and is receptive to consideration of alternatives. Limited confidence in expressing negotiated opinion without support of others.
Participatory	Offers explanation and is able to defend explanation with some evidence. Actively listens to other explanations – willing to accept alternate 'more correct' options. Willing to negotiate and accept mutual agreement Able to offer analogies about opinion and willing to try to convince others.
Overbearing	States opinion as correct without considering others; may resort to unfounded overbearing condemnation of other opinions. Reluctant to answer questions about their personal opinion – assumes others know.

Table 6.1: A taxonomy of the 'Share' component of the Predict-Observe-Explain-Share learning strategy.

Acknowledged by the Phase II findings as a tool that promotes constructivist learning principles, it was determined that during the Phase III application of the refined sequence there would be an increased emphasis on the modeling of the Predict-Observe-Explain-Share as a teaching strategy able to be applied with confidence in the classroom. This was followed by a session to seek feedback from the participants as to their confidence to implement such a strategy early in their career.

Reiterative cycles

The hands-on exploratory elements of the Phase III workshops were presented in a cyclical manner, where the incremental contribution of the individual activities was assessed as to the increased understanding of the construction of understanding of the phenomenon under investigation. The nature of the rotational activities meant that each of the groups undertook different activities at different times. Each of the activities provided an experience that contributed to an overall level of conceptual understanding achieved at the completion of the whole sequence, assessed by embedded specific formative assessment indicators. The other activities were designed to present the same concept increment in a different context and/or circumstance. This meant that the starting point in the sequence did not negatively impact on the overall understanding gained. Figure 6.1 below presents a diagrammatic model of the iterative loops developed as a guide to assist the construction of each of the interventions and the mapping of the desired outcomes with appropriate formative assessment mechanisms. Figures 6.2 through 6.5 illustrate the application of this process for an aspect of the final sequence – factors that affect the magnitude of the magnetic field of an electromagnet. The intervention is described on the right of the diagram and the formative assessment on the left.

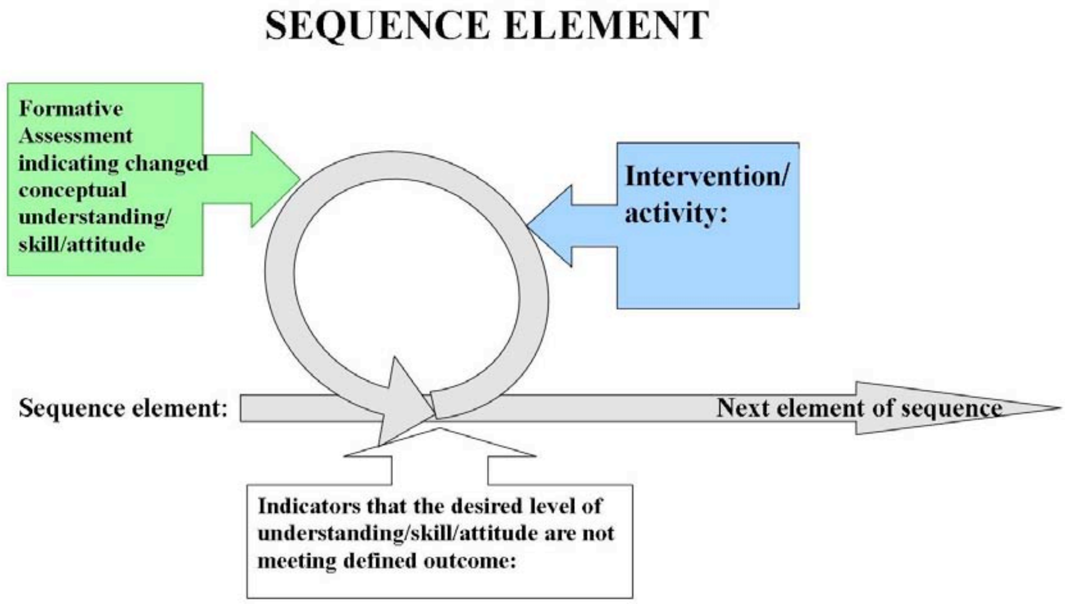


Figure 6.1: Diagrammatic model of the iterative loops developed to guide the construction of the interventions employed incorporating the desired outcome and formative assessment mechanism.

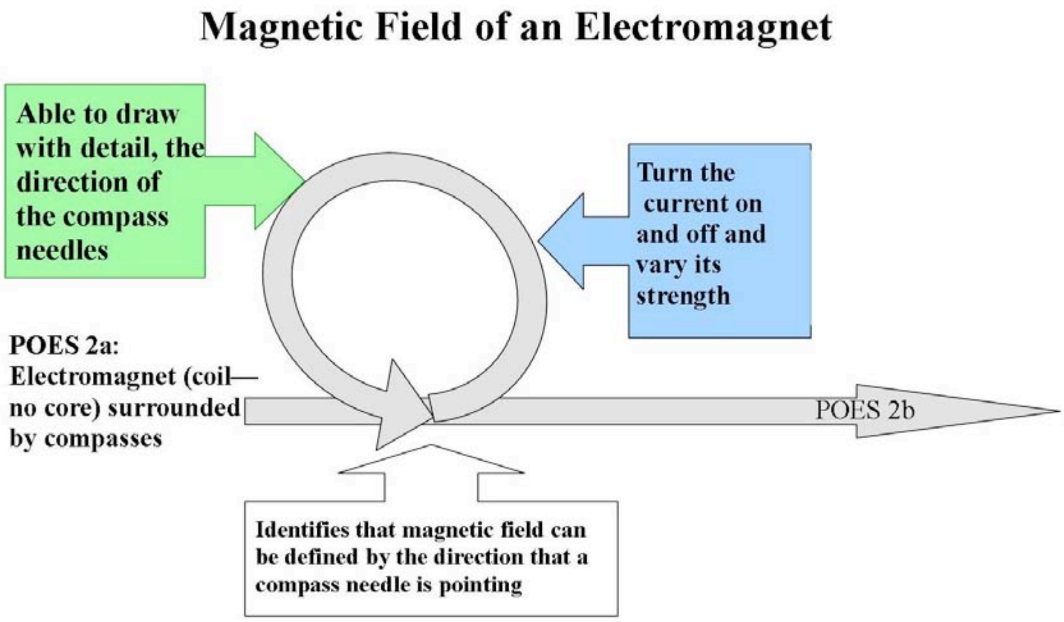


Figure 6.2: First loop of developing understanding for the effect of an iron core on the magnetic field generated by an electromagnet – promoted a visualisation of the magnetic field generated by an electromagnet coil, and how the magnitude is effected by the size of the current passing through the coil.

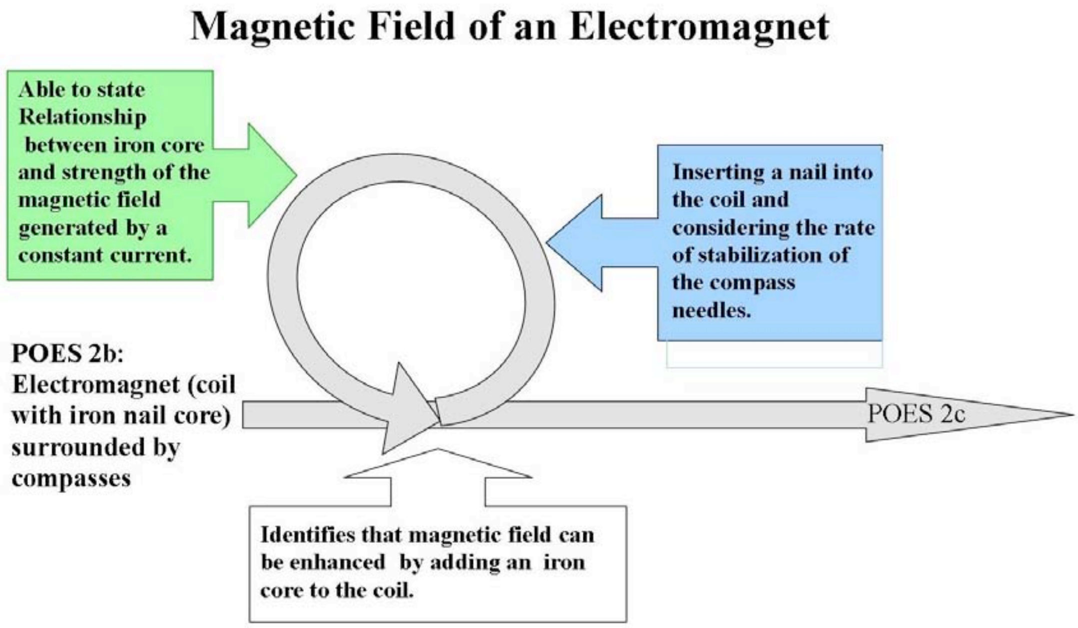


Figure 6.3: Second loop of developing understanding for the effect of an iron core on the magnetic field generated by an electromagnet – explored the effect of the insertion of an iron nail into the core of the coil on the magnitude of the field.

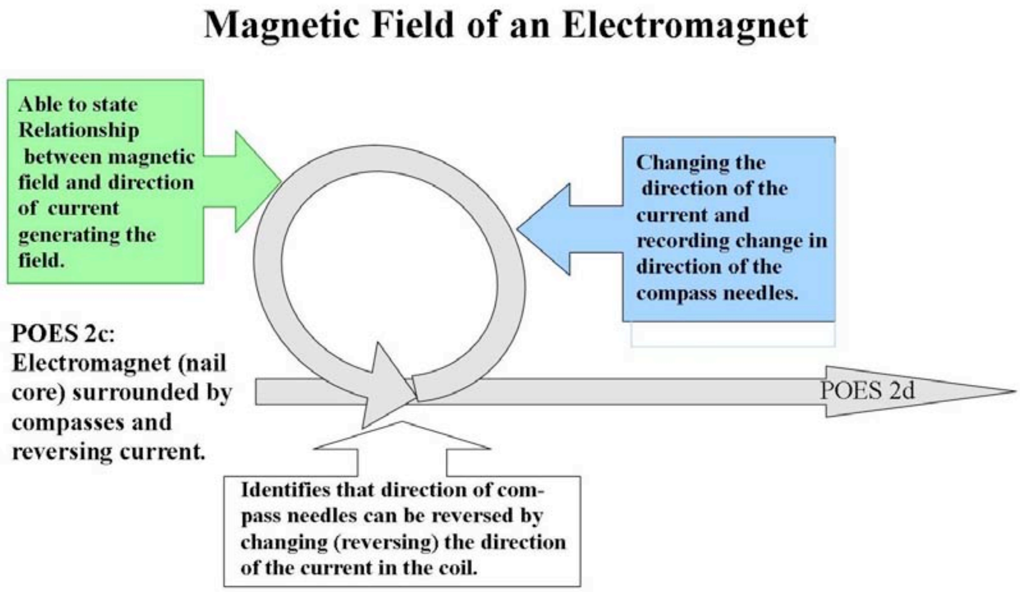


Figure 6.4: Third loop of developing understanding for the effect of an iron core on the magnetic field generated by an electromagnet – explores the direction of the magnetic field when reversing the current in the coil.

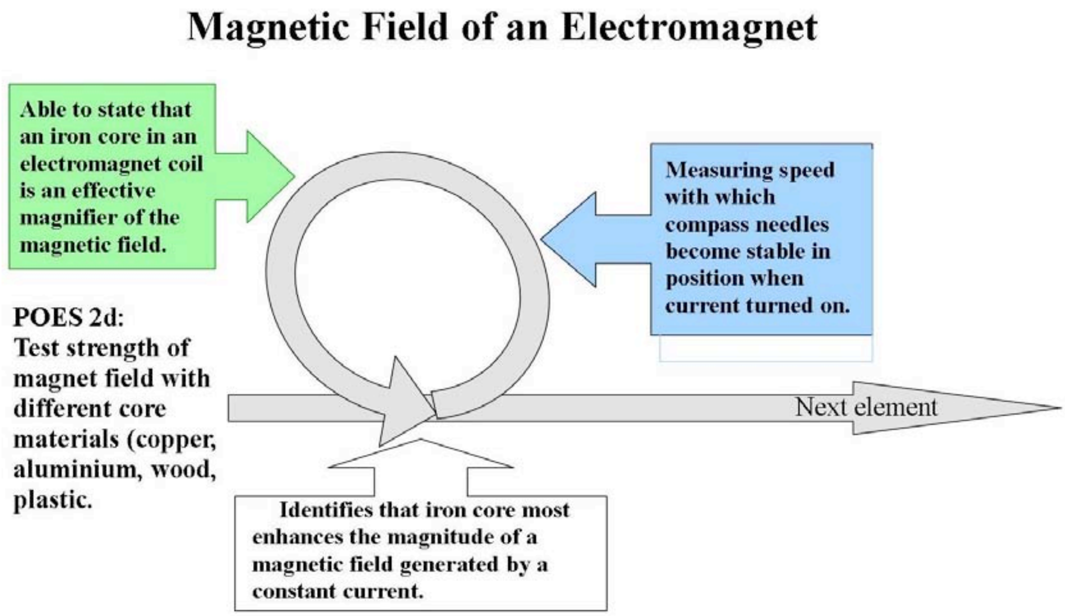


Figure 6.5: Fourth loop of developing understanding for the effect of an iron core on the magnetic field generated by an electromagnet – explores the effect other materials used as a core have on the magnitude of the magnetic field.

As previously noted, some of the elements of the initial sequence were not as effective at enhancing conceptual understanding or confidence to teach the concepts, as was anticipated. Consequently, some elements were modified to incorporate amendments identified as a result of findings from Phase II and feedback from colleagues. The specific differences between the Phase II initial sequence and the refined sequence undertaken by the EDSE213 cohort during Phase III are detailed in Appendix E.3.

Table 6.2 below provides a summary of the amendments to the refined sequence and provides a justification for each.

Amended Intervention	Justification
P-O-E-S – magnet down tube – SHARE component added.	Stimulate collaboration/peer-interaction – establish value as a pedagogical approach to involving all learners.
P-O-E-S – addition of multimeters to circuit to measure current and voltage.	Enhance familiarity with equipment – establish confidence and ease of use.
ENGAGE phase – interactive forum – collegial interaction – commonly held beliefs about electricity and magnetism.	Consolidate value of peer-interaction as a teaching strategy – enhance cooperation and teamwork.
EXPLORE component of 5Es – Shaky torch - paper clip placed on side of shaky torch.	The addition of the paper clips assists with the identification of the moving part as a magnet – moving inside a coil to generate electricity.
Additional elements of initial P-O-E-S - Magnet and a coil – testing variables o POES 1 - Moving the magnet outside the coil o P-O-E-S 2 – Moving the magnet inside the coil o P-O-E-S 3 – Magnet moving INTO the coil o P-O-E-S 4 – Magnet moving OUT of the coil P-O-E-S 5 - When magnet stops	Consolidate understanding of relationship between moving coil/magnet to generate electricity.
Exploring 'learner' suggested additional P-O-E-S o Turning the magnet around o Reverse the wires on the meter o Strength of the magnet? o Speed of the magnet o Number of turns of wire in the coil	Exemplifies teacher response to inquisitiveness and/or student generated questions – pedagogical consideration.
What's the connection? Insulation – safety.	Identified during Phase II as poorly understood – emphasises need for formative assessments to identify when teaching strategies not achieving desired level of understanding.
Household electricity consumption – efficient electricity use.	Limited knowledge of terminology and efficiency ratings on household appliances identified by Phase II analysis. Discussion undertaken regarding power bills and the terms used to describe electricity consumption.
DC brushed motor ⇔ DC brushed generator	Activities designed to exemplify relationship – physically moving a coil in a magnet *generates* electricity; electricity can cause a coil in a magnet to rotate as a *motor*.
Deconstructing an electric motor.	Building motor fun and engaging. Deconstructing real motor establishes links between model and real motor.
Discussion relating to pedagogical aspects of collaboration as teaching/learning tool.	Consolidate value of peer/collaborative learning – reference to constructivist approach.

Table 6.2: Justification for changing sequence elements taken into Phase III.

6.4 DATA COLLECTION

Recognising the different starting points of the rotation through the activities and the anticipated variation in knowledge of the participants based on the Phase II findings, the research instrument for this phase incorporated a range of tools. As in Phase II, these were applied to identify the participant's existing level of knowledge of the defined concepts, personal perception of their preparedness and confidence, to teach the concepts. The analysis of the pre-and post-intervention surveys also enabled a qualitative comparison between the change in conceptual understanding induced by the initial Phase II sequence and that resulted from the application of refined sequence during this phase.

6.4.1 Workbooks

The development team agreed that to provide a valid basis for comparison of the effectiveness of the Phases II and III, the tools applied during this phase should match those of Phase II. Thus, the data collection methods were integrated into 3 workbooks, one for the two interactive lectures and two others for each of the workshop sessions (see Appendix A.3). As in Phase II, the booklets were collected and copied for preliminary analysis and returned at the beginning of the next sequence component. Also as in Phase II, each of the work booklets elicited written responses from the participants with survey type questions, Likert-type scales, invitations for open responses, records of Predict-Observe-Explain-Share activities, requests for diagrams and the construction of lists.

6.4.2 Small-group and Individual Informal Interviews

Matching Phase II, informal, conversational interviews (Cohen, Morrison and Manion 2007:353), of approximately thirty-minutes duration, were conducted with small groups (n = 4 or 5) of participants and with each of two different observers, soon after each of the teaching sessions. These exchanges were electronically recorded, transcribed and matched with notes written by the observers during the teaching sessions and memo-notes taken during the interviews. The observer notes identified evidence for levels of engagement of the participants during the various activities and recorded perceptions of the effectiveness of the activities undertaken, and the collegial interactions taking place while sharing observations and negotiating explanations.

6.5 ANALYSIS TOOLS

6.5.1 Workbooks

Analysis (Colaizzi 1978), with a phenomenographic approach (Marton 1989), (see Section 3.3.5) of the pre- and post-intervention survey responses, the completed components of the interactive workbooks and the observations made by members of the research team during the workshops, informed the evaluation of the refined sequence.

The Likert-type scale ranking responses recorded by the participants before and after the refined sequence were again analysed using simple ordinal procedures and numeric counts. As the pre- and post-intervention questions referring to perceived confidence were identical for the 2009 and 2010 cohorts of participants, the differences in mean and standard deviation were identified as a measure of the change in the confidence to teach about the identified concepts (see Table 6.6). This analysis provided a qualitative measure of the change in participant confidence following the sequential interventions of the Phase III instrument and enabled a comparison to be made between the gains brought about by the two different sequences.

6.5.2 Interviews

During each of the small-group and individual observer interviews, responses were sought as to the:

- engagement of the participants in the inquiry-based, hands-on collaborative Predict-Observe-Explain-Share activities;
- perception of the effectiveness of the overall 5Es modelled sequence to:
  - enhance conceptual understanding of the learners;
  - enhance the confidence of the pre-service teachers;
- perception of the effectiveness of individual elements of the sequence to enhance participant understanding and confidence;
- appropriateness of the level of manipulative skills (Year 4 student) required to complete the tasks; and
- opinions of the effectiveness of the modelled teaching strategies for early career teachers.

As described in Chapter 3, the transcripts of the small-group and observer interviews were analysed, both individually and collectively, with Colaizzi's seven-step model (1978), to build upon perceptions and assertions regarding the teaching strategies employed. This process ensured that the ultimately-derived exhaustive description of the teaching strategies under investigation was consistently formulated.

6.6 CONDUCT OF THE INSTRUMENT

6.6.1 Research Setting

The refined instrument was administered to a cohort (n = 88) of EDSE213 during semester I of 2010. Discussions with the lecturer of the unit resulted in the allocation of two one-hour interactive lectures (Hake 1998; Mazur 1997; Nelson 1994; Steinert & Snell 2007), followed by two two-hour participatory workshops. This, it was agreed, would provide a suitable timeframe for delivery of the Phase III instrument. The 2010 university timetable dictated this change in format from that used in 2009. Workshop elements were again presented to three approximately equal groups of participants and were conducted in a classroom environment with a similar spatial arrangement to a typical K-6 classroom. The lectures were conducted with the whole cohort in a tiered lecture theatre. Although not representative of a classroom environment, the collaborative strategies incorporated within the elements of the interactive lecture were conducted with small groups of participants (n = 3 or 4) and replicated, as closely as practicable, the situation teachers could apply as part of their teaching program.

Administration of the Phase III instrument closely mirrored the Phase II application in that the sequence elements were presented and explored in a manner that modelled the 5Es learning cycle and incorporated Predict-Observe-Explain-Share elements as teaching strategies. Key ideas linked to activities are described as a comparison with those applied during Phase II in Appendix E.3.

Integral to the refined sequence were a variety of formative strategies. These were designed to exemplify the identification of desired student responses, teacher observations or behaviour changes, each of which would indicate the achievement of pre-defined outcomes. An example of the mapping of these is contained in Appendix E.4.

6.6.2 Conduct of Lecture 1

As described in Appendix E.3, the first lecture introduced the participants to the project and discussed pedagogical implications of teaching science early in their career. It began with an open forum discussion that sought to identify the proportion of the participants who had studied science beyond the compulsory years of schooling and their opinions about science as a 'subject'. This led to a discussion of what the study of K-6 science might entail. It was identified that before teachers introduce new concepts to their students, they should endeavour to establish the learners existing levels of knowledge and seek to identify any 'misconceptions' they may have. After the discussion, approximately 20 minutes was allocated to the completion of the pre-intervention survey.

The Predict-Observe-Explain (Palmer 1995) strategy, with which the participants were familiar, was modelled as a means to explore students' understanding and introduce new concepts. Three examples were presented and a discussion ensued regarding their personal level of engagement during the P-O-Es process. After outlining the *Primary Connections* (Australian Academy of Science 2007) incorporation of this approach within its 5Es teaching cycle, the possible advantages and disadvantages of such an approach were collaboratively identified. This enabled the effectiveness of 'collaboration' as a learning tool to be highlighted, resulting in the introduction of the SHARE component to the P-O-E strategy (see Chapter 3.5.3). The lecture concluded with a discussion of the ENGAGE phase of the 5Es approach and how the Predict-Observe-Explain-Share activities may be applied to facilitate such engagement in the learning process, thereby exciting the learner to participate fully in the later stages.

6.6.3 Conduct of Lecture 2

As in Phase II, to encourage a meta-cognitive awareness of processes that focus the learning of content and awareness of the applied teaching strategies, the results of the preliminary analyses were discussed with the participants at the commencement of the second lecture. This 'sharing of the findings' with the participating cohort, provided pedagogical credibility to the participants because it served to inform them about what they might experience as facilitators of learning in real classrooms – that is, as teachers.

This was followed by a discussion reviewing the ENGAGE and EXPLORE phases of the 5Es approach as a mechanism to incite continued involvement of the learner with the strategies being implemented. Specific examples of ENGAGE activities were conducted as Predict-Observe-Explain-Share investigations. During these, the collaboration process was explored in terms of the derived explanations of the phenomena being defined by the language of the learner rather than that promulgated by the teacher. These Predict-Observe-Explain-Share activities, pertinent to developing the concept of a moving magnet and a coil, are described in Appendix E.3. The value of this approach was evaluated by input of the participants in terms of suggestions for additional investigations to further build upon the conceptual understanding being developed by the activities.

The lecture concluded with an open forum seeking opinions of the effectiveness of the modelled strategies and the hands-on activities to teach the introduced concepts to a class of Stage 2, Year 4 learners and in enhancing the confidence of the participants.

6.6.4 Conduct of Workshop 1

Lecture 1 was conducted in a more transmissive mode than Lecture 2. The more active involvement of the participants with the interactive and collaborative nature of Lecture 2 was a strategy employed to exemplify the effect of active and collaborative strategies. The workshop, therefore, began with a discussion centred on the differences between the format and feel of Lectures 1 and 2 in terms of the participant's perception of their engagement, involvement and enjoyment of the two different approaches. The discussion led to the collection of feedback regarding effectiveness of collaborative/shared/peer learning strategies introduced and employed during Lecture 2.

After a brief introduction, five hands-on, exploratory activities were undertaken by each of the small-groups of participants on a rotational basis. To match the approximate attention span of Year 4 learners (Cornish and Dukette 2009), groups were asked to move to the next activity after 15 minutes. This time frame included the collection and construction of the necessary equipment, the group discussions, and the write-up of the collaboratively derived observations and explanations of the phenomena being explored.

The generation of electricity, as a consequence of the interaction of a moving magnet and a coil of wire was the underlying conceptual understanding being explored and developed by these activities. To conclude the lecture, the Faraday torch, introduced as the 'shaky torch' during Lecture 2, was revisited. The movement of the magnet inside the coil to provide the electricity to light the LED was discussed as a means to bring together the activities and collegial discussions undertaken during the lecture.

6.6.5 Conduct of Workshop 2

Highlighting the dual aims of increasing conceptual understanding and awareness of elementary science teaching strategies that might be adopted by inexperienced teachers, the introduction of the second workshop provided opportunity for the participants to reflect on the achievement of the aims of the previous sessions. Most particularly, the effectiveness of the collaborative exploration of the hands-on activities was discussed.

To further investigate the effectiveness of the refined sequence, five activities were undertaken, this time in a defined sequence, culminating in the building of the model electric motor (see Figure 5.5) and attempting to explain how it works. The sequential nature of these activities provided the participants with an opportunity to compare the sequential nature of this experience with the rotational format of the previous workshop. After the completion of the activities, the participants undertook the post-intervention survey.

6.7 DATA ANALYSIS

As described in the introduction to this chapter, Phase III incorporated the recommendations from Phase II to refine and test an instrument designed to:

- determine the level of knowledge and understanding of a cohort of pre-service K-6 teachers about specific electric and magnetic concepts;
- measure the variation in their understanding and identify possible reasons for the variation;
- enhance that knowledge and understanding, and hence reducing the variation;
- model effective strategies to enhance the self-perceived confidence of the participants to teach the syllabus prescribed concepts.

These themes were distilled from the research questions, and the results of the analysis of the data collected during this Phase informed a response to research questions 3 and 4, and initial consideration of a response to research question 5.

6.7.1 Participant Workbooks

In reporting on the level of understanding of the identified themes, the initial variation in understanding among the 2010 cohort was again defined by a simple count of the responses deemed correct and expressing this as a mean score or percentage of the total responses by the whole cohort.

A comparison of the Phase II and Phase III results for the pre- and post-intervention surveys is summarised in Table 6.6 below. It demonstrates that the 2010 cohort undertaking the Phase III instrument began their participation with a slightly higher score for most elements. It is also evident that the increase in conceptual understanding exemplified by their scores in the post-intervention survey are much higher than the increase gained by the initial Phase II sequence undertaken by the 2009 cohort. For example, the definitions of fundamental terms were more accurate and the small-group interviews suggested that the collaborative negotiation of definitions, derived during the sequence activities, significantly contributed to this increase.

Pre- and Post-intervention Survey Element	Phase II Intervention Scores		Phase III Intervention Scores	
	Pre-	Post-	Pre-	Post-
1. Listed electrical devices	$\bar{x} = 11$	$\bar{x} = 14$	$\bar{x} = 12$	$\bar{x} = 16$
2. Listed magnetic applications	$\bar{x} = 4$	$\bar{x} = 11$	$\bar{x} = 5$	$\bar{x} = 15$
3. Diagrammatic representation of circuits	$\bar{x} = 44\%$ SD = 14.7	$\bar{x} = 64\%$ SD = 9.6	$\bar{x} = 48\%$ SD = 14.1	$\bar{x} = 66\%$ SD = 11.1
4. Explanation of light globe working	$\bar{x} = 11\%$ SD = 31.5	$\bar{x} = 23\%$ SD = 23.3	$\bar{x} = 10\%$ SD = 28.0	$\bar{x} = 29\%$ SD = 21.3
5. Meaning of the term: Magnetism	$\bar{x} = 38\%$ SD = 15.1	$\bar{x} = 48\%$ SD = 9.2	$\bar{x} = 33\%$ SD = 14.4	$\bar{x} = 58\%$ SD=10.8
6. Meaning of the term: Electricity	$\bar{x} = 34\%$ SD = 14.9	$\bar{x} = 59\%$ SD = 12.2	$\bar{x} = 36\%$ SD = 14.1	$\bar{x} = 66\%$ SD = 11.2
7. Meaning of the term: AC	$\bar{x} = 9\%$ SD = 21.1	$\bar{x} = 19\%$ SD = 16.1	$\bar{x} = 5\%$ SD = 23.1	$\bar{x} = 11\%$ SD = 17.7
8. Meaning of the term: DC	$\bar{x} = 11\%$ SD = 19.4	$\bar{x} = 29\%$ SD = 13.4	$\bar{x} = 13\%$ SD = 18.6	$\bar{x} = 38\%$ SD = 15.5
9. Identification of ways electricity may be generated	$\bar{x} = 2$ Range 1-6	$\bar{x} = 4$ Range 3-6	$\bar{x} = 4$ Range 1-6	$\bar{x} = 5$ Range 2-6
10. Self-perceived reported Confidence Level as identified by Likert-type scales	$\bar{x} = 4.2$ Range 0–8.5 SD = 1.3	$\bar{x} = 5.8$ Range 0–8.5 SD = 1.7	$\bar{x} = 3.8$ Range 0-9 SD = 1.3	$\bar{x} = 6.6$ Range 0-9 SD = 1.9
11. Identified areas confident to teach	$\bar{x} = 2$ Range 1-5	$\bar{x} = 3$ Range 2-7	$\bar{x} = 3$ Range 1-6	$\bar{x} = 5$ Range 3-7

Table 6.3: A comparison in the mean student score achieved during the pre- and post-intervention survey scores for each of the identified fundamental concepts explored during the original Phase II and refined Phase III sequences. The percentages expressed represent a degree of 'correctness' as identified by the research team (see Appendix A.1 for the Assessment Rubric used).

Table 6.6 also reveals that the standard deviations (SD) of those items with a percentage score indicate a greater reduction of the variation in understanding for those experiencing the refined sequence. Points 10 and 11 demonstrate an overall increase in personal assessment of confidence to teach the concepts, even greater in the latter cohort. Point 11 particularly demonstrates that, although perceived confidence after the sequence increased, the change in standard deviation again reflects the reported perception that the activities in the sequence increased participant awareness of their limited knowledge, though it must be noted that this awareness resulted in decreased in confidence in some.

> *"The more I learned, the more I realise I need to learn before I can confidently respond to student questions, or unforseen circumstances."*
>
> (SID P3P2W3Gas144)

6.7.2 Informal Interviews with Participants and Observers

Effectiveness of the Modelled Teaching Strategies

Increased Knowledge of Concepts

An increase in overall understanding of the concepts being explored and the knowledge being constructed was acknowledged. Most of the small-group interviews yielded positive commentary on the effectiveness of the hands-on activities to facilitate the building of knowledge and understanding. Many reported that the activities prompted them to construct personal mental models to explain the phenomena being investigated. This was attributed to stimulation of natural inquisitiveness by different elements of the sequence, particularly those that encouraged the sharing of observations and explanations with peers. The reward for persistence and trying different things to achieve a result was identified as intrinsic, and reflected the fun and enjoyment felt by the participants during the activities.

> *"When we got something right, no, when we got it to work, or we could definitely describe what we saw, it was great when we all agreed. What was even better was when we worked together to work out how it happened – especially when we were applying our new knowledge – it was like we got a prize."*
>
> (SID P3P3W1GLt113)

The effectiveness of the collaborative nature of the inquiry-based activities was also corroborated by representative comments made by the observers.

> *"It was obvious that they (the participants) were actively engaged and enjoying, it was like they were kids playing again. When it came to sharing their observations and coming up with explanations, they listened to one another and tried to explain things using their own words. What was really interesting was that they sometimes introduced scientific terms into the conversations like 'current' or 'insulation' in a matter of fact way that was accepted by the others in the group as proper language."*
>
> (Observer O10P3_G1)

Increased Awareness of Pedagogies

Discussion relating to perceptions of the effectiveness of Predict-Observe-Explain-Share, focussed on an expressed desire to implement the modelled approach in their classrooms.

> *"I reckon that I can apply this strategy in my classes. The Predict-Observe-Explain activities were very simple, yet encouraged the observational skills and internalisation that promote learning. The Share bit was really effective at making us, well me at least, think carefully about how we explain things to others.*
>
> (SID P3P3W3GBs144)

Although the participants often made reference to the 5Es during the Phase II small-group interviews, their application in real classrooms was not mentioned. It was therefore apparent that the Engage and Explore activities were not recognised as specific entities of the 5Es learning cycle. However, when referred to specifically during the Phase III discussions, the 5Es approach was acknowledged as providing a foundation for consideration as a model, upon which to build classroom teaching programs. Again, the Predict-Observe-Explain-Share strategies were acclaimed as effective promoters of observing, thinking and collaborating.

Two of the observers reported that the participants were able to manipulate the equipment in an effective and efficient manner. One (Observer O10P3_G1) referred to additional explorations, evidenced by the participants testing different materials for conductivity (see Figure 6.6). This, and other self-initiated investigations exemplified a shift in cognition from the *lower order thinking skill* categories to higher orders (Bloom's Revised Taxonomy (Anderson & Krathwohl 2001)).

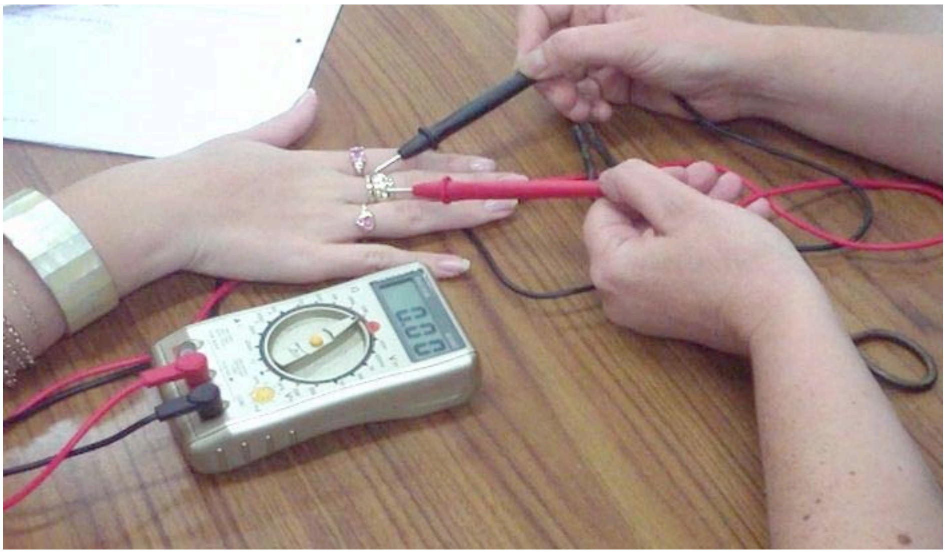


Figure 6.6: Participants conducting their own investigations of conductivity.

When building the model electric motor (Activity 5 of Workshop 2), some of the participants were observed to miss some stages in the process, which led to the motor not working as it should. As was observed in Phase II, however, the collaborative nature of the activity facilitated a diagnosis of the problem relatively quickly within the group. One group did not complete the task successfully within the allocated time. Their frustration was evident at the time, but interestingly, they requested the opportunity to complete the task after the workshop and subsequently spent some time building their model and others they "found on the web" (see Figure 6.7).

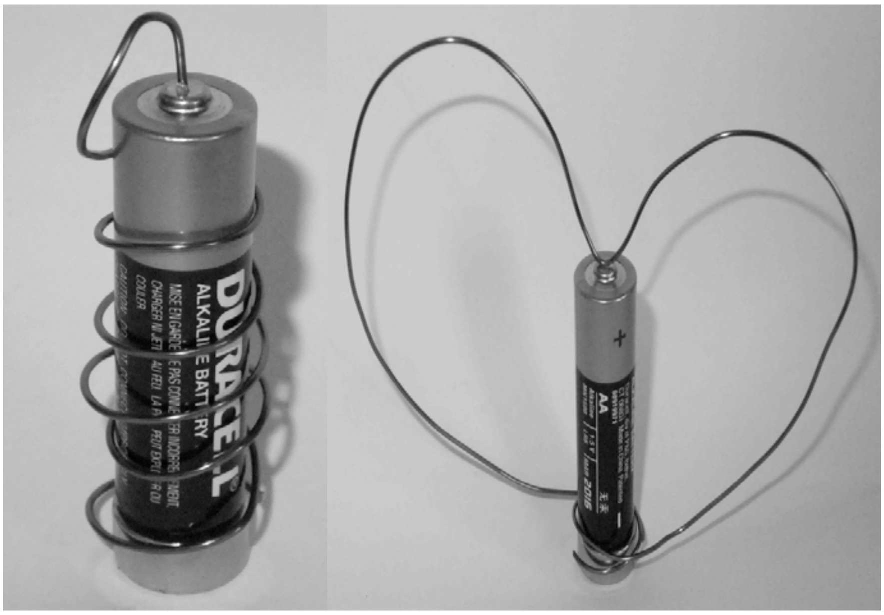


Figure 6.7: Two additional homopolar motors constructed by participants voluntarily.

During the small-group informal interviews, participants were asked to identify the indicators they chose to observe in the behaviour of their 'students' to provide evidence that the desired level of understanding had been achieved and, if not, what indicated to them a need for additional intervention(s). This reflection on formative, diagnostic assessment was reported as a valuable tool that would inform the 'teacher' about the learning processes being adopted by their students.

> *"I never realised that you could actually learn about how learners were learning just by watching them. You could almost see the penny drop on occasions in our group when we were sharing ideas, but when it didn't, you could follow a different line to get them to think again"*
>
> (SID P3P2W2GAs162)

and;

> *"I know now that I assumed too much sometimes, you know, that they (other group members) had made the same observations and reached the same conclusions that I did. I will certainly be looking closely at my strategies again before I teach anything like this in my class".*
>
> (SID P3P2W3GAs164)

It was also stated that this reflective process provided a means for consideration of possible barriers to effective learning, particularly in terms of the teaching strategies being applied. As in Phase II, comments made indicated a change in perspective about how best to enhance their own classroom practices. This was in terms of how they may identify the engagement of their students in the learning process, and how the students may be progressively assessed to guide future learning activities.

Observers similarly concluded that the emphasis placed on formative assessment as a progressive process seemed to have stimulated reflection of teaching strategies in the 'teachers'.

Change in Confidence

As described in Table 6.3, the mean increase in the perceived confidence of the participants increased more than it did as a consequence of the Phase II sequence. All of the participants interviewed during the small-group interviews reported that they felt more confident to face the challenges of teaching their students about the fundamental concepts with which they had now become familiar during the sequential interventions during this Phase. More specifically, their experiences with hands-on activities and collaborative learning were identified as major contributing factors to this increase in confidence.

6.8 RESULTS FOR RESEARCH QUESTION 3

Research Question 3 asks:

Within the context of pre-service K-6 teachers, what are the variations in the understanding of the identified fundamental concepts?

As reported in Chapter 5, the analysis of the participant responses to the workbook items revealed a significant range in the understanding of the identified fundamental concepts. A similar range was identified by the pre-intervention survey of Phase III within the EDSE213 2010 cohort. Table 6.3 lists the different scores achieved by the two cohorts to the same survey items. Participation in the refined sequence decreased the range by more than that promoted by the initial sequence. Significant inclusions in the Exhaustive Descriptions absent from those derived from the Phase II analysis are presented in Table 6.4.

Safety with Electricity

Participants identified the need for learners to be made aware of the electrical conductivity of materials and particularly the need to remain insulated from sources of electricity to prevent dangerous shocks.

Included in the Phase III Exhaustive Description	**Exemplified by participant statements:**
Insulation protects us from electricity by keeping it inside the wires.	*"kids need to know that metal objects conduct electricity – like do not put a knife into a toaster to get the toast out."; and* *"they (learners) should be made aware of the risks associated with pulling power cords out of the power points and what it can do to the insulation."*
Lightning is electricity that passes through the air and can be very dangerous because of its power.	*"it should be explained that lightning has enough power in it to cause the electricity to flow through non-metallic things like trees."*

Table 6.4: Participant statements, recorded in their workbooks, exemplifying an awareness of the safety aspects associated with the properties of insulation materials, as protection from electric shocks.

Efficient Energy Use

Analysis of the Phase II pre- and post-intervention surveys revealed that the participants had a limited knowledge about the terminology associated with the 'use' of electricity in everyday situations. The Phase III instrument incorporated a discussion centred on the information that could be gleaned from looking in detail at a household power-bill. Limited knowledge of efficiency ratings on household appliances was identified by Phase II analysis and this led to further discussion in this Phase regarding the terms used to describe electricity consumption. Questions were raised about how electricity is used and participants negotiated, through shared and collaborative conversation, an explanation relating to the conversion of electricity to heat, light and motion. It was also mentioned that electricity can generate a magnetic field. When considering the efficiency of electrical appliances, a small proportion of participants recognised that, with the energy conversion, some energy is lost to the environment, usually in the form of heat. The Phase III post-intervention survey revealed that the concept of efficiency is still a source of confusion.

Included in the Phase III Exhaustive Description	**Exemplified by participant statements:**
Energy Ratings on appliances tell us how much energy they use. They can help us decide which appliance to buy.	*"when it is explained like this, those star ratings on appliances make sense."*; and *"I am now more aware of the reasons why we should turn off TVs and computers at the wall, and not just leave them on stand-by."*
Electricity does not get used – it is a form of energy; we convert electrical energy to other forms like light and heat and motion some energy is lost to the surrounding environment.	*"electricity is so convenient – we just switch it on; but now I realise it is not just switching it on, it is converting it to usable energy we use like heat and light."*; and *"I remember from school science, energy does not get used up, or destroyed – we convert it into other forms. Electricity we have learned to convert."*; and *"if we could convert all the electricity into the energy we want, we would have 100% efficiency. But we turn some if it into other energy – like a light bulb gets hot, but a fluoro stays cooler – does that mean fluoros are more efficient?"*
We pay for the conversion of electricity from one form to another.	*"So, a kilowatt-hour is how much power you use in an hour – no, if you use 1 kilowatt in one hour, you pay the 23 cents – the cost of one kilowatt-hour".*

Table 6.5: Participant statements exemplifying an awareness of the terminology and symbols pertaining to the efficiency of household electrical appliances and the information that can be read from power bills.

Electricity Generation

As reported in Phase II, the participants initially demonstrated a limited understanding of how electricity may be generated for everyday use. A similar finding resulted from the analysis of the Phase III participant responses to the pre-intervention survey. Responses ranged from 'power stations' (37%), hydro-electricity' (21%), 'batteries' (21%), 'solar' (18%) and 'wind' (9%) without providing any detail of how the electricity is generated. The range of understanding again confirmed the need to apply strategies to draw the understanding of the participants toward a single entity, the interaction of magnetic fields to generate electricity. The hands-on activities that facilitated the step-by-step building of the understanding of the relationship between electricity and magnetism were consequently chosen for testing as part of Phase III sequence.

Included in the Phase III Exhaustive Description	Exemplified by participant statements:
A generator is an electric motor that is forced to rotate by some external means.	*"I had no idea what a generator was – it's just a motor forced to go round."*; and *"so, if I spin a motor it makes electricity"*; and *"a motor has a coil inside a magnet – if you turn the coil, you make electricity."*
A moving magnet inside a coil of wire makes electricity.	*"when you shake the torch the magnet moves in and out of a coil of wire and makes electricity."*; and *"a generator is a coil forced to rotate inside a magnetic field. You can make it spin with steam, water and wind."*

Table 6.6: Participant statements exemplifying an awareness of the interaction of magnets and coils of wire to generate electric current.

The Motor Effect

Again, the pre-intervention survey revealed that very few participants identified a magnet as being a component of an electric motor. The Predict-Observe-Explain-Share and hands-on activities undertaken in this phase exemplified the interrelationship between electricity and magnetism, and the generation of both. The building of the simple homopolar electric motor (see Figure 5.1), it was postulated, would bring together the fundamental concepts. The Phase II workbook responses and post-intervention survey indicated that the constructed motor was not identified as being typical of commonly used electric motors. This finding led to the inclusion of an additional activity, requiring the deconstruction of a small toy motor, the identification of the components, and the matching of them to the parts of the motor they built. Statement referring to the relationship between moving magnets inside coils of wire, or coils of wire rotating inside magnetic fields, were included in 55% of participant responses to the question asking for an explanation of how the constructed motor works.

6.9 RESULTS FOR RESEARCH QUESTION 4

Research Question 4 asks:

> *How is the variation in understanding in the identified fundamental concepts of electricity and magnetism reflected in the confidence level of pre-service K-6 teachers to teach them?*

As detailed in Chapter 2, much of the literature about primary science education makes reference to the preparedness and apparent reluctance of many K-6 teachers to teach science due to a lack of knowledge about the concepts being taught. This exemplifies the link between Research Questions 3 and 4, highlighting the growth in confidence as partly attributable to an increase in knowledge and understanding of the concepts, and to a reflective consideration of how best to teach the concepts upon assuming their teaching roles.

Again, a correlation exists between the level of understanding, as determined by the pre- and post-intervention survey instruments, and the level of confidence expressed by the participants to teach about electricity and magnetism. The Phase III post-intervention survey also revealed that the modelling of the teaching strategies had further increased the confidence to teach the fundamental concepts than had the Phase II instrument (see Figure 6.8). As in Phase II, the peer learning and hands-on activities were cited as major contributors to this increase. This further supports the assertion that teaching strategies that incorporate a social constructivist approach, incorporating peer learning processes, develop and enhance the learning of these fundamental science concepts.

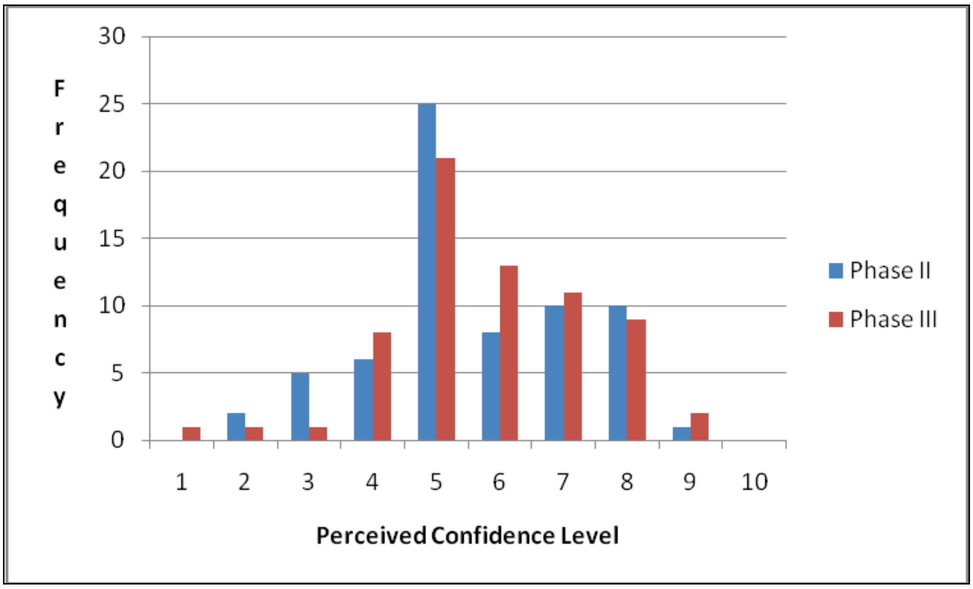


Figure 6.8: Post-intervention survey histogram – comparison of Phase II (left) and Phase III (right). Note shift to right.

Dave's Psychomotor Domain Taxonomy (1975) was used by the observers to categorise the manipulative skills demonstrated by the participants during the latter activities of the sequence (see Appendix E.5). These indicated a marked improvement in their confidence to explore with the equipment made available to them. This was particularly evident when the participants were shown how to use the large-scale digital multimeters to measure current, voltage and resistance (referred to as *conductivity* in this case) (see Figure 6.6). It was noted by the observers that the participants felt increasingly comfortable with the meters as they tried to measure different things including the voltage of single cells. One observer reported hearing a discussion regarding the conductivity of a small light bulb with one of the participants referring to the bulb not conducting as well as ordinary wire. It was subsequently surmised that the 'filament' was not conducting as well and that it must get white hot when the electricity passes through it.

> *"we tried to measure the conductivity of lots of things – plastic is an insulator, and all the metal things we tried conduct really well. The best bit was finding out that our skin conducts a bit – I suppose that is how electric shocks occur"*
>
> (SID P3P2G2Was160)

6.10 RESULTS FOR RESEARCH QUESTION 5

Research Question 5 asks:

Does the integration of Predict-Observe-Explain-Share strategies into the 5Es pedagogical model provide an effective means to support and enhance K-6 pre-service teachers' learning of fundamental concepts?

The modelled strategies of Phase II, exemplified an approach that the pre-service K-6 teachers could apply with confidence to the teaching of fundamental electricity and concepts, as required, from the beginning of their classroom teaching career. The Phase III sequence, with its incorporation of additional hands-on activities, and opportunity for peer-negotiation of conceptual definitions, was demonstrably more effective at increasing the level of knowledge and understanding of the identified concepts. The participants acknowledged that this approach was engaging and enjoyable, relevant to their interest and experience and probably applicable to the teaching of other science concepts. Indicators categorised by Bloom's Affective Domain (Krathwohl, Bloom, & Masia 1964/1999) were selected to qualify the participant level of enjoyment. These indicators readily translated into an assessment of change in student enjoyment while undertaking the activities and this, in turn, was considered to be a reflection of their confidence to engage with the teaching of the concepts. Examples of identified indicators used by the research team to make this assessment are regarded as formative and are presented in Appendix E.4.

6.11 SUMMARY AND CONCLUSIONS

6.11.1 Discussion of Results for Research Question 3, 4 and 5

A comparison between the variation in the understanding by the participants about the Phase I fundamental concepts revealed very similar findings for both Phases II and III. A sentiment regarding a dislike of school science was also expressed by participants in both Phases, relating it to the boring and irrelevant way it was taught. However, as in Phase II, analysis of the Phase III guided activity workbooks revealed that the majority of the participants changed and built on their personal models of the phenomena determined by Phase I, improving their perceived competence and confidence to teach the identified concepts. Participants cited a high level of engagement and relevance to their personal experience during the intervention activities as major contributors to the success of their learning. The reflective practices facilitated and collaborative teaching strategies modelled were recognised as effective. This was summed up by one participant who said, during a small-group interview:

> *"…when I thought about what I was trying to learn, and how I was learning it, I came to realise that when I was interested, engaged, or enjoying the experience, I was learning. I will certainly take this with me into the classroom and try to interest, engage and promote enjoyment of science – I now regard it as fun learning."*
>
> (SID P3P2G2Was160)

The effectiveness of the refined sequence, incorporating examples of the application of the 5Es teaching cycle and Predict-Observe-Explain-Share hands-on exploratory activities as both a classroom-teaching tool and pedagogical modelling tool for pre-service K-6 teachers was acknowledged. Participation in the collaborative learning experiences was also confirmed as a major contributing factor to this effectiveness, highlighted by numerous references during the small-group interviews, as being applicable in future classroom teaching situations.

Masters (2009) sums up the findings of many science education research projects by proposing that highly effective teachers have a deep understanding of the subjects they teach, beyond the level being imparted to the learners in their classrooms. This project identified that pre-service K-6 teachers have a limited knowledge and understanding of some fundamental science concepts. This was attributed to their own lack of enjoyment in learning the subject and consequent limited participation in post-compulsory science study. Acknowledging that it is almost impossible to impart this desired level of understanding in the restricted timeframe available during teacher education courses, this project proposed and tested a means by which pre-service teachers can develop this understanding as their career experience develops. The enhancing of their confidence to teach one thing well, using strategies that are applicable to other concepts, has also provided them with a means to build their own knowledge and understanding. The increased confidence expressed by the participants was strongly linked to their increased knowledge and understanding of the concepts being explored.

6.11.2 Findings taken forward to Phase IV - Peer Teaching

The hands-on, exploratory activities trialled and refined during Phases II and III led to the development of a suite of strategies able to be applied by early career teachers in classroom situations. To consolidate the building of the pedagogical awareness of the participants and in response to requests from participants to rehearse the application of the modelled strategies, a peer-teaching environment was established and explored by small groups of volunteers during Phase IV.

The acknowledged effectiveness of the components led to the identification of aspects that would lend themselves to this rehearsal of small-group, collaborative, reiterative teaching episodes. These aspects incorporated:

- Engaging and exploratory hands-on activities, relevant to the learner;
- Predict-Observe-Explain-Share opportunities;
- Formative assessments designed to shape subsequent learning interventions;
- Simple and readily available equipment; and
- Reflective opportunities for the participants to evaluate their teaching.

Chapter 7 details the application of these principals to the peer-teaching episodes.

CHAPTER 7

PHASE IV – PEER TEACHING

7.1 INTRODUCTION

In this Phase, aspects of peer-teaching and learning were exemplified two ways. In the first, described as Component 1, small groups of 'learners' were given the opportunity to interact during a series of Predict-Observe-Explain-Share and hands-on activities in an interactive lecture environment. Subsequently, in Component 2, small-groups of learners were actively taught by one of their peers using exploratory activities demonstrated during Component 1 or developed by themselves.

Australian surveys of early career graduate teachers suggest that many pre-service teacher education programs are not effectively preparing individuals for the challenges they may meet in a teaching career. The Australian Education Union's New Educators Survey (AEU 2009) reports that only 41% of new teachers identified their pre-service training as having prepared them well for the reality of the teaching experience. This and other similar surveys (for example, Standing Committee on Education and Vocational Training (SCEVT) 2007), highlight several areas in which teachers think that current pre-service training courses are lacking. These include perceptions that:

- the link between 'theory' and 'practice' is weak; and
- some of the theoretical components of courses are not relevant.

More specifically, the surveys point to scope for improvement in regard to:

- managing a classroom; and
- conducting assessment and reporting.

To explore the link between 'theory' and 'practice', this phase explores the perceived value of the provision of pre-service K-6 teachers with the opportunity to rehearse the teaching strategies developed during Phase II, refined during Phase III and modelled as part of the initial component of this phase.

When re-considering the results of the analysis of the first three phases of this project, it became apparent that the sequential approaches to the development of conceptual understanding provided an opportunity for participants to gain first-hand experience with their application. Phase IV, therefore, endeavoured to: emphasise the modelling of the practices espoused; validate particular sequence elements as effective through the application of peer-teaching episodes; to consolidate the findings of the previous phases; and facilitate a considered response to the issues raised by Research Questions 5 and 6, namely:

5. *Does the integration of Predict-Observe-Explain-Share strategies into the 5Es pedagogical model provide an effective means to support and enhance K-6 pre-service teachers' learning of fundamental concepts?*

6. *Can a peer-learning enquiry-based pedagogy be adopted and used as a framework in pre-service science teacher education for learning and as a model for teaching?*

The first part of this chapter describes the way that specific concepts for further development were identified and strategies designed to enhance fundamental understanding of those concepts. Further, as reported in Chapter 3, pre-service K-6 teacher participants expressed a desire to have effective teaching strategies modelled during the science component of their course. They also sought opportunities to practise some of the specific strategies and activities. The second part of this chapter reports on the peer-teaching undertaken by volunteers of fourth year pre-service K-6 teachers, while teaching small groups of second year participants, who sought to enhance their conceptual understanding. This facilitated the exploration of some of the activities and sequence elements as 'teachable' by early career teachers in their classrooms.

The chapter concludes with a discussion of the results and points to further research that may contribute to a higher proportion of class-time being allocated to the teaching of science concepts in K-6 classrooms as a direct consequence of enhanced teacher confidence.

7.2 INFORMING AND DEVELOPING PHASE IV

7.2.1 Brought Forward from Phase I

Phase I of this project identified fundamental concepts, an understanding of which was desirable in K-6 school graduates. It was also recognised that teachers tend to teach the way they were taught. It is interesting to note that the experienced teachers interviewed during this Phase stressed the need for the teaching of fundamental concepts in science to get away from the traditional transmissive approach adopted by many in their early and often formative years of their career. Most of the interviewees (69%) recommended that a greater emphasis be placed, in teacher-education programs, on the benefits to be gained by the application of inquiry-based exploratory approaches to science activities. It was further espoused that this would stimulate a more 'scientific' approach to investigations of phenomena, and exemplify the collaborative nature of shared observations and explanations of such phenomena. Most strongly supported was the need to meet the learner's desire for the learning to be relevant to their immediate life and interest. This was proposed as a means to engage and support learning in a context deemed valuable to that learner. This opinion is ably summed-up by a Phase I interviewee who stated:

> *"Although the syllabus states what it thinks is important, it often does not match what the kids want to find out about. We (teachers) should be matching what the kids want to learn about with the syllabus, responding to what they think is meaningful to them in their context."*
>
> (Interviewee 15PAP-ACPS-11_04)

The underlying implication being that, in her experience, K-6 students tend to seek and engage more with exploration of issues that are somewhat familiar and relevant to their learning experience.

A greater emphasis on the tracking of the progress of learners through their educational experience, using appropriate assessment strategies, was also espoused and summed up as:

> *"A lot of us (teachers) these days teach to get good results in the external exams, and we assume that the exam will assess the students' knowledge of content and literacy and numeracy skills. In responding to the syllabus, we do not teach problem solving, or cater for real inquisitiveness of youngsters exploring the world around them. Classroom assessment needs a different emphasis, one that allows us (teachers) to know how well the students are responding to our teaching."*
>
> (Interviewee 09PET-ACPS-11_04)

In response to these findings, the project development team recommended the selection of activities, the teaching of which could be observed, as well as experienced, as part of an exploration of concepts by participants in small groups in a classroom teaching and learning situation. Specific criteria were identified to foster a realistic approach, with the requirement that the activities demonstrate most, or all, of the following:

- Time efficient – they should be able to be completed in 15-30 minutes, with only basic psychomotor skills required (emulating the average manipulative skills of Year 4 students);
- Problem solving – the participants either identified the problem or accepted it as one relevant to them in terms of finding a solution;
- Modelling – modern, research validated pedagogical approaches to K-6 science teaching;
- Formative assessment – incorporated in recognition of the need to find out where learners are situated in terms of the progress of their learning, to shape further learning experiences;
- Hands-on skill improvement – utilised commonly–available, and simple-to-use resources (to allay apprehensions of participants to manipulate basic science equipment;

- Implement Predict-Observe-Explain-Share – in context of 5Es (specifically, Engage, Explore and Explain) – reiterating previously adopted teaching cycle and pedagogies; and
- Collaborative learning – facilitating further qualitative assessment of applied constructivist learning principles.

7.2.2 Brought Forward from Phase II and III

During Phases II and III, specific inquiry-based, hands-on teaching sequences were designed, trialled, experienced and further developed by two cohorts of second year pre-service K-6 teachers. The findings revealed a large range in the understanding of the fundamental concepts identified in Phase I, and that there exists a contextual relationship between their knowledge and their perceived confidence to teach the concepts. Whilst it can be demonstrated that participation in the modelled sequence of activities enhanced understanding of both content and pedagogy, analysis of participant responses to surveys and interviews revealed that some of the activities did not realise the desired level of conceptual change that could be translated to increased participant confidence to teach the concept to Year 4 students in their classrooms. Another criterion for the selection of the activities for exploration during this Phase was, therefore, that they address identified shortcomings of the sequence experienced by the participants during Phase III.

7.2.3 Focus of Phase IV Components

During the Phase III small group informal interviews, participants reflected positively on their experience with the modelling of the teaching strategies and hands-on exploratory activities during the project, and that this had prompted an enthusiasm to apply elements of the sequence to their classroom situation early in their career – a desired outcome of this project. Some expressed a concern, however, that they were unsure of their ability to maintain control over a whole class of young learners participating in a variety of tasks.

> *"What do you do if the kids don't want to be engaged, or, just like us, get frustrated at not being able to do the task? I reckon it could turn into a disaster if you weren't in complete control."*
>
> (SID P3P1W3Lu113)

This participant went on to state, however, after considering the comments of others in her group, that keeping the learner engaged with the activity at hand was the key:

> *"If they're playing, or involved in something that excites them, then, I suppose, you're less likely to have behavioural problems to deal with."*

As in Phase II, these interviews also realised recommendations for additional activities to address possible limited understanding by some participants about specific concepts. Recognising the reiterative and cyclical nature of the experience of the sequence, 85% of participants were able to nominate the place where these activities could fit into the sequence.

Discussions with the research team led to the identification of a process with two components that would best yield appropriate data to test effectiveness of the sequence, and assess the confidence of participants before and after they had worked with small groups of their peers.

Component 1 modelled the evaluated and effective strategies using hands-on problem solving activities developed from the findings of Phases II and III. Negotiation with my supervisors led to the nomination of an opportunity to work with final year pre-service K-6 teachers undertaking a mandatory science education unit EDSE412 (for course details, see Appendix B). Two sessions were allocated to enable a full exploration of the teaching strategies, assessment methods and sequence elements.

Component 2 called for volunteers from the EDSE412 cohort to conduct small-group peer-teaching episodes with volunteers from EDSE213, providing a mechanism to validate the additional activities and identify any change in perceived confidence of the participants to engage in these strategies early in their career. This was in response to the perception identified by the Phase I interviews, and Phase II forum, that beginning teachers tend to teach the way they were taught as they come to grips with their teaching responsibilities. An anticipated outcome of this component was the application of constructivist teaching strategies with the EDSE213 participants to enable them to assimilate the recently accumulated new knowledge with the fundamental concepts being presented with more detail to build competence (knowledge and understanding) and confidence (first-hand experience of teaching strategies at work).

7.3 COMPONENT 1 – MODELLING OF PREDICT-OBSERVE-EXPLAIN-SHARE AND ACTIVITIES

7.3.1 Activity Development

The four fundamental concepts identified by Phase I and explored during Phases II and III were *Safety, Efficient Electricity Use, Efficient Electricity Generation* and *The Motor Effect*. It is interesting to note that the analysis of Phases II and III data revealed that limited conceptual understanding of magnets, their properties and interactions, was a barrier to a deeper understanding of the latter two fundamentals. Recognising the need for further exploration of phenomena that would lead to a deeper understanding of the fundamental concepts in question, the development team constructed and compiled a number of

Predict-Observe-Explain-Share elements for the lecture and activities for the workshop. As the motor effect and generation of electricity are closely linked, the team identified a set of seven Predict-Observe-Explain-Share activities and five exploratory investigations that:

- incorporate open-ended, inquiry-based, hands-on and exploratory aspects demonstrative of E*ngage, Explore* and E*xplain* activities representative of those prescribed by the 5Es approach;
- exemplify clearly observable phenomena;
- are simple in terms of teacher construction;
- may be safely and confidently conducted in a standard K-6 classroom; and
- draw upon, and enhance, the experiential observations of phenomena of the learner.

The Predict-Observe-Explain-Share and hands-on inquiry activities were designed to enhance the level of conceptual understanding of the specific elements described in Figure 7.1. For details of the tasks assigned to the participants, see Appendix A, Workshop EDSE412.

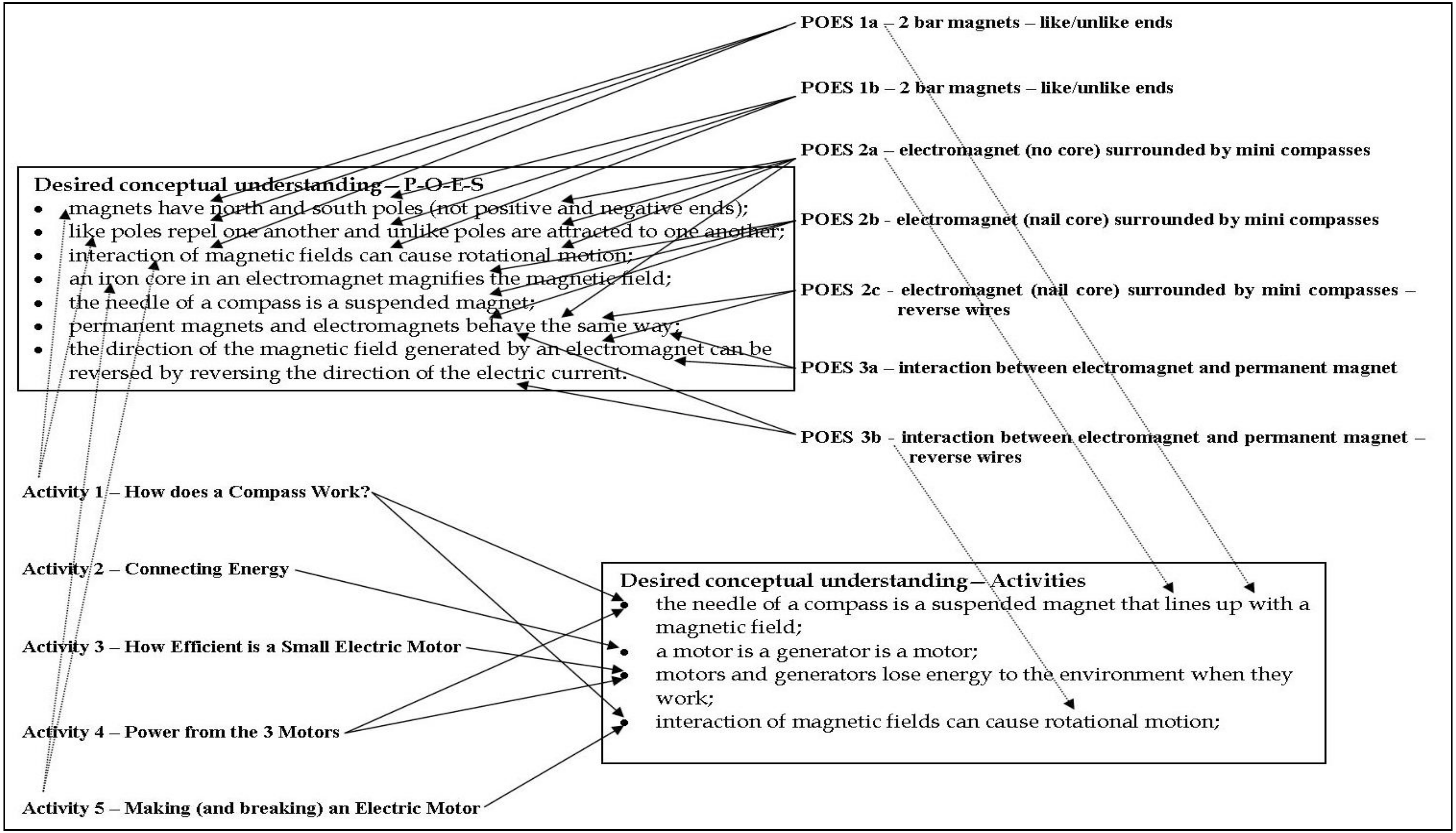


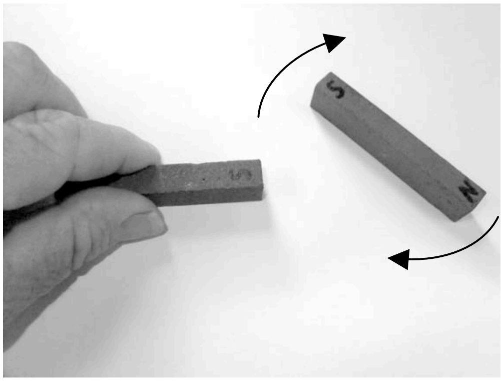
Figure 7.1: Relationship between the Desired Conceptual Understanding, the lecture Predict-Observe-Explain-Share and the workshop Activities.

Predict-Observe-Explain-Share

The Predict-Observe-Explain-Share activities were designed to be prepared and presented using readily available materials. In conducting these, participants were asked to predict what will happen, observe what happened, write an explanation of their observation(s) in their workbooks, share the explanation with their group members then derive and record an agreed explanation.

During the lecture, these activities were conducted sequentially to build on the level of understanding identified by the pre-intervention surveys conducted during Phases II and III. The completion of the sequence established a foundation upon which to build this understanding using the activities in the workshop.

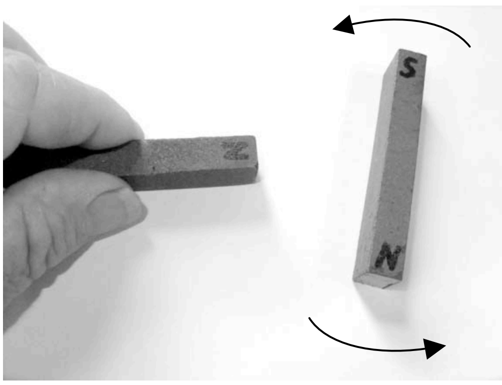
- **POES 1a – 2 bar magnets – like/unlike ends.**



What happens when you slide a bar magnet across a smooth table toward another with the ends pointed at one another?

Particular attention was drawn to the rotational nature of the motion as the free magnet moved toward the held magnet.

Figure 7.2: Two inexpensive and readily available bar magnets moved toward one another.



POES 1b – 2 bar magnets – like/unlike ends.

What will happen if you turn one of the magnets around?

The rotational motion was again noted.

Figure 7.3: Two bar magnets again moved toward one another with the moving magnet being turned around.

- **POES 2a – electromagnet (no core) surrounded by compasses.**

What happens to the compass needles when we turn on an electromagnet that is just a coil of wire, surrounded by compasses?

Note that different types of compasses were placed around the electromagnet to demonstrate the similar reactions of the compasses to the presence of a nearby magnetic field.

Figure 7.4: A student built electromagnet (from Phase III) surrounded by a variety of commonly available compasses. Note that the compass needles align themselves up with the magnetic field generated by the electromagnet.

This activity led to an extension activity used by a 'teacher' in Component 2 with the compasses being replaced with iron filings to illustrate the shape of the magnetic field.

- **POES 2b - electromagnet (nail core) surrounded by compasses.**

What happens to the compass needles if an iron nail is in the core of the electromagnet coil when the electromagnet is turned on?

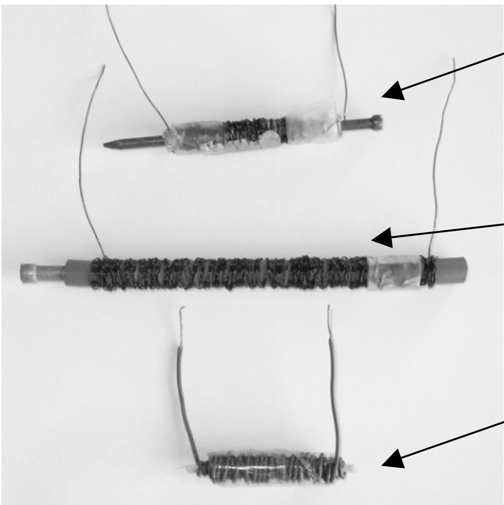


Figure 7.5: Examples of participant constructed electromagnets. Each used different types of insulated wire, and core material for subsequent testing with the surrounding compass array.

- **POES 2c - electromagnet (nail core) surrounded by compasses – reverse wires.**

What happens to the compass needles if an iron nail is in the core of the electromagnet coil when the electromagnet is turned on with the wires turned around?

- **POES 3a – interaction between electromagnet and permanent magnet.**

What does the suspended electromagnet do when we connect it to a battery?

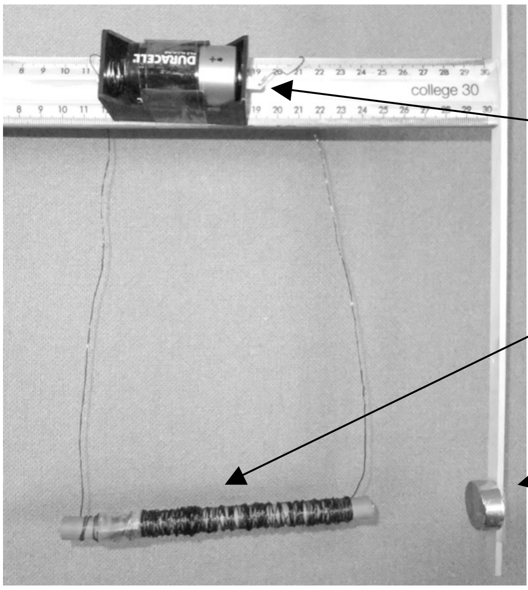


Figure 7.6: A 1.5V battery in a holder was taped to a 30cm ruler. On one end of the ruler was taped another with a simple button magnet taped to it. An electromagnet with an iron nail core was suspended in the proximity of the button magnet and when connected to the battery, the resulting movement of the suspended electromagnet noted.

- **POES 3b - interaction between electromagnet and permanent magnet – reverse wires.**

What happens to the electromagnet when we reverse the wires on the battery?

Activities

The Predict-Observe-Explain-Share focussed on demonstrating the interactions between permanent magnets and electromagnets in terms of their polar nature, and of their capacity to cause attractive and repulsive forces depending upon their spatial orientation. To further explore the cyclical and reiterative nature of the activities, they were planned and presented to the participants in rotation. Each of the five groups attending the workshop was allocated 15 minutes to complete the activity and record their observations, explanations and identify what they had learned. Another 5 minutes was allocated to discuss their observations. By moving between the activities, the premise that it did not matter in which order the activities were undertaken was tested, in terms of a consistent level of conceptual understanding developed across the participating groups.

It is also important to note, as it was noted to the participants, that setting up a series of activities to be conducted in rotation where only a single set of equipment needs to be set up for each activity, rather than sequentially, where multiple sets of equipment are required for each activity.

During the two-hour workshop, the course presenter, and the research team undertook the dual role of guiding the groups through the activities and observing the interactions in terms of the collaboration being exhibited. These were discussed during the informal interviews conducted after the workshop sessions.

Activity 1 – How does a Compass Work?

Phases II and III analyses revealed that the participants did not commonly understand the identification of a compass as a suspended magnet that could align itself with the earth's magnetic field. To address this, groups were provided with a bar magnet, large glass jar, adhesive and piece of polystyrene foam, and invited to make a compass, record the steps they undertook, and draw and label the product.

This activity is designed to reinforce several concepts:

- A compass needle is a suspended or floating magnet.
- The poles of a magnet line up with the direction of the earth's magnetic field.
- The north pole of a magnet points to the north magnetic pole of the earth.
- Differently shaped magnets (button, horseshoe, disc etc.) may be substituted for the bar magnet to demonstrate that magnets have similar properties regardless of their shape.

A recurrent question from participants in each of the workshops was recognised as worthy of further discussion as it was identified as a significant contributor to the lack of understanding as detailed during Phases II and III:

> *If the north pole of a magnet always points to the north pole of the Earth, how can this be if like poles repel one another?*

The asking of this question indicated a deeper understanding of the nature of like and unlike poles of magnets and peer-discussion revealed considerable confusion as to whether magnets had a different magnetic field to the Earth's. In two of the three workshops, a 'more knowledgeable' peer explained:

> *"The poles of a magnet were originally called 'north-seeking' and 'south-seeking' – it has been shortened to 'north' and 'south' poles by laziness I guess."*
>
> (SID P4P3W3Gt131)

The workshop groups acknowledged this peer-derived explanation as accurate. In the third group, the question did not arise, but was explained to them after some directed questioning did not reveal an understanding of this concept.

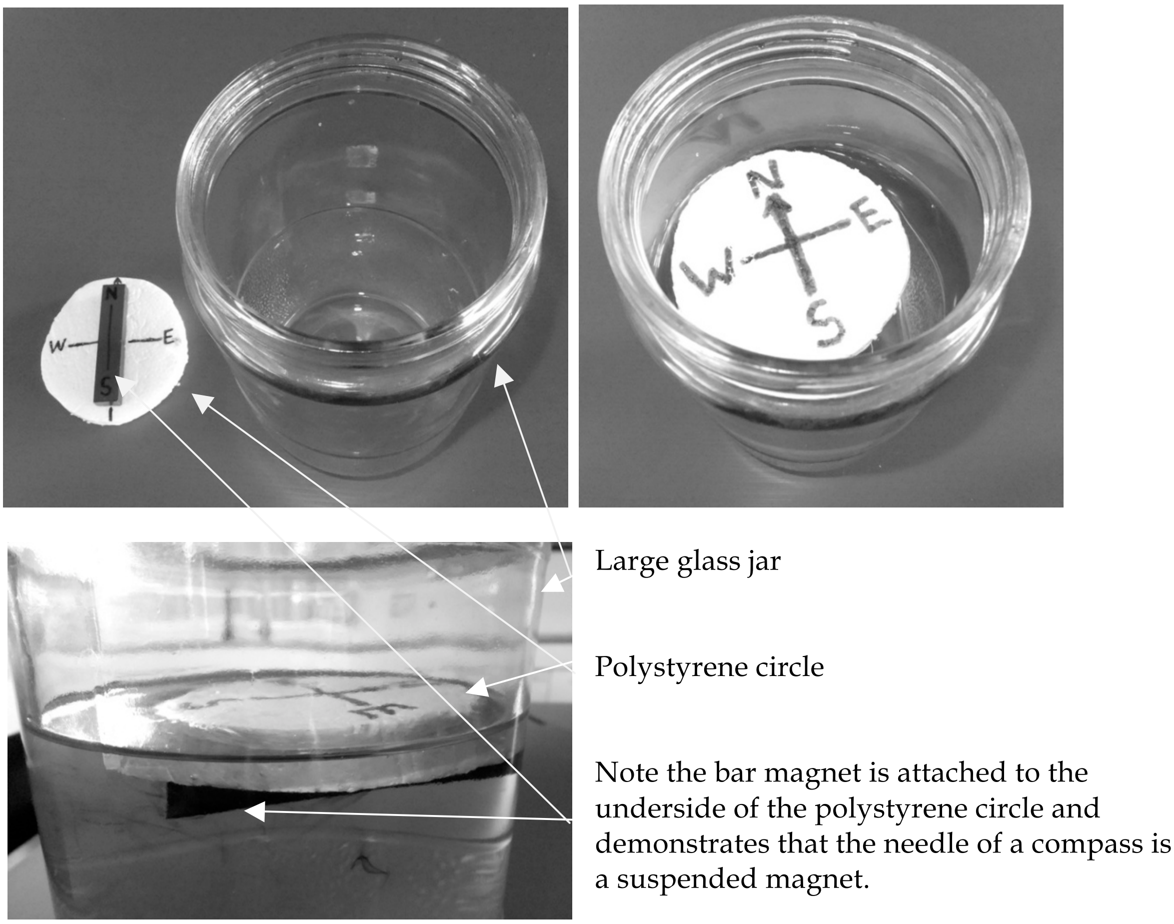


Figure 7.7: The 'home-made' compass composed of a bar magnet stuck to a piece of polystyrene and floated in water.

Activity 2 – Connected Energy.
Two sets of the apparatus (see Figure 7.5) were set up to facilitate the successful completion of Activities 2 and 4. At the beginning of the workshops, it was pointed out to all participants that the measurements taken during this exercise were to be applied in Activity 4.

To enhance the recognition of the relationship between the use and generation of electricity using mechanical means, the shafts of two small electric motors were joined with a small piece of plastic tube. These were then connected to a third motor with wires. When the motor connected to the battery rotates, it rotates the second motor, which generates enough current to power the third, thus demonstrating that a motor and a generator are one and the same. The participants were invited to record their observations and draw and label the equipment used. They were also asked to use a simple and inexpensive digital multimeter (see Figure 7.10) measure the *current* and *voltage* coming out of the battery (going into the first motor), and that coming from the second motor (generator) powering the third motor. Note the introduction of the correct terminology during this exercise.

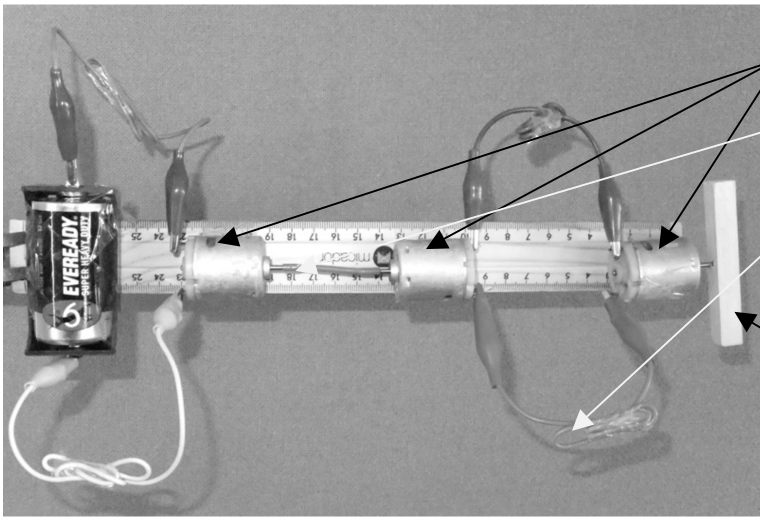


Figure 7.8: Three small, inexpensive, toy 1.5V electric motors were set up with two connected physically, and two connected by wires. The wooden peg demonstrates motion.

Activity 3 – How Efficient is a Small Electric Motor – calculations.

A limited understanding of the relationship between the mechanical power that can be produced by an electric motor and the electrical power required was evident as a result of considering participant generated definitions of *power, volts, amps* and *watts* (See Appendix A, EDSE213 Guided Activity Workbook).

As described to the participants, (see Appendix A, Workshop EDSE412), the electrical power used by the motor to lift the weight is calculated using P=VI with the voltage and current being measured by the participants using commonly available, inexpensive multimeters. The power output of the motor is determined by measuring the time it takes for a known mass to be lifted through a defined distance and applying the formula P=mgh/t (g assumed to be $10ms^{-2}$). By comparing the power input with the power output, the efficiency of the motor can be estimated. Whilst this investigation is designed to redress the stigma attached to scientific formulae and calculations, it was also anticipated that the investigation would enhance the understanding of *power* and *efficiency ratings* quoted on electrical appliances.

It is interesting to note that if the units were originally defined in terms of kilograms, metres, seconds and watts, the use of electronic calculators by the students to derive approximately correct answers did not appear to present any problem.

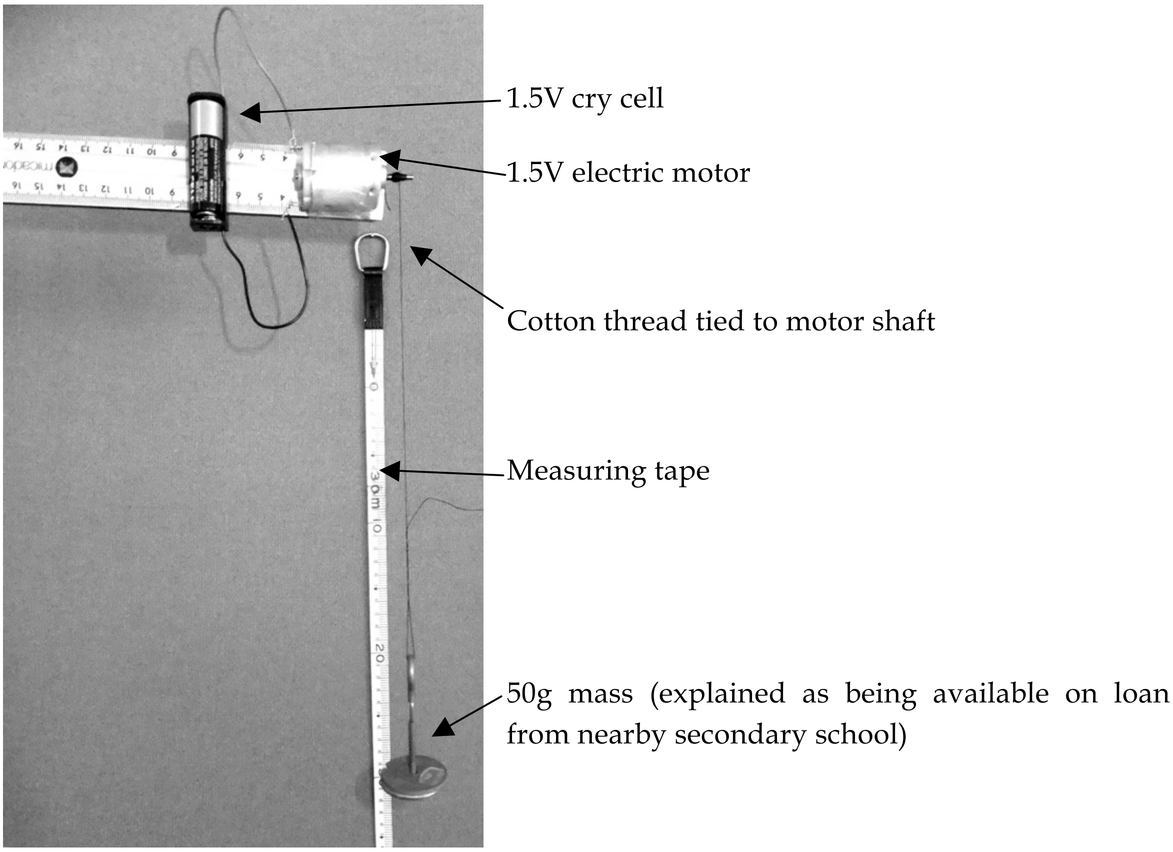
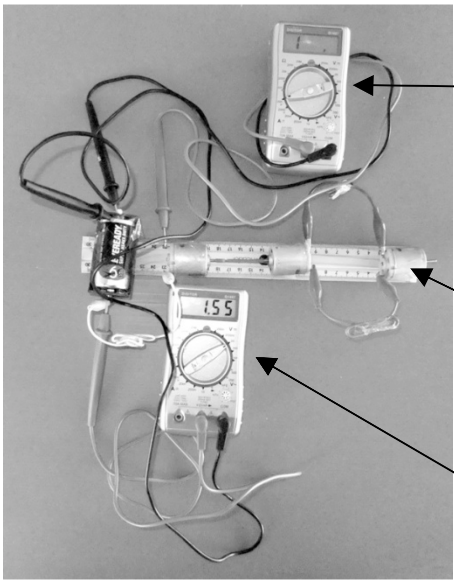


Figure 7.9: Taped to a 30cm ruler are a small 1.5V toy electric motor connected to a AA battery. A fine cotton thread is tied to shaft of the motor. The time taken for the motor to lift the 0.05kg through a 0.5m distance provides the data for the power calculation.

Activity 4 – Power from the 3 Motors.

Pre- and post-intervention surveys from Phases II and III revealed that the term *power* is most commonly linked to the volume able to be generated by electrical amplification devices and speakers. Less commonly, but equally as important, some participants (18%) linked the term *power* to physical strength and that *loss of power* was attributable to loss of strength. No reference was made to the linking of electrical power *consumed* by household and industrial appliances. Nor was there any question asked as to “where does the power consumed go”. To establish that energy is lost to the environment during the generation of electricity, a comparison of the power generated by the first and second motors is made. This leads to a number of exercises to calculate the power ‘consumed’ by common electrical appliances. A basic understanding of the content of electricity bills is also promoted by calculation, leading to an appreciation of the need for efficient use of electricity.



Multimeter connected in series to measure current to from dry cell – later connected between motors 2 and 3 to measure current from motor 2.

The same setup of the 3 1.5V toy electric motors connected together and taped to a 30cm ruler as in Activity 3 – Connecting Energy

Multimeter connected across dry cell to measure voltage output of dry cell – later connected across motor 2 to measure voltage output of motor.

Figure 7.10: The simple and inexpensive multimeters used by participants during this phase the students measuring the voltage output of the battery and later, out of motor 2; and the current flowing into out of the battery into motor 1, and later, out of motor 2 into motor 3.

Activity 5 – Making (and breaking) an Electric Motor.

An activity that requires no knowledge of electric or magnetic phenomena is the step-wise construction of a simple homopolar motor. The task does, however, require a fundamental level of manipulative skill. With appropriate instructions, and guidance, children as young as five years old have successfully built this motor. In this scenario, the activity serves multiple purposes:

- It is an ENGAGING activity that stimulates further enquiry.
- It is an EXPLORATORY activity that facilitates the investigation of variables including the effect of the placement of the button magnet and the effect of reversing the current.
- It ties together fundamental concepts of magnetic interaction in terms of attraction and repulsion causing rotation – the motor effect.
- It demonstrates the link between induced and permanent magnetic fields.

In this case, the whole workshop group was shown how to build the motor, and specific instructions were included in the participant workbook. Each of the smaller groups built the motor as part of their rotation through the different activities. Participants were asked to draw and label the components of their model, and to describe what was happening to make the model work. They were also asked to consider the conduct of this activity with a

Year 4 class of school students and possible difficulties students may face when building the model.

As a follow-up activity, participants were asked to deconstruct a small 1.5V electric motor of the same kind as was used in other activities. Again, a drawing of the parts was requested, and an explanation of the purpose of the various components identified.

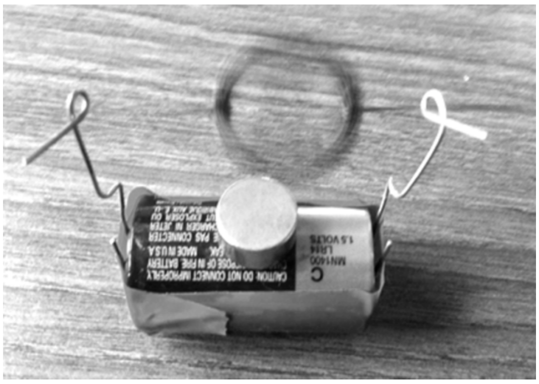


Figure 7.11: One of the homopolar electric motors constructed by participants in less than 10 minutes.

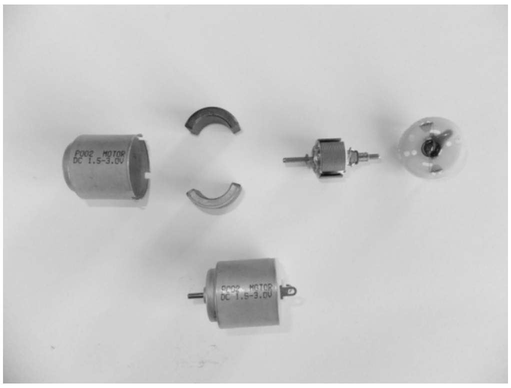


Figure 7.12: An inexpensive, readily procurable 1.5V toy electric motor deconstructed by the participants to identify the parts and establish a foundation for the learner to consolidate their observations.

7.3.2 Organisation

Negotiation with the course presenter of EDSE412 resulted in the allocation of a one-hour lecture and two-hour workshop conducted toward the end of Semester 1, 2010.

During the lecture, a whole cohort forum was held facilitating a revision of the participant knowledge about the relative value of:

- The Primary Connections (Australian Academy of Science 2007) 5Es approach as a model of a teaching cycle;
- Incorporation of inquiry-based activities in science lessons as an approach to meet the problem solving outcomes defined by the NSW K-6 Science and Technology Syllabus (Board of Studies NSW 1993); and
- Application of Predict-Observe-Explain-Share as teaching strategy incorporating constructivist principles of peer-oriented collaborative knowledge building.

Following the open forum, specific examples of Predict-Observe-Explain-Share activities were undertaken. The explorations led to a discussion focussing on the derivation of definitions of further fundamental concepts and commonly used terminology associated with those concepts, to further build on the understanding gained during the Predict-Observe-Explain-Share.

To demonstrate the promotion of understanding to the application level of cognition (Bloom 1956-64), a series of calculations were described to calculate the power consumption of common appliances (detailed in Appendix A, Workshop EDSE412), and lead into the exploratory activities to be undertaken during the workshop.

The two-hour workshop began with a review of the desired outcomes of the lecture, namely:

- to identify and establish a foundation level of knowledge about the fundamental concepts to be further explored by the activities undertaken during the workshop;
- to provide first-hand experience with the teaching strategies and approaches being modelled during this component; and
- to establish a degree of familiarity with the calculations to be applied during the workshop.

In groups of 4 or 5, the participants undertook each of five activities developed to address identified shortcomings of the refined sequence elements. The rotation of the groups through the activities provided a means of assessing the iterative nature of the elements in terms of each group recognising the same achievement of knowledge and understanding of the concepts, and the pedagogical implications of the activities. The design and implementation of the activities is outlined in 7.3.3 below. To facilitate reflection, as a teacher, upon the effectiveness of the activities in developing conceptual understanding students, the participants were invited to evaluate the activities in terms of their difficulty at both a cognitive and psychomotor level.

7.3.3 Data Collection and Analysis

To facilitate a comparison between the findings of Phases II and III, the development team recommended that the workbook format again be employed as it best serves the participant and researcher requirements. During the lecture and workshop, participants made their own notes during the discussions, and recorded responses their to each of the prescribed Predict-Observe-Explain-Share activities. The workbooks were collected at the end of each session, copied and returned prior to the next.

The participants were invited to engage in informal, conversational interviews (Cohen, Manion and Morrison 2007) in small groups as soon after the lecture and workshops as possible. The focus was on their opinions about the effectiveness of the workshop and what concepts needed to be further explored using different strategies during later learning opportunities.

The members of the research team and course presenter were present to act as observers. Prior to this component, the observers were asked to note in particular:

- level of involvement by the participants in the manipulation of the equipment;
- enthusiasm exhibited by participants to share observations and explanations; and
- any observable change in confidence to present, and/or negotiate explanations as part of the process of building understanding.

The copies of the collected workbooks, interview transcripts and memo-notes were analysed using a subset of steps 1, 2, 4, 6 and 7 of Colaizzi's seven-step phenomenological process, concentrating on the perceptions of the participants as learners and as teachers to yield exhaustive descriptions of the perceptions of the effectiveness of the approaches utilised to model the developed strategies.

7.3.4 Research Setting

The participants (n = 72) in this component of Phase IV were fourth-year students enrolled in the *Primary Environmental Science for Sustainability*, EDSE412 during Semester 1 2010 at the UNE. This is a 6-credit point unit, one semester course that purports to focus on implementation strategies to facilitate children's learning consistent with contemporary, constructivist views of learning and teaching in the K-6 primary school (see Appendix B for course details).

The interactive lecture was conducted in a tiered lecture theatre and the activities in a classroom set up to resemble a typical K-6 learning space. At the commencement of the lecture, the participants were issued with an interactive workbook, the contents of which are described in Appendix A, Workshop EDSE412.

Three informal conversational interviews were conducted with small groups (n = 3,3,4) of participants, as well as one with the course presenter. Each interview lasted approximately thirty minutes and focussed on:

- The perceived effectiveness of the elements of the 5Es teaching cycle and the Predict-Observe-Explain-Share, collaborative and hands-on inquiry based teaching strategies modelled;
- A qualitative measure of the enthusiasm for, and engagement with, the activities undertaken;

- Opinions regarding the usefulness of the specific activities undertaken in terms of their ease of use, applicability to a Year 4 classroom context and the accessibility of the resources;
- The identification of any considered doubts with respect to the implementation of any elements of this component.

7.3.5 Preliminary Results – Modelling of Predict-Observe-Explain-Share and Activities

Reflecting the findings of Phases II and III, during the interviews the opinion was strongly supported that the Predict-Observe-Explain-Share demonstrated an approach to stimulate inquiry and promote investigative activities undertaken later in the sequence. The majority of interviewees specifically identified the value of the Predict-Observe-Explain-Share as contributors to the relevance of the hands-on investigations. They were also recognised as facilitating the construction of a personal model of the phenomenon being explored, explaining previous observations, and creating links between 'old' and 'new' knowledge.

> *"The POE about the electromagnet with a nail in it helped me realise that the wire in a motor's coil is wrapped around steel bits to amplify the magnetic field – I always thought it was just to give the wire something to wrap around."*
>
> (SID P4P1W3Gt144)

The peer-interaction experience of the Predict-Observe-Explain-Share was also appraised during the small-group interviews as an effective mechanism to encourage internalisation of constructed understanding, in terms of the use of familiar language, and the opportunity to negotiate explanations of the observed phenomena.

> *"I was able to talk to Lisa about what she meant about the compass behaviour and how the needles always pointed to one end or the other. She explained it to me using words that I understand."*
>
> (SID P4P1W1Gt137)

The hands-on nature of the inquiry-based activities was universally acclaimed as an "interesting", "exciting" but "sometimes frustrating" approach that the participants acknowledged they would try in their classrooms. Further exploration of the frustration expressed revealed reluctance on the part of some participants to suggest explanations, or to express their opinion, in fear of being wrong. This led to a discussion about the recognition that K-6 students may have similar feelings and, consequently, it was agreed that effective implementation of the Predict-Observe-Explain-Share would require a level of 'training' of the learner involving encouragement to participate and role definition in group situations.

> *"…to make them (the Predict-Observe-Explain-Share) work, you'd have to constantly remind the kids what they were supposed to be doing, and how they are supposed to share their ideas with each other without fear of being wrong – how do you do this when you're one teacher with 25 students?"*
>
> (SID P4P1W2Sc113)

Whilst it was acknowledged that the 5Es appeared to represent a valuable tool that could guide the planning and presentation of learning experiences, a reticence to apply it was expressed. This was in terms of a perception held by the majority of the participants (85%) that their lack of experience early in their career could manifest itself in a "chaotic classroom". Fear of loosing control was strongly expressed by two of the three groups interviewed.

Particularly noted by participants in the small-group interviews was a personal perception of an increase in their knowledge brought about by the establishment, or strengthening, of links between the application of their new knowledge to everyday circumstances, such as the increased understanding of power bills and energy ratings on appliances.

> *"At least now I'll know what those stickers on fridges and things mean – you know, the energy-rating things with the stars."*
>
> (SID P4P1W1Gt137)

By incorporating the multimeters into the measurement of aspects of electricity, the participants were introduced to the quantitative nature of electricity use. It was widely reported that prior to working with the multimeters, there was a fear related to the perception of "complicatedness" associated with this equipment. It was also widely acknowledged that the participants gained a level of confidence to use such equipment, once the stigma of difficulty with its use, had been reduced. Two of the observers noted that some of the participants began to experiment with the other settings on the meter, once they had completed the assigned measurement tasks. These participants also actively sought assistance and advice as to how the meters may be used for such things as measuring the voltage of different batteries, combinations of batteries, and determining the conductivity of different materials.

It was evident, as reported by the observers, and in comments made by participants, that the opportunity to explore and complete the activities was initially regarded as a daunting task: "a challenge" as one participant noted. It was widely acknowledged, however, that at the completion of the workshop, the participants were enthusiastic and excited about undertaking more investigative activities similar to those experienced during the workshop. An opinion was also expressed by members of two different groups:

> *"I can't wait to try this sort of thing with my students – I learned so much and it was fun doing it".*
>
> (SID P4P1W3Ws127)

A concern was expressed during Phase III regarding issues of classroom management when using activities in rotation with young learners. This issue was again raised during the small-group interviews during this Phase.

> *"I don't know if I would be game to run lessons like this – I'd be worried that there would be distractions and misbehaviour and I would not be able to control the class – they would need to be trained."*
>
> (SID P4P1W3Ws129)

Consequent discussion among group members resulted in these fears being shared, but eventually ameliorated when it was acknowledged that:

> *"…I suppose that if the kids are engaged and excited to be participating in the activity, their focus, well, most of them will focus on the fun activities – yeah, I reckon I'll try it, you know, the 5Es."*
>
> (SID P4P1W3Ws129)

This was affirmation that the initial discussions held during the lecture had led to a recognition of the possible effectiveness of the 5Es approach with embedded Predict-Observe-Explain-Share and that, in fact, such an approach may actually contribute to better classroom control, because the environment has been created whereby the learner is enjoying learning, particularly with peers, sharing the knowledge and celebrating the learning.

In précis, the overall findings from this component suggest that the majority of respondents responded favourably to the adoption of Predict-Observe-Explain-Share as a teaching strategy, demonstrating an increased knowledge of the concepts being explored, and an increased awareness of the pedagogical issues associated with the teaching of those concepts to K-6 students. Overt modelling of the initial stages of the 5Es approach espoused by the Australian Academy of Science (2007) was acknowledged as an effective means to enhance the conceptual understanding of fundamental science concepts by pre-service K-6 teachers. The participants strongly indicated that the increased knowledge and pedagogical awareness gained, significantly enhanced their confidence, not only to teach the identified fundamental concepts using the strategies modelled, but also to apply these, or similar pedagogies, to the teaching of other aspects of science defined by the syllabus and student questions.

Discussion to Inform the Conduct of Component 2 – Peer-Teaching Sessions

At the conclusion of each of the workshops, an invitation was made for volunteers to participate in peer-teaching sessions, with small groups of second-year pre-service teachers, and practice the application of the modelled strategies in which they had been active participants. At the first preparation meeting with these volunteers (n = 13), the aims of Component 2 were outlined (see 7.4.1 below), and the type and format of the data to be collected, required to respond to Research Question 6, was negotiated. This group was then invited to consider the roles of 'teacher' and 'observer' as described to them, and to discuss the pedagogical aspects, pros and cons, of adopting this approach. This resulted in the selection of a suite of activities they may wish to present to small groups of EDSE213 students in the peer-teaching sessions. This discussion was recorded electronically and provided a shared insight as to the pedagogical considerations the participants may have to address in preparation for the delivery of the peer-teaching sessions to groups of 3 or 4 volunteers from the EDSE213 cohort.

7.4 COMPONENT 2 – PEER-TEACHING SESSIONS

During the initial preparation discussions, the five activities undertaken during the workshop sessions were identified, by the participants, as suitable to achieve the desired outcomes discussed in terms of reaching a desired level of conceptual understanding.

7.4.1 Outline

Of the thirteen volunteers who attended the initial preparatory discussions, eight elected to participate in the peer-teaching sessions, resulting in the identification of four 'teacher/observer' pairs to conduct a session each. During the second preparatory discussion, the format of the peer-teaching sessions was negotiated. This included the definition of an appropriate time-frame for their completion, the allocation of a period where interviews could be conducted with the 'teacher' and the 'observer', and times when interviews could be conducted with the members of the small group of EDSE213 volunteers acting as the 'simulated Year 4 students' being taught. Eight sessions were negotiated with the 'teacher' and 'observer' swapping roles for the delivery of the same activity to different small groups of EDSE213 volunteers. During this discussion, the roles of each participant were negotiated.

Combined Role of the 'Teacher/Observer' Pairs

Working in pairs, the EDSE412 'teacher/observer' was tasked with:

- Selecting an activity from the five negotiated;

- Identifying desired outcomes (what they wanted to achieve in terms of building conceptual understanding);
- Planning the form of assessment they were looking for to recognise and hence verify the change in conceptual understanding and the achievement of the desired outcomes;
- Set up and trial the activity (to be completed in a 30-minute timeframe) to ensure they were familiar with the iterations of the variables that may influence the successful achievement of the outcomes.

Role of the 'Teacher'

- Conduct the activity as 'teacher' of small group of EDSE213s acting as 'simulated Year 4 students'.
- Immediately following the completion of the session, record their impressions of the effectiveness of the activity, any problems they were able to identify with their plan of delivery, and their personal feelings regarding their confidence to apply the activity to their own class.

Role of the 'Observer'

While the 'observer' is not an active participant during the peer-teaching session, their primary responsibility is to offer a more objective view of the interactions that occurred during the teaching session as feedback to the 'teacher'. During the session, they were charged with:

- Observing the teaching and conduct of the activities reflecting on the presentation of the 'teacher' and the responses of the learner;
- Form a considered opinion as to the appropriateness and effectiveness of the formative assessments applied during the session; and
- Provide feedback to the 'teacher' on the overall effectiveness of the session in terms of how the learner(s) conceptual understanding was identified and subsequently developed to achieve the pre-defined outcomes of the teaching strategies employed during the session.

7.4.2 Addressing Research Question 6

As detailed in Chapter 3, a *reciprocal peer-learning* environment as described by Boud, Cohen & Sampson (2001) was established. They describe the peer-teaching process as:

> *…students learning from and with each other in ways which are mutually beneficial and involve sharing knowledge, ideas and experience between participants.* (cited by Longaretti *et al.* 2002, online)

Peer-teaching describes a collaborative and co-operative teaching and learning strategy - learners are active and equal partners; students are self-directed; they share in interventions; and actively participate in discussions and feedback (Clarke & Feltham

1990; Walker-Bartnick, Berger and Kappelman 1984). The pedagogical origins of this teaching and learning strategy lie with theorists such as Piaget, Perry and Vygotsky (cited in Perry 1970), who espoused the virtues of social interaction and collaboration as essential elements to the construction of knowledge (Vygotsky 1978).

The process explored in this component was adapted from the teaching experiment methodology (Engelhardt *et al. 2004;* Komorek and Duit 2004), with a single intervention being undertaken by the teacher, rather than a series of 'experiments'. In this case, the peer-teaching provided the opportunity for participants to practise the strategies and activities modelled, facilitating awareness in the pre-service teacher ('teacher' and 'observer') of their own conceptual understanding and its limitations in terms of unexplained observations and possible student questions. In response, in situation designed to simulate a realistic classroom situation, they were stimulated to find alternative explanations to meet the needs of the learner as the opportunity presents itself.

The elements of Research Question 6:

> *Can a PEER-LEARNING, ENQUIRY-BASED pedagogy be adopted and used as a framework in PRE-SERVICE SCIENCE TEACHER EDUCATION for learning and as a MODEL FOR TEACHING?*

were discussed during the preparatory sessions with the EDSE412 volunteers. The pedagogical implications of the terms *peer-learning* and *inquiry-based* were discussed and the participants asked to consider ways they could identify the impact the peer-teaching sessions may have on their confidence to teach the activities they selected, and on their attitudes to teaching science early in their career. The participants were informed at this stage that they would be asked to comment on their perceptions of the value of these modelled strategies in terms of their preparation as science teachers in a K-6 classroom context; and whether they could see these strategies as being effective vehicles of learning in their own classrooms in future.

7.4.3 Data Collection and Analysis

Each of the eight preparatory discussions conducted with the volunteer 'teacher' and 'observer' were electronically recorded and subsequently analysed (Colaizzi 1978) to identify any common perceptions held by the participants with regard to the type of activities, formative assessments required, and preparation necessary for the conduct of each session. A description of the conduct of these meetings, along with an example of the derived outcomes and assessments for the 'Compass' activity are provided in Appendix F.1.

The recorded reflections of the 'teacher' and 'observer' were collected and mapped against the collated descriptions of the elements resulting from the preparatory discussions. An example of the mapping matrix is presented in Appendix F.2.

At the conclusion of each of the peer-teaching episodes, informal, conversational interviews were conducted with each of the small groups of participants comprising a 'teacher' and 'observer' (EDSE412) and the EDSE213 volunteers who acting as 'simulated Year 4 students' being taught during these episodes. Again these interviews were electronically recorded and analysed (Colaizzi 1978) to reveal perceptions of the effectiveness of the teaching and the activities explored during the sessions, and the mechanisms employed by the learners to build their conceptual understanding. The result of the analysis of one of these interviews is outlined in Appendix F.3.

7.4.4 Implementation of Activities

Research Setting

During the concluding stages of Phase III, an open invitation was made to the participating cohort of EDSE213. Twenty-nine volunteers submitted a range of times during which they would make themselves available to participate in the 30- to 40-minute peer-teaching session, followed by an informal interview of approximately thirty minutes duration. A timetable was constructed that matched two EDSE412 volunteers with groups of three or four EDSE23 volunteers acting as students.

The peer-teaching sessions were conducted in a room set up to resemble a classroom typical of normal K-6 classrooms. The 'teacher/observer' team were tasked with preparation of the activity to present during the peer-teaching session. They were also to prepare any support materials by way of notes or worksheets for use during the session. All of the 'teacher/observer' pairs elected to prepare worksheets for their 'students': some worksheets sought to provide additional support for the concepts being explored with diagrams and additional activities to be undertaken (see Figures 7.13 – 7.14).

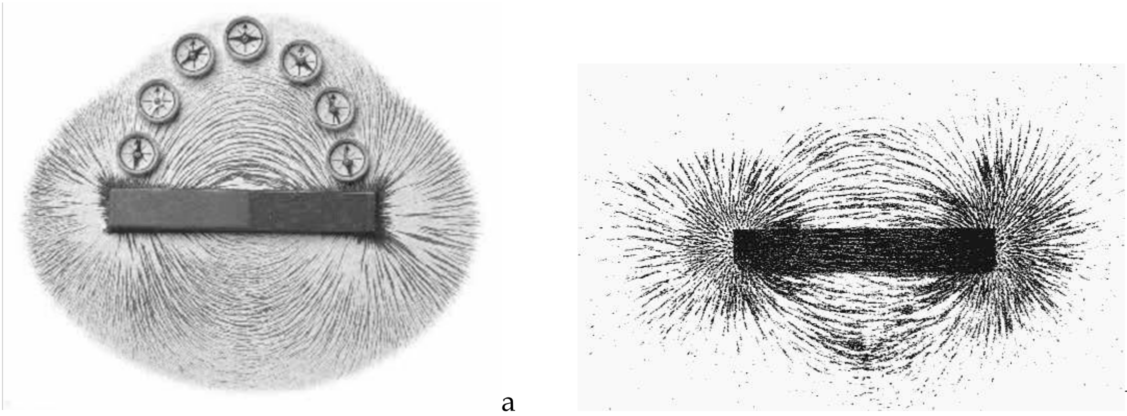


Figure 7.13: Examples of diagram used by 'teacher (SID P4P1W3Ws139)' as part of the "How Does a Compass Work" activity. (a: sourced from http://www.school-for-champions.com/science/magnetic_detection.htm; b: sourced from http://www.fi.edu/htlc/teachers/lettieri/classroomexperimentsandactivities.html)

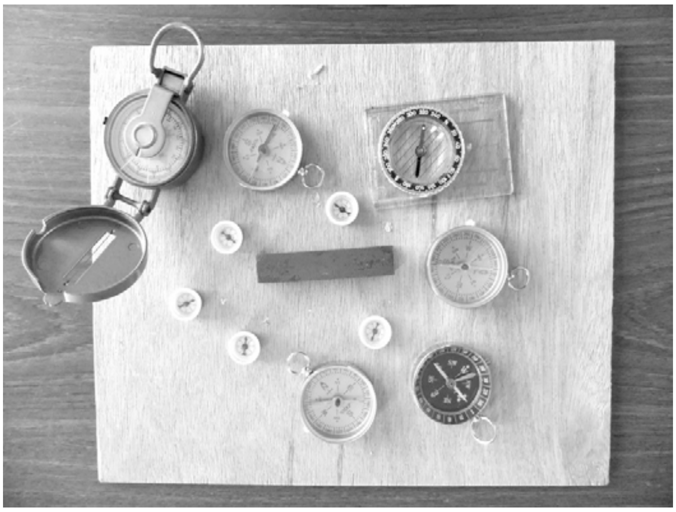


Figure 7.14: Demonstration equipment constructed by 'teacher (SID P4P1W3Ws139)' for use during "How does a Compass Work?" activity.

7.4.5 Preliminary Results – Peer-Teaching

Although the four 'teacher/observer' pairs were offered a suite of five activities from which to choose to present to their 'students', it is interesting to note that only two of the five were selected: the construction of the home-made compass, and the construction and deconstruction of the model electric motor. When asked why they chose those particular activities, three themes emerged from their responses. Those related to:

- familiarity with the concepts being explored facilitating the collection of support materials to present the activities in a relevant manner;
- a judgement that they were most likely to be fun for the learner; and
- accessibility of the equipment necessary to prepare for the activity.

The analysis of the transcripts and memo-notes of the small-group interviews revealed a number of commonalities with respect to the perceptions of the 'teacher/observer' pairs, and their peers acting as 'simulated Year 4 students', about the value of the experience. In précis, the identified themes were distilled into four main categories:

1. Hands-on, inquiry-based activities promoting collaborative interaction.

All participants and the 'observer' commented positively about the engagement of the 'learners' in the activities. The 'teachers' in particular identified the relationship between the experience of the learners and the perception of relevance the activity had to the apparent mystery left by unanswered questions the learner had about that experience. For example, SID P4P2W2Gm156 commented that:

> "*Although the 2nd years* (referring to the EDSE213 'learners') *knew what a compass was, and have used one, they didn't know that they could be affected by magnetic materials in close proximity. Recognising this, we talked about the effect this could have on navigation, like if you had your compass near something magnetic, you could head off in the wrong direction.*"

This was complemented by a learner, SID P4P2W2Gm156, from the same group, who stated:

> *"I like the word 'explore'. Yeah, it was like we were exploring the workings of the magnet as a compass at the same time as you (the teacher) were, and we looked for answers to our questions together – it was not intimidating as I remember my science lessons to be – like I was supposed to know that…"*

These comments highlight a positive aspect of the collaborative learning approach as it diminishes the aloof but oft employed transmissive 'delivery' aspect of science teaching – identified by the participants as ineffective and contra to effective learning.

Some of the 'learners' pointed out that consideration should be given to the ability of the learner (Year 4 student in this case) to manipulate the equipment in order to successfully complete the allocated task, referring to the apparent complexity of some apparatus. In one group interview, this observation led to a discussion relating to the recognition that frustration with a personal inability to do something regarded by others as 'simple' can lead to a block or barrier to learning. The nature of the discussion in terms of how to best determine an appropriate level of manipulative skill highlighted the participants' consideration of the pedagogical issues, and that this reflection positively contributed to their confidence to teach the activity in a real classroom situation. This discussion, as well as other discussions, was referred to by the observer in each case as a good example of the:

"…increased awareness of the context and hence the process of learning that results from well-moderated collegial discussion"

(Observer O10P4_G3).

1. **Formative assessments required to identify successful learning or additional interventions necessary to achieve the desired outcomes.**

As part of the preparation necessary for the conduct of each session, the 'teacher/observer' pair identified behaviours that would exemplify the achievement of the defined outcomes for the peer-teaching session. In six of the eight interviews conducted interviewees reported that the initial consideration of:

"…what we were looking for was really hard because we've never done this before."

(SID P4P2W4GGt113)

highlighted the need for more practise at designing formative assessment strategies to match pre-determined student outcomes. In four of the six groups that expressed a similar concern, the nature of formative assessment was subsequently discussed resulting in an acknowledgement that if the learning was to be beyond a surface level, such assessment was essential as part of a teacher's skill set. This excerpt of a lively conversation during small-group interview 5 exemplifies the point:

"Just answering simple questions, or them showing you, or each other, how to do something, or how you could apply it in real life, are examples of formative assessments – I reckon I'll have a column in my lesson plans just for this type of thing so I know what I'm looking for before I move on."

(SID P4P2W4GGt113).

"But that's fine if you can work one-on-one, but what about the rest of the class while you're identifying where Freddy or Mary are at?"

(SID P4P2W4GGt118).

"That's where annotated student work samples and info you can get from just walking around the room comes in – no, I still reckon if the kids know, that you know, what they know, they'll try harder – it's as if you are interested in helping them learn"

(SID P4P2W4GGt113)

2. **Perceptions of the effectiveness of the teaching and the activities explored during the sessions.**

While each of the 'teachers' was familiar with the activities presented to the 'learners', there was an expression of enjoyment and satisfaction with the achievement of the outcomes by both. The 'teachers' identified the specific achievement of the identified outcomes, and the 'learners' stated that they gained in knowledge and understanding after having participated in the activities. The learners particularly acclaimed the hands-on nature of the activities:

> *"It was really fun. We were finding things out for ourselves – things that we sort of had an inkling about, but when we could find answers to our questions ourselves, the learning became meaningful"*
>
> (SID P3P2W2GLt145)

Most of the 'teachers' expressed their increased confidence by stating that they now felt more equipped to prepare and deliver learning experiences based on hands-on activities in small groups with their classes. This was exemplified by SID P4P3W3GGg111 who stated:

> *"… that was fun for me too. To help the learning rather than force content onto kids will be the focus of my teaching. I'm going to start collecting books of experiments – not to use them out of the book, but to work out ways to make them inquiry-based – you know, encourage 'finding-out'."*

Comments made by other 'teacher'-participants pointed to the prescriptive, step-by-step nature of most of the 'experiments' presented in popular text and web-based sources of activities – that is, they pose a question/problem to which some of the learners (and the teacher) already know the answer, or are activities confirming what the teacher has previously explained. Interestingly, comments made by some of the 'learners' put this into context as something that should be considered by a teacher:

> *"yeah, I remember science experiments (at school), we were given sheets and told to follow the steps, and even what to look for. It was boring and a long way from the learner exploring."*
>
> (SID P3P2W2GLt145)

The 'observers' during these interviews stated a belief that both the 'teachers' and 'learners' had benefited from the sessions – the 'teachers' by gaining in confidence through the experience of successful application of learning theories that

> *"… were just theories up until now."*
>
> (SID P3P2W2GLt145)

and the 'learners' by actually having their conceptual understanding developed.

Most of the 'teachers', when asked if they were able to witness how the 'learners' were building their conceptual understanding, responded with affirmative statements exemplified by:

> *"we ('teacher/observer') agree… right?, that we could almost hear the ticking of the brains as they looked for their own meaning of what they observed with the motor they made. Although there were many questions left unanswered, those basic elements were identified successfully – you know, the magnet and the coil interacting to make the rotation, and the attraction and repulsion of the fields. They even stated this when we asked them… right?"*
>
> (SID P4P3W3GLt151)

3. Considered Doubts

Three of the 'teachers' expressed concern about how they could respond to learner questions to which they did not have a prepared answer or background knowledge to answer. Interestingly, in two different interview sessions, the 'learners' offered a strategy that would give the teacher time to find out, and enable further inquiry to occur.

> *"I think if you're unsure about how to answer a student question, respond with 'Good question - I'm not sure of the answer. Let's find the answer together. How do you think we can find out?' – do you think that would work?"*
>
> (SID P3P2W2GLt145)

7.5 SUMMARY AND CONCLUSIONS

The results of the applied analyses provided an insight into the perceptions of pre-service K-6 teachers with respect to the opportunity to practise theoretical elements of teaching, in a small, yet controlled, environment.

7.5.1 Overall Findings of this Phase

The majority of participants identified the Predict-Observe-Explain-Share approach as an effective mechanism to stimulate initial inquiry and promote investigative activities, typical of elements of the ENGAGE phase of the 5Es. It was also recognised that the level of engagement in, and enjoyment gained by, participating was enhanced by ensuring that the phenomena being explored are within the experience of the 'learner' when the 'learner' can see relevance in those phenomena. The peer-interaction aspect in terms of the SHAREing of personal observations and explanations was also recognised as a means to encourage internalisation of negotiated and hence 'owned' understanding, in terms of the use of familiar language and experience. Although tenuous in its presentation, some participants proposed the idea that these factors, when considered together, offer a means to overcome the possible problems associated with the management of several small groups in a classroom. Others were reluctant to accept this premise, although they expressed newly established confidence and a willingness to 'try' the approach with their classes.

Strongly supporting the findings of many other researchers, the nature of the hands-on, inquiry-based activities was acknowledged by representatives of the small-groups, the 'teacher/observer' pairs and 'learners' as a valuable means to initially engage learners and to keep the engagement at a high level. Peer-interaction was also recognised as a means to support the learning as relevant to the learner in terms of the negotiation of meaning and the language being used to describe that meaning.

It is interesting to note that when given the opportunity to select 'exploratory activities', most of the 'teachers' chose those with which they felt most familiar. This observation leads to an interesting and vexing question – how do we get new exploration going in the classroom, elementary as it may be in the process of scientific inquiry, where the teacher is learning with the learner?

Recognising that many K-6 Australian teachers have not formally studied science since Year 10 in secondary school, the adoption of this approach as part of their pre-service education was strongly supported by the participants and exemplified by the comment made by a 'teacher' participant:

> *"I wish we'd done this sort of thing in 2nd year."*
>
> (SID P4P2W4GGt113)

This was in terms of them gaining confidence with the teaching of science; the recognition that it can be presented as a fun 'subject' with relevant to the learner; and the nature of activities that facilitate the building of knowledge and understanding need not be complicated. Significant for acknowledgement of the latter was the opportunity to actually use the equipment and, once the stigma of 'difficulty' or 'complicatedness' associated with its use was diminished, confidence to use it was enhanced. Although the volunteer participants for Component 2 of this Phase probably represented a typical sample of the EDSE213 (n = 80) and EDSE412 (n = 72) 2010 cohorts, it is important to note that the findings have not be generalised due to the relatively small size (EDSE 213 n = 27; (EDSE412 n = 8) and self-selected nature of the sample.

The advantages of the peer-teaching approach were identified as contributing to both the preparation of pre-service teachers to teach inquiry-based approaches to learning, and to the construction and enhancement of student skill, knowledge and understanding.

For the pre-service teachers:

- they gain confidence in small group teaching sessions, where classroom management issues are not contributing to the situation;
- on-the-spot reflection is encouraged and meaningful feedback provided by peers as stakeholders in the learning as to the effectiveness of the strategies being proffered; and
- opportunities are provided for the development of strategies to address student questions in an immediate and non-confronting manner.

Participants identified advantages for the learners as:

- increased motivation due to lowered inhibition to try things in the presence of their peers;
- the barrier that exists between the authoritarian teacher and the passive student is broken down as the learner is the active participant in the investigative and sharing process; and
- Students are given the opportunity to develop and enhance teamwork, collaboration, cooperation and presentation skills as identified by many K-6 syllabi.

The participants perceived two disadvantages to this approach. That more time is needed to prepare engaging activities was countered by the suggestion that once a suite of activities was developed, tried and proven to work, the sequence could be archived and drawn out and used again with a minimum of modification, hence, saving time in the long run. Similarly, the question of classroom management arose when trying to keep several small groups on task in the one classroom space, where each group may be undertaking a different exploration. Contrary arguments were presented that related to the engagement of the learners and it was stated by several participants that if the activities were engaging and the learners collaborating constructively, classroom management issues would be minimised and the teacher would have time to get around to each group regularly.

In précis, analysis of the participant workbooks, small-group, 'teacher' and 'observer' interview transcripts affirms that the peer-learning enquiry-based pedagogy adopted during this Phase develops pre-service science teacher conceptual knowledge and provides a degree of pedagogical experience in a controlled environment.

7.5.2 Recommendations for Future Research

Whilst it is acknowledged that the concepts explored in this project are fundamental, and in the real world context participants saw today's technology as more complicated, it is evident that a fundamental understanding of these concepts is needed to establish foundation for pedagogical practice, and for future learning and exploration of successful approaches to teaching these fundamentals. For example, today's mobile phone batteries have many connections, and each has a different appearance. Adoption of this inquiry-based, hands-on approach may assist teachers when their students ask the question "why?". This premise suggests an avenue of research that further delves into means to further enhance the confidence of learners to ask questions relevant to their experience and inquisitiveness, and to enhance teachers' abilities to facilitate means to find answers to these student questions, through exploratory and inquiry-based approaches.