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IMPROVING THE TRAINING OF PRE-SERVICE PHYSICS TEACHERS IN MALAYSIA USING DIDAKTIK ANALYSIS

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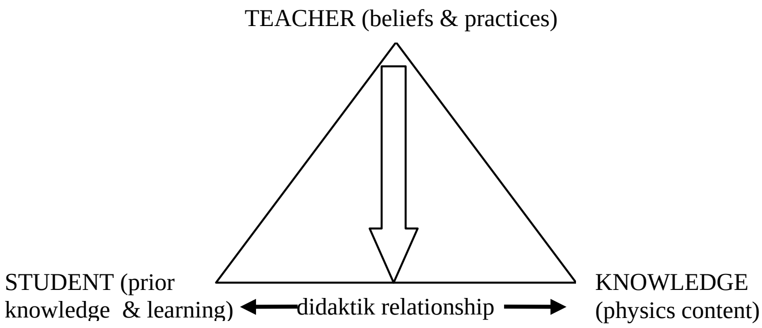

To prepare for my exam in Pedagogy as a student teacher, I read a book by Martin Wagenschein, **The Pedagogical Dimension of Physics**, in which the idea was that physics offers only one facet of the world outside. To learn physics is to reduce the worldview. Physics is a reduced aspect of the world (Reinders Duit, Germany, cited in Fensham, 2004, p. 157).

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ABSTRACT

The research in this thesis examined the use of a didaktik-based approach to thinking about teaching and learning to the training of pre-service physics teachers in a Malaysian teacher training programme. The process of developing a specific content knowledge (*real* or *true* physics) was done through a didaktik analysis of specific physics content, to develop physics content knowledge suitable for schooling, in a particular educational context. Didaktik analysis used as intervention in this study involved: analysing specific physics content as contained in the curriculum specifications and textbooks; analysis of literature on students' alternative conceptions; developing a lesson plan; developing teaching sequences that involve teaching and learning activities, enacting lesson plans and teaching sequence in the microteaching and practicum, and subsequent reflection.

Klafki's (2000) model of didaktik analysis was used as the basis of an intervention employed in a physics teaching methods course (TT4133) at the School of Education, University of Malaysia Sabah (UMS). The intervention consisted of the 14 week course: first seven weeks on theoretical aspects of teaching methods, followed the usual course synopsis, but with modifications in content resulting from didaktik analysis, and the remainder dealt with microteaching; and 8 weeks practicum. To illustrate the use of didaktik analysis in the training programme, the specific physics content in the areas of *force and motion* was provided as an example, showing how this was presented to the pre-service physics teachers in the programme. The researcher began with a conceptual analysis of *force and motion* as presented in the Malaysian secondary physics curriculum specifications and textbooks. This was followed by analysis of the science education literature on students' alternative conceptions involving *force and motion*, analysis of textbooks presentations of *force and motion*, and importantly a synopsis of the history of scientific thinking about *force and motion*. Subsequently, the pre-service teachers were required to prepare lesson plans aided by the researcher based on the above tasks, and this was followed by the development of a teaching sequence which was intended to be implemented in teaching practice with peers (called microteaching in Malaysia), and after further refinement in the practicum in a real classroom (under supervision).

Participants were third year (15 males and 20 females) and fourth year (18 males and 60 females) pre-service physics teachers in their final year of undergraduate studies. The third year cohort consisted of experienced primary school teachers seeking to become secondary school physics teachers via a three-year conversion course. The fourth year cohort had no prior teaching experience, but held degree-level qualifications in physics. Quantitative data were gathered through two tests of conceptual understanding, *The Test of Understanding Graph in Kinematics,* TUG-K and *The Force and Motion Conceptual Evaluation,* FMCE tests, and a purpose-designed instrument the *Beliefs About Physics Teaching,* BAPT questionnaire. Qualitative data were constructed through the inspection of self-written reports about prior physics learning experiences, inspection of assignments on the didaktik analysis of physics, and individual lesson plans. Video recording and field notes made during observations of microteaching and the practicum, examination of 'written reflections' done in the middle of the methods course, during the practicum, and in the final examinations, and interviews and field notes made by the researcher during meetings with the pre-service physics teachers, completed the data corpus.

The research findings indicate that generally both cohorts had difficulty understanding kinematics graphs, and weak conceptual understanding of Newtonian concepts. These findings support the findings from the BAPT questionnaire and interviews, which point to perceptions of lack of ability to teach physics, negative attitudes towards teaching specific physics topics at the secondary level, and overall low physics teaching self-efficacy. Overall the findings from the BAPT questionnaire and interviews, before the intervention based on didaktik analysis of physics suggest that these pre-service physics teachers' attitude toward, and beliefs about, physics teaching were based on career interest in teaching, and not on any intrinsic interest in physics or physics teaching as a profession.

After the didaktik analysis intervention it seems that the pre-service physics teachers' teaching practices were shaped by their beliefs about, and experiences of, the physics teaching methods course generally, and the didaktik analysis experience in particular. Overall, it seems this part of methods course helped to improve pre-service physics teachers' understanding of specific physics content, improved their attitude-toward-physics and teaching, helped them to identify problems with students' learning of physics concepts, and helped their teaching practice, subsequently making them more confident about teaching secondary school physics.

The pre-service physics teachers commented on the value of didaktik analysis and this was evident in the microteaching, but not in lesson plans and teaching sequence used in the practicum. It seems this was as a result of a limited amount and a drive by schools to adhere to curriculum specifications. Overall it seems the introduction of didaktik-based analysis intervention increased participants' confidence to teach secondary school physics and that these pre-service physics teachers have gone some way in developing into reflective practitioners in terms of their experiences of: their own secondary physics learning; their physics methods course, both of which led to a better and deeper understanding of physics and methods course content; and the teaching practices in the microteaching and practicum, both of which gave confidence to teach secondary school physics.

Three recommendations are made from this thesis. First, the introduction of a didaktik analysis-based intervention in physics teaching methods courses such as the one in this study, necessitates identification in advance of pre-service physics teachers' attitude toward, and beliefs about physics teaching, along with their attitude-toward-physics and learning, their physics teaching self-efficacy beliefs, and their conceptual understanding of specific physics content. Second, didaktik analysis involving other specific physics content, with other cohorts of pre-service physics teachers, experienced secondary physics teachers, and physicists, is worthy of consideration. Third, the success of the use of a didaktik-based analysis in a physics teaching methods courses requires scaffolding of the teaching sequences employed, and strong support from associate/mentor teachers during the practicum, if didaktik-based teaching is to be realized in the classroom.

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INTRODUCTION TO THE THESIS

CHAPTER OVERVIEW

This chapter provides an introduction to the thesis. It begins by describing the context and origins of the study, followed by the background to the research. The research questions posed in this thesis are presented next, along with a brief discussion about the focus of the investigation. The rationale for the study is presented next, contextualizing the major features of this research by discussing past and current developments in secondary science education curriculum, and the usual physics teaching methods course at the institution that forms the context for this thesis. Next is a brief description of the limitations of study, along with an outline of the structure of the remainder of the thesis. The chapter ends with a chapter summary.

1.1 CONTEXT AND ORIGINS OF THE STUDY

The context for this study is a secondary teacher education programme in Malaysian higher institutions, specifically the School of Education, University of Malaysia Sabah. The enrolments of pre-service teachers in such science education programmes have increased tremendously in Malaysian public universities recently, and in particular, at the University of Malaysia Sabah. This is due to a government policy that seeks to establish a ratio of science to arts secondary students of 60:40. It also is intended to fulfil one of the nine challenges in Malaysia's Vision 2020 which places emphasis on science and technology, with an overall aim of achieving developed nation status by 2020.

There are two cohorts of pre-service teachers in the science education programme of the School of Education, University of Malaysia Sabah: third years and fourth years. The third years are pre-service teachers who come to the programme with secondary school qualifications (Matriculation or Higher School Certificate), and who were former primary school teachers. These third years are sponsored by the Ministry of Education under a scheme called the *Special Conversion Programme for Non-Graduate Teachers*. Under the Scheme, they are required to enrol in a physics content course as a *minor*, and mathematics as a *major*, a condition imposed by the Ministry because of a teacher shortage for these subjects at secondary school. The third years' entry into science education courses (physics, mathematics, chemistry and biology) is thus based on their science teaching experience at the primary level. A few third years did not actually teach science at primary schools, and had only a general science learning background at the secondary. The second cohort was the fourth years, who also had matriculated or gained Higher School Certificate, but who had learned more science at secondary school (e.g., physics, chemistry & biology).

During their first year at the University of Malaysia Sabah the third years were thus adult trainees and science 'learners'. The fact that their enrolment in science education courses generally, and in the physics education programmes specifically, was compulsory, means that they are not doing such courses by choice. This, along with previous experience as a trainer of teachers, resulted in concerns held by the researcher and his colleagues about the third years' capability and willingness to teach physics. For example, the fact that they were required to study physics and physics education purely to satisfy government rules, might mean they were not particularly positive in terms of attitude-toward physics and learning, and physics teaching. In support of this, feedback from mentor teachers and school principals about previous cohorts of third years, suggest the attitudes and teaching competencies of the third years does seem to negatively influence their practice of teaching physics in secondary schools. Whether this is true or not, the contextual factors described above represent significant challenges for any teacher training programme, and like any pre-service teachers, it is necessary to develop teaching skills before the trainees can enter physics teaching with any confidence of success. A key limitation in training is the limited science content background of pre-service teachers such as these third years. Hence, based on past experience (and an analysis of the literature – see Chapter 2) it seems approaches to teacher training are needed that take into account the pre-service trainees' background, content knowledge, and attitude-toward science and science teaching.

After an extensive review of the literature, the researcher decided to draw upon the notion of *didaktik analysis* as described by Klafki (2000) and Colomb (1999) to inform the training of Malaysian pre-service physics teachers. In general, research suggests that the didaktik analysis is effective in improving the practice of science teaching. For example, Viennot and Rainson (1999) report that their designed teaching sequence (part of the didaktik analysis) took less time than a conventional teaching approach, and resulted in consistent year-on-year improvements, in student learning. Remarkably, Leach and Scott (2002) also report that the time taken for 'staging' the teaching sequence is typically less than that needed in emphasizing the effectiveness of the sequence of teaching activities, and that developing didaktik-based analysis teaching sequences result in consistent improvements in students' learning. In particular, this approach places emphasis on the development of content-specific knowledge for pre-service physics teachers, which as noted above is a key concern. Before going on to explain didaktik analysis, a brief overview of literature about the problems of teaching and learning physics is provided. From this, the importance of science content and its role in science teaching becomes evident.

1.2 BACKGROUND OF THE STUDY

1.2.1 Student Understanding and the Teaching of Science

Research reported in the international science education literature suggests that many students worldwide hold ideas that are contrary to the intended outcomes of school science teaching (Duit, 2004; Duit & Treagust, 2003; Fensham, 2001). These students' science 'alternative conceptions' are reported to be robust and difficult to extinguish through teaching, although a variety of conceptual change approaches have been proposed and evaluated (Duit & Treagust, 2003; Harrison & Treagust, 2000). However, Duit and Treagust (1998) claim that students' conceptual progress towards understanding and learning science concepts and principles, remain limited even after instruction. This is, in many ways, an extraordinary observation, given that there have been literally thousands of studies investigating and attempting to remediate students' alternative conceptions (see, e.g., Duit, 2004).

Wellington and Osborne (2001) comment on the role science teachers can play in mediating secondary school students' conceptions, saying that "as teachers of science … our primary skills lie not in our ability to do science, but in our ability to interpret and convey a complex and fascinating subject" (p. 138). This points to the importance of content, and is in accord with what Fensham has commented on a number of times – the importance of focusing on the content of science (see, e.g., Fensham, 2000, 2001 & 2004). Fensham (2004) argues that one fundamental reason science concepts may be poorly learned is that *the problematic nature of the content itself is often ignored* when trying to develop appropriate pedagogies. In brief, this means teachers seldom think deeply about what content to include, and the relationship between science, as practised and understood by scientists, and what science can and should be taught in the classroom (this issue is developed in more detail below). The content and the relationship between science as practised by scientists and school science as noted here (Driver, Guesne & Tiberghien, 1985; Duit, Niedderer & Schecker, 2007), are related to Shulman's (1987) notion of pedagogical content knowledge (PCK), but differ in detail; specifically in the *emphasis* placed on development of the science content during teaching planning. This is discussed in more detail in Chapter 2.

Fensham (2004) thus emphasizes the need to develop content from the primary source of scientific knowledge such as scientific experts, or scientific publications. Fensham's emphasis is similar to the notion of *didaktik analysis* as described by Klafki (2000). This aspect (scientific experts) is not included in this thesis as the seven weeks allocated for the assignment of didaktik analysis was not adequate for the pre-service teachers to fully utilise all aspects of didaktik analysis as noted by Klafki (2000). Wells (1994) argues that scientific knowledge has four features: generality, systemic organization, conscious awareness, and voluntary control. The first two features are criteria used to determine the concept as 'scientific', and differ from everyday language, as scientific knowledge is both more abstract and more general. The second two features, in contrast, are as seen as more general characteristics of the stage of mental development associated with how scientific knowledge is acquired. The term 'scientific' here has special qualities: rationality, precision, formality, detachment, and objectivity. Such knowledge has been developed in a scientific context which is different from the context of schooling. In other words, teachers may need to look at the original work of the specific content, and consider how to transform this into the intended school science curriculum.

1.2.2 A Didaktik Analysis Approach to Teaching Science

Colomb (1999) describes teaching as a process in which *scientific knowledge* is transformed into *school knowledge* and then into *taught knowledge*, and termed this 'didaktik analysis' (For the case of physics, he would call this the *didaktik of physics* - see Section 2.5.2 & Chapter 3 for more detail). In Colomb's (1999) analysis, physics content is presented in terms of: *school physics*, *formal physics*, *true physics* and *hidden physics*. *School physics* takes into account *formal physics*, that is, the physics contained in the physics syllabus or curriculum specifications (see Section 2.3.1, Table 2.3), *true physics* is physics that is composed of current scientific theory, but recognises the chronology, historical development, and philosophy of specific physics content or theories (see Section 3.2.1) and *hidden physics* is the ontological, conceptual, and epistemological aspects that underpin physics content (see Section 2.3.1, Tables 2.4 (a), (b) & (c)). During teaching the *school knowledge*, *taught knowledge*, and *student knowledge* interacts and these together constitute the *didaktik triangle* (see Section 2.5.1).

A didaktik analysis approach to teacher training as might be expected, differs substantially from more conventional approaches to training, certainly in the case of Malaysia. Traditional pedagogical-based training approaches in Malaysia have sought to equip pre-service teachers with knowledge of a variety of pedagogies, in the hope that such knowledge will allow them once in the classroom to use the approach they think best suited to the content and their students' needs. Didaktik analysis as developed in this thesis is derived from Klafki's (2000) work and here the focus instead is on the *conceptual analysis* of specific science content, analysis of *literature on students' alternative conceptions*, developing *lesson plans*, developing a *teaching sequence*, and *reflections* on these components of didaktik analysis and teaching experiences. Klafki (2000) developed a series of *fundamental questions* concerned with the specific science content - based on the notion that different science content requires different pedagogical strategies in accord with Fensham's (2001) recommendations. So, for example, rather than simply relying on what is offered in textbooks for obtaining content (which may not be suitable for the particular educational context, even if such resources were developed for the school curriculum), according to Klafki the science teacher needs to analyse what options are open to him or her in terms of presenting the 'official curriculum' when choosing school science content for teaching.

1.2.3 Treating Science Content as 'Problematic'

To say a teacher should treat science content as problematic, does not mean that students find the content itself difficult (i.e., they struggle to understand, say mechanics), but instead refers to the relationship between science as viewed by practising scientists, and what the teacher presents in the classroom; what we might call 'school science' (Gravemeijer & Terwel, 2000; Lijnse, 1995; Tiberghien, 1994). According to White (1994), there are a number of reasons why the character of the content of school science can influence teaching. For example, science is often abstract and complex, meaning it is outside the students' normal experiences. Similarly, science tries to provide alternative models of good explanatory power whereas students are typically satisfied by one 'correct solution'. Other issues identified include the presence of confusion between common words and scientific terms. As an illustration of how such things might influence school learning, many student alternative conceptions in mechanics are derived from students' interpretation of their common everyday experiences (Fensham, Gunstone & White, 1994). For example,

- The problem of distinguishing between points of time and time intervals which relates to the concepts of instantaneous velocity and acceleration: "if the velocity is zero, there can be no acceleration".

- The misunderstanding that ‘action’ and ‘reaction’ refer to the same body (thus students believe that in order to cause motion, ‘action’ must be stronger than ‘reaction’).

(Duit, Niedderer & Schecker, 2007, p. 616)

1.3 RESEARCH QUESTIONS

The research in this thesis is based on the notion of didaktik analysis that has been practiced in Central and Northern European countries for many years. The researcher sought to identify to what extent didaktik analysis might help improve the training of pre-service physics teachers in Malaysia, particularly those with limited physics content knowledge. Therefore, the research questions for this thesis are:

1. What effect does the incorporation of a unit of work based on didaktik analysis into a pre-service Malaysian teacher education training programme have on pre-service teachers’ beliefs?

   a. What beliefs about physics and teaching physics do pre-service physics teachers possess prior to their commencement in a pre-service teacher education training programme?, and

   b. What effect does exposure to didaktik analysis have on pre-service physics teachers’ beliefs and teaching practices in terms of their personal content knowledge and pedagogical content knowledge?

2. What factors didaktik analysis experience from assignments, microteaching, and practicum influence their effectiveness in terms of improving the practice of teaching for Malaysian pre-service physics teachers?

3. To what extent does didaktik analysis help the pre-service physics teachers engage in reflection on teaching and learning? To what extent do pre-service physics teachers undertake reflection on teaching and learning associated with the didaktik analysis experience?

4. What is the ability for pre-service physics teachers to develop a teaching sequence based on didaktik analysis and enacted for other physics content areas by the pre-service physics teachers during their microteaching and practicum?

   a. How successful were pre-service physics teachers in implementing a teaching sequence based on didaktik analysis in their microteaching and practicum?

   b. What factors inhibit or facilitate the use of didaktik analysis in a teaching sequence in their microteaching and practicum?

This research reported in this thesis was carried out at the University of Malaysia Sabah and in selected secondary schools in Sabah province. The researcher taught a physics teaching methods course (code TT4133), commencing December 2005 and ending March 2006. This course is that offered to pre-service physics teachers in the final year of their science education programme, and involves three contact hours a week. In stage one of the study, the researcher followed the usual course synopsis, but included modifications involving the use of didaktik analysis.

To illustrate the use of didaktik analysis in the training programme, the specific physics content in the areas of *force and motion* is provided as an example, showing how this was presented to the pre-service physics teachers in the programme (see Chapter 6). The researcher began with a conceptual analysis of the content to be taught (e.g., as presented in the Malaysian secondary physics curriculum specifications and textbooks). This was followed by analysis of the science education literature on students' alternative conceptions involving force and motion, analysis of textbooks presentations of force and motion, and importantly *a synopsis of the history of scientific thinking about force and motion*. These analyses together lead the researcher to identify a marked difference between scientific knowledge and school science curriculum (Gravemeijer & Terwel, 2000; Lijnse, 1995; Tiberghien, 1994). Subsequently, the pre-service teachers were required to prepare *lesson planning* (see Section 2.3.2) aided by the researcher based on the above tasks, and this was followed by the development of a *teaching sequence* (see Section 2.3.3) which was intended to be implemented in teaching practice with peers (called microteaching in Malaysia), and after further refinement in the practicum in a real classroom (under supervision).

Stage two of the study, which occurred during the eight weeks of the teaching practicum (including the three week school term break), was used to help the pre-service physics teachers employ their experience of didaktik analysis in their classrooms.

During the course the researcher also administered a questionnaire on teaching attitudes and perceptions of competency, along with two tests of conceptual understanding for two physics content areas: *The Test of Understanding Graph in Kinematics* (TUG-K) (Beichner, 1994) and *The Force and Motion Conceptual Evaluation* (FMCE) (Thornton & Sokoloff, 1998). The aim of the two tests was to evaluate the conceptual understanding of the pre-service physics teachers, and their knowledge of specific physics content. Other data obtained came from examination of documents such as group assignments of didaktik analysis and lesson plans, observations of microteaching, selected items from the normal course evaluations, selected items from the final examinations for the course, and focus group interviews.

During the eight weeks of the practicum, the researcher also conducted classroom observations at selected secondary schools in which the pre-service physics teachers were placed. The pre-service physics teachers were observed, their lesson plans and teaching sequences investigated by the researcher, with an overall intent of seeing whether or not their teaching was in fact based on the didaktik analysis. After each classroom observation, the researcher conducted interviews with three Form 4 physics students (Year 10 students about 16 years old), and the pre-service physics teachers. During the first half of the school practicum, the pre-service teachers were again interviewed after they returned to the University to do their reflection. The intervention is described in detail in Chapter 6.

1.4 RATIONALE FOR THE STUDY

This study seeks to make a substantial and original contribution to the science education literature of non Northern European countries, and specifically to the literature on pre-service physics teacher education, by trialling and evaluating the use of didaktik analysis for the training of pre-service physics teachers in Malaysia. Several reasons for the use of didaktik analysis in secondary science teacher education have been argued above. The following sections elaborate on some factors that make this study significant for teacher education programmes.

The major feature of this research is the use of the didaktik analysis of physics in a pre-service teacher training programme. Utilizing didaktik analysis in this study has implications for pre-service physics teachers involved in the teaching and learning during their school practicum (Fensham, 2004). Mastering specific physics content is seen as crucial and influential in teaching attitudes and competency (Barros & Elia, 1998). In addition, differences in pre-service teachers' knowledge of physics content may influence the nature of didaktik analysis produced, as teaching sequences and activities differ depending on content (Gunstone & White, 1998). Additionally, if their physics knowledge differs for specific content, it is difficult for them to apply a specific pedagogical strategy for *specific* content. Therefore, pre-service physics teachers' perceptions or views of didaktik analysis needed to be considered, so that any difficulties or problems in the practice of teaching and learning might be identified and addressed.

A key contextual feature that may influence this work is a shift in the medium of instruction from Malay to English for both primary and secondary school science and mathematics teaching. This occurred in 2003 and clearly under such circumstances, the linguistic ability of the teacher becomes critical in terms of whether or not science and mathematics teaching in English is implemented successfully. A particular factor here is that the pre-service teachers' own learning experiences at the secondary and tertiary levels were in Malay. This change to English as the medium of instruction was phased in beginning with pupils in Year 3 (primary school) and students in Year 7 or Form 1 (secondary school) with other school curricula initially remaining in the Malay language. At the beginning of 2006, Year 10 or Form 4 physics curriculum was taught in English for the first time. At the time of writing, nearly three years have passed since the delivery of science and mathematics in English first started. The inclusion of didaktik analysis in the physics teaching methods course to the pre-service physics teachers might also then be influenced by the impact of using English as a medium of instruction.

In summary, the research presented in this thesis seeks to develop an understanding of the use of didaktik analysis for Malaysian pre-service teachers for school physics, and a key feature of this process is to aid the transformation of scientific knowledge or authentic science to school science, in a way that is cognisant of the particular learning context, and that can facilitate better learning. Specifically, didaktik analysis as used in this study is concerned with pre-service physics teachers' preparation of their lessons for teaching physics: analysing specific physics content as contained in the curriculum specifications and textbooks, and identifying any differences between scientific knowledge and everyday knowledge; analysis of the literature on students' alternative conceptions; developing a lesson plan; developing teaching sequences (which are part of the lesson plan) that involve teaching and learning activities, and finally reflection on their assignment of didaktik analysis and teaching experiences. A detailed example of these didaktik analysis components is provided in Chapters 2 and 3 along with a detailed account of the notions of both didaktik analysis and didaktik of physics.

1.5 LIMITATIONS OF THE STUDY

The limitations of the study and the measures taken to address these for the research methodology are presented in Chapter 5. However, a feature of didaktik analysis is to identify research limitations in advance, and subsequently reflect on limitations that evolve during the study. Consistent with this approach, here the researcher describes unavoidable constraints anticipated in advance of the study. This included constraints with respect to costs, time, and human resources. It also is considered unlikely that any intervention can address all aspects of didaktik analysis as noted by Klafki (2000). Therefore, the intervention was restricted to the improvement of the conceptual analysis of science content by the pre-service physics teachers, developing lesson plans, teaching sequences and activities, and the experience of pre-service physics teachers in the teaching and learning of physics during their microteaching and in the practicum. It is also evident that the eight weeks allocated for the practicum is probably not adequate for the pre-service physics teachers to fully utilise didaktik analysis. During this time the schools involved in the practicum would be busy with a number of activities, such as revising and preparing for mid-year term examinations.

Other issues identified include the fact that some of the pre-service physics teachers involved in the study took a physics course (mechanics) in their first year of study in which the researcher was the teacher. Thus, the pre-service physics teachers were known to the researcher, and it is possible that some volunteered to participate in the study out of some sense of personal commitment. Another issue is that during the intervention the participants in the teaching physics methods course may have realised that the researcher is, in fact, he who taught the course previously. This may mean some of the participants tried to make a 'good impression' on the researcher rather than reveal their own thoughts during say the focus group interviews. The researcher was conscious of these potential threats and all possible efforts were made to minimise bias in this study (see research methodology, Chapter 5).

1.6 THE STRUCTURE OF THE THESIS

This thesis is organized into nine chapters. Each chapter begins with a chapter overview, in order to help readers understand the flow of ideas presented. A brief outline of each chapter follows:

Chapter 1: Introduction to the Thesis, presents the context and origins of the study - setting out the reasons why this study is currently the focus of the researcher's attention and interest.

Chapter 2: Literature Review–Pedagogy and Didaktik Approaches to the Teaching and Learning of Science, provides an overview of the conceptual framework that guided the research study, and presents a review of literature on didaktik analysis. An overview of the literature of the traditional teaching approaches is compared with approaches to didaktik-based analysis teaching practice. A related component in didaktik analysis includes teaching and learning approaches, and science content is discussed. This review also presents a brief discussion of didaktik and pedagogy. A delineation between didaktik and pedagogy is teased out here.

Chapter 3: Didaktik of Physics, presents the definitions of a subject 'didaktik', that is, the analysis and mapping of the different ways pre-service teachers experience and conceptualize various physics content areas in terms of how *specific physics content* is taught and learned.

Chapter 4: Theoretical Underpinnings of the Thesis, presents a teaching dimension, a learning dimension, and a personal dimension, other than physics dimension presented in Chapter 3, which form the research dimension in Chapter 5, that together form the theoretical underpinnings for the thesis.

Chapter 5: Research Methodology, presents discussion of the main educational research paradigms, the research methodology adopted in the thesis, a discussion of quantitative and qualitative research methods, and details the steps taken to minimize the threats to objectivity and to enhance credibility, transferability, dependability, confirmability, subjectivity, trustworthiness and authenticity, and triangulation. The chapter concludes with a consideration of the ethical issues associated with this work.

Chapter 6: Research Findings and Discussion on Beliefs About Physics Teaching, presents the results about establishing the pre-service physics teachers' beliefs in terms of their learning experiences prior to the intervention, and the effect of didaktik analysis experience after the intervention in terms of their physics teaching self-efficacy beliefs and attitude-towards-physics teaching.

Chapter 7: Research Findings and Discussions on Didaktik Analysis and Reflections, discusses the findings about factors didaktik analysis experience from assignments, microteaching, and practicum influencing the effectiveness of didaktik analysis in terms of improving the practice of teaching, and the ability of pre-service physics teachers to engage in reflections on their didaktik analysis, microteaching, and practicum.

Chapter 8: Research Findings on Pre-Service Teachers Teaching Experiences, presents the findings of the use of didaktik analysis in teaching sequence from observation for the pre-service physics teachers during their microteaching and practicum.

Chapter 9: Discussions, Conclusions, Reflections and Recommendations, summarises the methodology of the study, makes conclusions derived from the research findings, reflects upon the implications of the findings for teaching and learning. It also revisits the limitations of the study, and makes recommendations for further research.

1.7 CHAPTER SUMMARY

This chapter has presented an introduction and rationale for the thesis. In summary, the researcher proposes that we need to consider a new approach to the training of pre-service physics teachers. There are two approaches that might usefully be considered; the traditional pedagogical approach, and the didaktik approach, in particular *didaktik analysis* which sees science content as a key factor for consideration. The next chapter present a review of literature about these two approaches, and considers how they might inform the research undertaken in this thesis.

CHAPTER 2

LITERATURE REVIEW: PEDAGOGY AND DIDAKTIK APPROACHES TO THE TEACHING AND LEARNING OF SCIENCE

CHAPTER OVERVIEW

The previous chapter highlighted some problems associated with teaching and learning of secondary school physics, and the implications for pre-service teacher training. The proposition here is that if we wish to address the numerous and widely reported problems associated with physics teaching and learning we need to draw upon literature reports of research into the teaching and learning of physics. Furthermore, the researcher proposed that we need to maintain an open mind and consider alternatives to what can be termed the traditional approach which emphasizes pedagogy (strategies of instruction) in Malaysia, and which lies within what might be called 'the curriculum tradition'. This chapter seeks out relevant literature to consider how we might enhance the training of pre-service physics teachers, and is in six sections. Section 2.1 presents an overview of the conceptual frameworks for the thesis. This then sets out the scene for the literature review and its connection with the theoretical underpinnings in the thesis; as we shall see the theoretical underpinnings and the literature review are intertwined. Section 2.2 presents an overview of the literature on two traditions, the curriculum tradition and the didaktik tradition, and a review of the use of didaktik analysis within the didaktik tradition. Section 2.3 focuses on a model of didaktik analysis, that of Klafki (2000), and specifically considers how the content of physics should be taught. Section 2.4 compares a didaktik analysis-based approach to teacher training with a pedagogy-based approach. Section 2.5 discusses the nature of didaktik analysis, and shows how this leads an approach specific to a particular content of knowledge – here termed the *didaktik of physics*. The chapter concludes by considering how the literature described here informed the research undertaken in this thesis.

2.1 OVERVIEW OF THE CONCEPTUAL FRAMEWORK FOR THE THESIS

Zevenbergen and Begg (1999) state that a conceptual framework for an educational inquiry is a skeletal structure of justification, rather than a skeletal structure of explanation, and that it is based on formal theory or accumulated experience or practice. Zevenbergen and Begg add that conceptual frameworks are based on previous research and the literature. A conceptual framework is an argument involving different points of view, culminating in a series of reasons for adopting some points, ideas or concepts. It is also used as a guide to review the literature to collect data, and ways in which the data might be analysed and explained. Miles (1994) defines a conceptual framework as the factors, constructs or variables being studied, and their presumed relationships. Thus, the conceptual framework of didaktik analysis is presented in this chapter, and is used to inform the next three chapters. It includes: analyses of previous research on teacher training; perspectives of the pedagogy approach and the didaktik approach; didaktik of physics; the concepts and processes of research design, methods and procedures used in preparing to conduct this study; in collecting data; and in organizing, analysing, and synthesizing the data. Based on these accounts, the conceptual framework for this study is illustrated in the form of a flowchart as shown in Figure 2.1. The remainder of this chapter deals with the first part of the conceptual framework, the review of related literature.

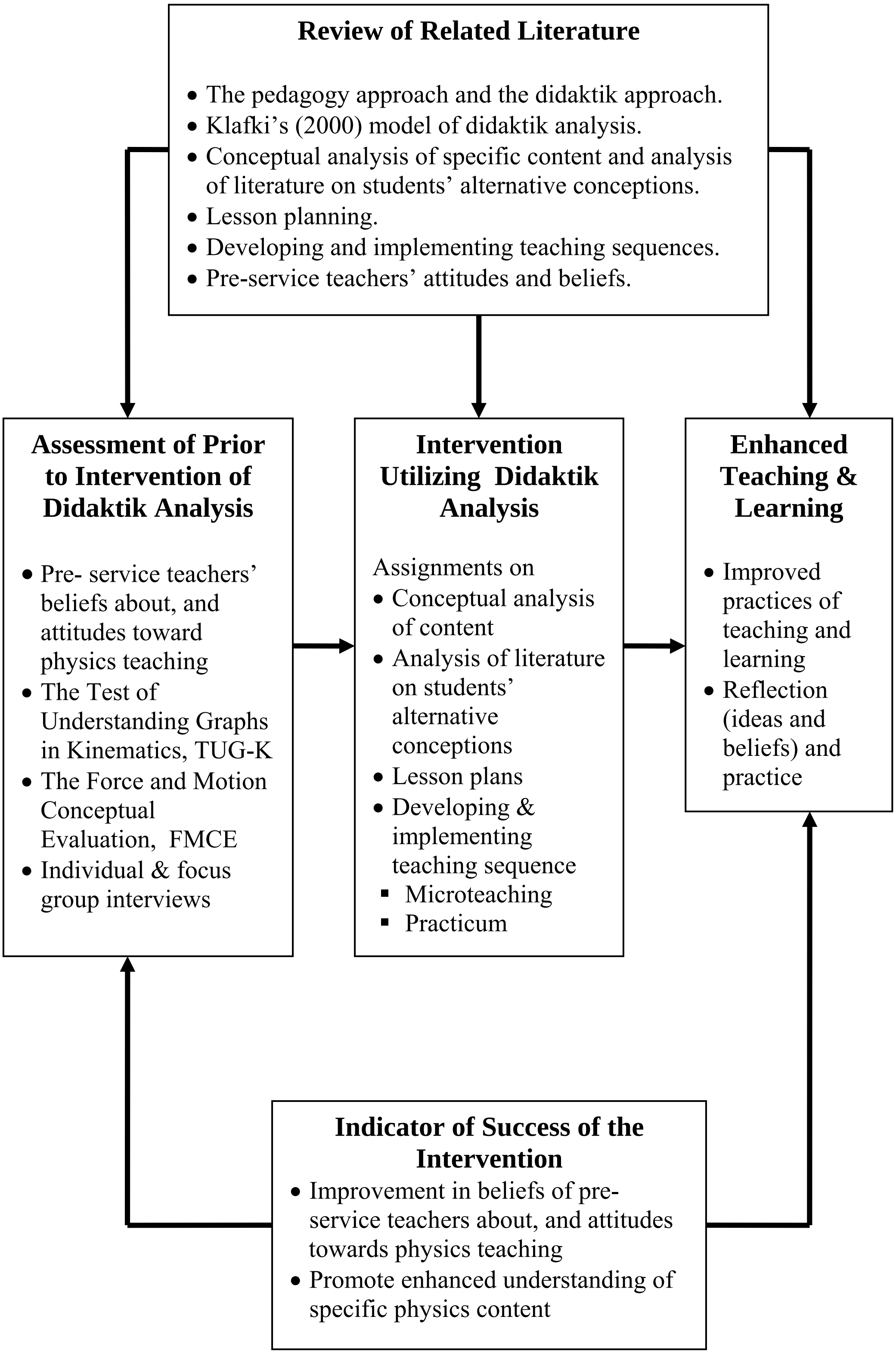


Figure 2.1
Conceptual framework for the thesis

2.2 TEACHER EDUCATION IN THE CURRICULUM TRADITION AND THE DIDAKTIK TRADITION

Before we consider didaktik analysis and how it might impact upon teacher training, we need to consider the underlying 'traditions' that form the basis of a pedagogical approach in comparison to the didaktik approach to teacher training. The origins of teacher training approaches are related to the conduct of science research and educational research which are two distinct fields, and that are typically viewed from different perspectives (Fensham, 2004). Fensham says that the researcher in science research needs a deep understanding of a specific area of natural science. A parallel assumption for science education research requires different things. Researchers need to have *a level of scientific knowledge*, a capacity for *asking of distinctive questions*, knowledge of *conceptual and theoretical development*, and understanding of *research methodologies*, and of student *progression in learning*. In other words, to become a researcher in science education requires much more than knowledge of science (Fensham, 2004). However, according to Fensham many of these criteria are absent in the curriculum tradition used as the basis of pedagogy driven teacher training. The German didaktik tradition of how to do educational research in general and teacher training in particular – often described as a 'well-kept secret' (Fensham, 2004; Kansanen & Meri, 1999; van Dijk & Kattmann, 2007) differs in important ways.

Westbury (2000) details a comparison of core assumptions for the curriculum and didaktik traditions (see Table 2.1), and only didaktik analysis is described throughout this thesis as it is relevant to the study. Teaching in the curriculum tradition is perceived as delivering content coverage, and teaching methods are seen as consisting of the teacher providing content and guiding the student. The teacher prescribes and directly controls routine classroom work. Here, the role of the teacher is to implement the educational system's curricula in a relatively mechanical fashion. This is the case, for example, in Malaysia, where the teacher is accountable for implementing a syllabus and curriculum specifications provided by the Curriculum Development Centre (CDC). Teachers in the curriculum tradition are thus controlled (in the sense of following the curriculum specifcations), and their professionalism consists of contested aspiration through being 'trained' and 'certified', and 're-trained' usually 'in-service' (Hudson, 2002). Hudson (2002) suggests that Shulman's (1987) critique of lesson-related instructional theory is too limited for a research-based professional practice.

In contrast, in the didaktik tradition teachers are *licensed* as a self-determining professional in that their work is based on an expectation of autonomy of practice, self-discipline and peer review. Teaching in the didaktik tradition, a teacher does not begin by asking how a student learns, or what student should be able to do or know. Rather a teacher asks what it (specific content knowledge) can and should signify to the student, how students themselves can experience this significance.

Table 2.1
Comparison of the curriculum tradition and the didaktik tradition
(from Westbury, 2000, pp. 18)

Level	Curriculum	Didaktik
1. Lesson Planning		
• core question	• how?	• what and why?
• content as	• object	• example
• aims as	• task	• goal (direction)
• lesson plan as	• a course of action	• frames of reference
• teaching as	• enactment	• licensed
2. Research		
• focus	• individual teacher • teacher thinking (interpretative)	• art of teaching, • didaktik analysis (hermeneutic)
• assessment of successful teaching	• student achievement (score and standing)	• professional appropriateness, reflection
3. Theory		
• function	• preparation	• initiation
• sequence	• subject matter comes first	• *Bildung* (formation) comes first

To illustrate differences between the curriculum tradition and the didaktik tradition, consider the Malaysian education system as an example (see Table 2.2). Key differences are in terms of curricula content and teaching in a particular educational context. In the curriculum tradition, the Malaysian Curriculum Development Centre (CDC), the Malaysian authority responsible for providing the particular content for learning, decides the curriculum specifications and syllabus (Kementerian Pendidikan Malaysia, 2001). The content is to be taught by a subject teacher to the learners using appropriate pedagogical strategies that the teacher develops. The Malaysian Federal Inspectorate of Schools through its Science Unit is responsible for the supervision of the teaching and learning process of science at the school level.

In the didaktik tradition, according to Fensham (2004) the purposes of schooling and disciplinary sciences as knowledge sources are determined by the system (the authority body). So here using the purposes and disciplinary science as *guidelines*, the *teacher* would determine the science content knowledge to be taught (Hudson, 2002). The process of developing the school science to be taught is called *didaktik analysis*. The teacher is responsible for this didaktik analysis, and developing the knowledge termed *school science*.

Table 2.2
Responsibilities for curricular content and teaching using Malaysian as an example
(from Fensham, 2004, pp.149)

Education System in the Curriculum Tradition	Education System in the Didaktik Tradition	
Malaysian Curriculum Development Centre	*Purposes of Schooling*	*Disciplinary Science Knowledge Sources*
Detailed Science Content to be taught		
Teacher	Teacher	
Appropriate Pedagogy	*Didaktik Analysis*	
Learners	Knowledge for School Science	
	Appropriate Pedagogy	
	Learners	

A more detailed description of the two approaches; the pedagogy approach based within the curriculum tradition and the didaktik approach is provided in Section 2.4. The following section presents in detail the process of didaktik analysis which involves consideration of: before teaching activities (conceptual analysis, analysing of literature on students' alternative conceptions, lesson plans, and developing teaching sequences); during teaching activities (implementing teaching sequences); and, after teaching activities (reflection). This description and model of didaktik analysis is based on a model proposed by Klafki (2000).

2.3 KLAFKI'S (2000) MODELS OF DIDAKTIK ANALYSIS

There are a number of models of didaktik analysis reported in the literature. Each model seeks to draw upon the epistemological assumptions and presuppositions of didaktik analysis described in Section 2.5. However, by far the most commonly used model is that based on Klafki's (2000) model of didaktik analysis, and this is now described, along with examples of the application of this model in a conceptual analysis of specific content through curriculum specifications and textbooks, analysis of literature on students' alternative conceptions, lesson plans, teaching sequence, and reflection.

Klafki's (2000) model of didaktik analysis is now widely used in teacher education in Central and Northern European countries, and as noted in Chapter 1, a key feature is to treat the science content as 'problematic', and to develop a specific content knowledge in physics. It also is used to develop appropriate pedagogies, and subsequently use these in the classroom in order to address students' alternative conceptions. Historically, Gundem (2000) notes that the model was used as a tool for preparing and planning classroom teaching, and lesson evaluation. Emphasis is placed upon meaning and intentionality or purpose. Colomb (1999) reports that didaktik analysis strives to help pre-service teachers foresee the 'moment in the future'. In other words, pre-service teachers should be able to anticipate what is going to happen in the classroom. This is not at all meant to downgrade pre-service teachers' limited experience in the classroom, but only serves to emphasize the importance of reflections or thinking critically about planning (their ideas and beliefs). Klafki's (2000) model of didaktik analysis can be summarised as:

- What is to be taught and learned? (the content aspect)
- How is content to be taught and learned? (the method aspect), and
- Why is content to be taught and learned? (the goal/aims aspect).

(Gundem, 2000; Kunzli & Kruger, 2000)

As it is believed that different science content requires different pedagogical strategies in didaktik analysis, then didaktik analysis of physics (based on Colomb's (1999) definition on didaktik of a discipline – see Section 2.5.2 and Chapter 3) is defined as the analysis of, and theorizing about, the phenomena of teaching and learning that are specific to the particular physics content knowledge, to be taught (Tochon, 1999). The origins of school physics knowledge are highly diverse from one content specific to another content specific areas, and are extremely abstract and idealised (Duit, Niedderer & Schecker, 2007). Thus, each content area needs to be transformed in order to become 'teachable' through the didaktik analysis of physics.

Klafki's (2000) model of didaktik analysis poses five 'sets of questions' to be used in pre-service teacher courses, as a guideline for preparing lesson plans concerned with specific science content. Hudson (2002) notes that the five 'sets of questions' used to prepare for teaching are not a technical, but rather an interpretative issue (i.e., an issue to be considered in the light of a pedagogical situation). In addition, Gudmundsdottir, Reinertsen and Nordtømme (2000) suggest that the five 'sets of questions' also can be used as a research instrument to elicit teachers' explanations for what they have done and why. However, reflection on the five 'sets of questions' in terms of the interactive relationship between theory and practice, and the interplay between experience and reflection, should inform decision for planning teaching, and studying/learning. The five 'sets of questions' are:

I. What wider or general sense or reality does this content exemplify and open up to the learner? What basic phenomenon or fundamental principle, what law, criterion, problem, method, technique or attitude can be grasped by dealing with this content as an 'example'?

II. What significance does the content in question or the experience, knowledge, ability or skill to be acquired through this topic already possess in the minds of the children in *my* class? What significance should it have from a pedagogical point of view?

III. What constitutes the topic's significance for the students' future?

IV. How is the content structured?

V. What are the special cases, phenomena, situations, experiments, persons, elements of aesthetic experience, and so forth, in terms of which the structure of the content in question can become interesting, stimulating, approachable, conceivable, vivid for the students of the stage of development of this class?

(Klafki, 2000, p. 151)

The first three 'set of questions' establishes the significance of the content, the importance of the content in shaping students' past, present and future experiences, and the structure of the content (Duit, Niedderer & Schecker, 2007; Fensham, 2004; Vasquez-Levy, 2002). Klafki (2000) stresses that questions one and two should not only be seen as schooling or education for acquiring knowledge, skills and attitudes; but the 'world of the mind', the habits of the students as a whole. Within this mental world, a school should be understood as a place of clarification, purification, consolidation, expansion, and stimulus. Thus, students' learning in school will involve lively activities and be related to everyday applications. According to Fensham (2004), questions one and two emphasize the importance of students' prior ideas. Therefore, it is important that the researcher utilises findings from literature about students' alternative conceptions when analysing specific science content. Question three requires the teacher to try to anticipate the students' future, and consider what might affect them as adults. A series of questions the teacher can ask is:

i. Does this content play a vital role in the intellectual life of the adolescents and adults the children will become, or is there justification to assume that it will, or should, play such a role?
ii. Are the students already aware of the content's relevance to the future?
iii. Can it be made clear to them or is it so difficult to understand that it cannot be explained to the students?

Question four requires teachers to undertake a close examination of the structure of content and consider the exemplary value of the content, meaning how to use content from everyday life to illustrate the teaching of physics content (Vasquez-Levy, 2002). According to Klafki (2000, p. 153-155), the basic questions about the structure of particular content can be broken down to:

- What are the individual elements of the content as a meaningful whole?
- How are these individual elements related?
    a. Do they form a logically obvious series? In this case a certain order of logical steps must be adhered to, or
    b. Do they form an interdependent structure, where all or some elements are interrelated, so that the order in which they are examined is not necessarily given by logic.
- Is the content layered? Does it have different layers of meaning and significance? In the case of a reading text, either a complete text or an extract, this would involve:
    a. the layer of the narrated events and actions
    b. the layer of inner experiences of the protagonists not expressly described
    c. the possible symbolic meaning of the phenomena and relations ascertained in the first and second layers, and
    d. Can the layers first be understood in relative independence of each other, or is knowledge of one layer a pre-requisite for the understanding of another?
- What is the wider context of this content? What must have preceded it?
- What peculiarities of the content will presumably make access to the subject difficult for the children?, and
- What is the body of knowledge which must be retained (minimum knowledge) if the content determined by these questions is to be considered acquired, as a vital, working human possession?

According to Klafki (2000, p. 155), the fifth (last) 'set of questions' considers the form in which the content will be presented and made available to students, and this can be developed in three ways (Vasquez-Levy, 2002):

i. What facts or states of affairs, phenomena, situations, experiments, controversies, and so forth that can be employed to make the content accessible, interesting, and comprehensible. In other words, what experiences are appropriate for exciting the pupils' minds interest in, and a positive attitude toward, and developing questions oriented to deciphering the structure of the given problem?

ii. What pictures, hints, situations, observations, stories, experiments, models, and so on, are appropriate in helping students to answer, as independently as possible, their questions directed at the essentials of the matter?

iii. What situations and tasks are appropriate for helping the principle of content grasped by means of an example of an elementary case, become of real benefit to students, helping to consolidate it by application and practice (inherent repetition)?

Although the application of didaktik analysis covers a wide range of aspects of teacher education, as noted in Chapter 1 the researcher here focused only on one aspect; that is, how is content to be taught and learned? Having outlined the guidelines (Klafki, 2000) and teaching sequence (Leach & Scott, 2002), the framework or structure that forms the didaktik analysis which supports this study is now presented. The researcher here develops an account of didaktik analysis that aims to improve the practice of physics teaching in the classroom (Duit, Niedderer & Schecker, 2007).

As noted earlier, again the process of developing didaktik analysis thus involves analysing specific science content (Duit, Niedderer & Schecker, 2007; Leach & Scott, 2002; Marton & Ramsden, 1988; Tochon, 1999), identifying students' alternative conceptions (Halloun, 1998; Wandersee, Mintzes & Novak, 1994), preparing lesson plans (Gudmundsdottir, Reinertsen & Nordtømme, 2000; Roth, 2000), developing teaching sequences (Buty, Tiberghien & Maréchal, 2004; Leach & Scott, 2002; Lijnse, 2000; Mėheut & Psillos, 2004; Tiberghien, 2000); and subsequent reflection on teaching (Barros & Elia, 1998; Gunstone & White, 1998).

A sample account of the researcher's didaktik analysis for Newton's third law, together with a brief conceptual analysis of content, analysis of textbooks and analysis of literature on students' alternative conceptions is shown in Section 2.3.1. Part of this didaktik analysis involves preparing a lesson plan by analysing the content of teaching, and this is discussed in Section 2.3.2. Another part of didaktik analysis involves developing (the development of) a teaching sequence (that is subsumed in the lesson plan), and this is presented in Section 2.3.3. Conceptual analysis of force and motion in general, is discussed in Section 3.2, Chapter 3. Following is a sample account of the didaktik analysis of Newton's third law that is the process of developing didaktik analysis.

2.3.1 Didaktik Analysis of Newton's Third Law

Conceptual Analysis of Content: A review of literature shows that the researcher's conceptual analysis of content is similar to the concept of *didactical transposition* (cited in Tiberghien, 2000), *elementarization* (Duit, Niedderer & Schecker, 2007), and *learning demand* (Leach & Scott, 2002). According to Leach and Scott (2000), the learning demand describes the differences between everyday and scientific ways of thinking about the world. The learning demand is associated with differences of conceptual tools used, differences which relate to the basic assumptions about the nature of the world (ontological assumptions), and differences related to the nature of the knowledge being used (epistemological assumptions). As learning demand relates to an analysis of science content, thus the differences between everyday and scientififc ways of thinking about the world can be identified. For example, the ontological assumptions for 'force and motion' are: physical objects are categorized as animate and inanimate; physical objects have properties; and force is a property of animate and inanimate objects, and epistemological assumptions for this area include:

i. A physical object in motion or at rest can be studied using a particle model

ii. The particle model refers to a physical object the internal structure of which can be ignored when it is in 'translation' without rotation or precession, in specific reference system

iii. The content of a particle model consists of a single, dimensionless object: a particle

iv. The environment of a particle model consists of agents representing physical entities outside its physical object that interact with entities inside (no entities within, for example, a force acts on objects rather than being contained within objects)

v. There are two types of agents: interaction at a distance, and contact interaction

vi. A particle model has features that can be intrinsic or state properties

vii. A particle model has only one intrinsic property: the mass of an object

viii. A state of a particle model represents a physical property that can vary in time. State properties are the kinematical properties of the object: position, displacement, velocity, acceleration, and

ix. There are two particle models relevant in the study.

Gundem (2000) also provides some criteria to be included in conceptual analysis of specific science content. The criteria are:

- The historical background of mechanics (discipline) and physics (school subject), and only this criterion is discussed in this thesis for Newton's third law (see Section 3.2.1)
- Changes to the content, structure and scope of the school subject
- The contemporary value of the school subject
- The role of the school subject in the overall programme of schooling
- The nature and structure of the discipline related to the transformation process from scientific discipline to school subject, including phenomena like representation, selection and adaptations, and
- Issues concerned with instruction and evaluation.

Based on these guidelines, a conceptual analysis of content based on the Malaysian Form 4 Physics Curriculum Specifications provided by the Malaysian Curriculum Development Centre, and Form 4 physics textbooks follows. The researcher selected the topic of mechanics as it is a basic and essential pre-requisite for much other physics content. Taking Newton's third law as an example, here didaktik analysis involves: conceptual analysis of the Form 4 Physics Curriculum Specifications, analysis of textbooks, analysis of literature on students' alternative conceptions, and developing and implementing teaching sequences. This didaktik analysis seeks to provide insights into the didaktik analysis process that can be utilised for teaching other content areas.

The science education literature suggests that Newton's third law of motion is not easy to teach and to learn (Duit, 2004; Duit, Niedderer & Schecker, 2007). Some researchers suggest it should be introduced much earlier than Newton's first and second laws in the teaching of dynamics (e.g., Savinainen, Scott & Viiri, 2005). For example, consider forces in equilibrium. Apart from a no-force situation, all equilibrium situations (i.e., no acceleration or constant velocity) involve more than one force. Such forces are less complex, because they have no changes associated with them. Savinainen, Scott and Viiri (2005) argue that Newton's third law is a crucial feature of the force concept. However, Newton's third law in the Form 4 Malaysian physics curriculum specifications is introduced towards the end of the topic 'force and motion', as shown in Table 2.3.

Table 2.3
Learning outcomes and suggested learning activities in the areas of 'force and motion'
(Kementerian Pendidikan Malaysia, 2001)

Learning outcomes	Suggested learning activities
To analyse the balanced force	
Level 1	
• To explain the ideas of balanced force with examples • To explain the balanced force	To make observations and discussions of forces in equilibrium including weight and reaction force. Note: Newton's third law can be introduced at this stage.
Level 2	
• To explain the principle of resultant force • To solve problems related to resultant force • To explain the resolution of force • To solve problems related to force resolution.	To discuss a. the principle of resultant force b. the principle of force resolution To solve problems related to balanced force such as lift, pulley, and objects at the inclined plane using scale drawing method and force resolution.
Level 3	
• To solve problems related to balanced force	To solve problems related to balanced force (limited to three forces).

Other than 'forces in equilibrium', conceptual analysis of the curriculum also shows that a number of physical phenomena in the curriculum involve a combination of several concepts such as momentum, normal force, net force, friction, impulse, impulsive force, Newton's second law, gravity, weight, mass, Newton's first law, free fall, sinking, floating, and surface tension. Such concepts or scientific knowledge have intrinsic characteristics, and this specific content may not be directly transferred into the teaching in the classroom before the tasks of conceptual analysis are established (Duit, Niedderer & Schecker, 2007; Viennot, 2001). For example:

- emphasizing common sense knowledge about Newton' third law equation and scientific knowledge, everyday language and scientific language by writing and analysing sentences containing the word or term force meaning in different contexts – weight (heavy, light), speed (fast, slow), strong, weak, firm, hard, active, energetic, greater, size (big, small), action, reaction, opposite, normal, contact. Think over the language used in physics and to learn to use the word force correctly

- differentiating ordinary meaning of force such as push and pull, ambiguous meanings of words such as constant, and physics language of force (the terminologies or ideas associate with force differ from the ordinary meaning of force, or the idea of force as understood by physicists differs from the idea as understood by the students) such as scientific knowledge differ in terms of the way of the thinking about phenomena, are seen to be counter-intuitive, challenging common sense notion about those phenomena, the vector nature of forces, and interaction between two objects.

Analysis of Textbooks. In Form 4 physics textbooks, there is a statement of Newton's third law: 'Whenever an object exerts a force on a second object, the second object exerts an equal and opposite force on the first'. This statement does not explicitly address the notion of interaction. It is also common for sayings such as *the book exerts a force on a table* to mislead students. Other terms commonly used in instruction and textbooks, such as *at rest, constant motion* also may cause students to misunderstand.

Analysis of Literature on Students' Alternative Conceptions. A literature review of students' alternative conceptions about Newton's third law has revealed three main themes (Bao, Zollman & Hogg, 2002; Savinainen, Scott & Viiri, 2005).

- Force is an innate or acquired property of object (impetus)
- Inert or inanimate objects cannot exert forces, and
- Newton's third law is used in some situations depending on the contextual features of the situation at hand.

If students' alternative conceptions are compared with scientific knowledge three themes emerge (Table 2.4). A list of students' alternative conceptions for each theme is shown in column one from each of Tables 2.4 a–c, and the corresponding scientific knowledge (hidden physics), in column two. Detailed analysis of scientific knowledge corresponding with three themes of students' alternative conceptions, together with hidden physics also are explicitly addressed in suggested teaching activities, and are shown in Tables 2.4(a), (b) and (c). These three Tables show learning demand helps identifies hidden physics and physics suited for teaching, and ultimately helps of how to transform physics into school physics. Analysis of literature on students' alternative conceptions is discussed in more detail in Section 3.1.

Table 2.4 (a)
Force is the property of an interaction between two objects

Student everyday knowledge	Hidden physics [1]
Force is an innate or acquired property of object (impetus). • Objects stop because they have used up all the force. • Force is proportional to velocity. • Slow down motion is caused by the decrease of the force in the direction of motion. • The mass has a force.	• The quantity force is not a characteristic of an object, but the means of describing an interaction between two objects • Force is not an internal property of objects but a process that explains changes in the kinetic state of physical objects.

[1]Hidden physics is mentioned in Chapter 1 (see Section 1.2.2) and is often not clear to students, and this needs to be emphasised by the teacher in the classroom.

Table 2.4 (b)
Interaction between two objects implies that they exert forces on each other: Forces always come in pairs

Student everyday knowledge	Hidden physics
Inert or inanimate objects cannot exert forces • Students believe in the 'existence' of the reaction force; and their views on the 'cause' of the reaction force • Action and reaction are equal and opposite forces apply to the same object. • Misname the actual action and reaction forces involved.	The term reaction force refers to the reciprocal which is equal in magnitude and involved in an interaction between two objects. However, the term normal or contact is more accurate than reaction as these terms have a connotation of animation. • $\mathbf{F}_{(1)\ on\ (2)} = -\mathbf{F}_{(2)\ on\ (1)}$ for the reciprocal actions of two objects, (1) and (2), on one another (this is not limited to cases of equilibrium).
• Action and reaction take place as a sequence	• Action and reaction take place always simultaneous

Table 2.4 (c)
The notion of symmetry of interaction between two objects is generally applicable to all situations

Student everyday knowledge	Hidden physics
Newton's third law is used in some situations but not others depending on the contextual features of the situation at hand. *A. the dominance principle may be applied.*	
• Velocity: object with larger velocity exerts a larger force.	• In a collision, two objects have the same mass (different size), after the collision, the smaller moving at a slower speed.
• Mass – object with larger mass exerts a larger force	• In a collision, two objects with different mass. Before the collision, both objects are moving at the same constant speed.
• Pushing – object that 'pushes' exerts a larger force.	• Both objects have the same mass, one object pushes another causing both to move.
• Acceleration – object that is speeding up exerts a larger force.	
B. the gravitational force • Students believe that the weight of the object A and the reaction force of the object B on the object A form a Newton's third law pair of forces, and the weight of the object A is the cause of the reaction force.	• There are two pairs of forces: the weight of the object A or the gravitational force exerted on object A by the Earth (the true weight); the apparent weight exerted on A by the object B (the normal or elastic force). The apparent weight is numerically equal to the normal or elastic force, usually a reading on a spring scale.
• Heavier object would fall faster than a lighter object. The force of gravity is associated with free fall, weight with objects feeling heavy	• Weight is associated with contact force: weight, W, is the force exerted by the object on the support, the normal force, N, is the elastic contact force exerted by the support on the object. These forces are an action and reaction pair according to Newton's third law, and are numerically equal. Weight and the force of gravity are the same thing
• The weight of an object increases with the height above ground	• The weight of an object decrease with the height above ground

2.3.2 Lesson Planning

Part of didaktik analysis based on Klafki's (2000) five 'sets of questions', is to prepare a lesson plan *before* the content is taught in the classroom. According to Roth (2000) and Duit, Niedderer and Schecker (2007), this part of didaktik analysis is one of the important practical problems for teaching because it involves developing the content, and is comparable to mastering and organizing the content. Roth (2000) notes that teachers should have a real relationship with the 'deepest objective substance' of the content, teacher should have 'real content science knowledge', that is, to understand the science content in the same way a scientist does. In order to achieve this, the teacher is required to study the original work of the content, and consult scientific experts. Gudmundsdottir, Reinertsen and Nordtømme (2000) rephrase Klafki's (2000) five 'set of questions' for pre-service teachers in terms of preparing a lesson plan, and ask questions, such as:

- Contemporary meaning: What significance does the content in question or experience, knowledge, ability or skill to be acquired through this topic already have in the minds of the students? What significance should it have from a pedagogical point of view?
- Future meaning: what constitutes the topic's significance for the students' future?
- Content structure: how is the content structured?
- Exemplary value: What wider or general sense or reality is exemplified and revealed to the learners by the content? What basic phenomenon or principle, what law, criterion, problem, method, technique or attitude can be grasped by dealing with this content as an example?, and
- Pedagogical representations of the ideas: What particular cases, phenomena, situations, experiments, people and events can be used to make the content in question interesting, worth asking questions about, accessible, comprehensible for the students at their level and grade?

In addition, all variables of teaching such as teaching objectives, content, students' alternative conceptions, the teaching sequence (although it is thought of *after lesson planning*, it has to be developed in advance before implementing the lesson in the classroom), teaching aids or media are the key point of reference for lesson planning (Duit, Niedderer & Schecker 2007).

It is important to note again that the process of developing didaktik analysis involves analysing specific science content, analysis of literature about students' alternative conceptions, developing a lesson plan, developing a teaching sequence, and reflections. The first three components of didaktik analysis involve thinking about planning the content (not about *planning activities* but focusing on *developing the content*). This includes making explicit the scientific knowledge or transforming scientific knowledge into school science knowledge, and probing students' prior knowledge from the literature on their alternative conceptions. As a result of content analyses through curriculum specifications, textbooks, and literature on students' alternative conceptions by using the five 'set of questions' and guidance for lesson planning suggested by the above authors, together with slight modification of the existing lesson plan in the physics teaching methods course, the researcher produced another version or format of **lesson plan** in particular on **teaching sequence** and **reflections** (see Figure 2.2). The term **teaching sequence** is developed by taking into account the pedagogical relationship (the students and teacher), and the didaktik relationship (the student and content). The development and implemention of the **teaching sequence** – starts on developing strategies based on school science knowledge to be taught and implementing classroom activities (more detail is in Figure 2.2, Sections 2.3.3 & 3.3). Thus, developing a **lesson plan** itself consists of thinking about planning (the first three components), developing and implementing strategies (**teaching sequence**), and **reflections** on *before*, *during* and *after* planning the lesson, and developing and implementing teaching sequence (see Figure 2.2 & Section 4.1.4) and **reflections** on before, during and after implementing teaching sequence.

Lesson Plan

Content - concepts or skills, predetermined by physics syllabus and curriculum specifications.

Learning outcomes: *General learning outcome* – general objectives that indicates what is to be learned such as knowing, understanding, applying, analysing, synthesizing, and 'evaluation', and

Specific learning outcome – written in the form of behavioural objectives of what individual student will do, and not a group will do, and relate to physics content such as scientific skills, thinking skills, scientific attitudes and values, and according to cognitive, affective, and psychomotor domains.

Pre-requisites – knowing about students' characteristics, knowing what the students already know or able to do in the lesson, and state specific on students' alternative conceptions.

Teaching sequence - descriptions of what to be done in teaching the lesson: How the lesson to be introduced to the students: *opening* – rules established (settle class), preparation for activities, induction or triggering activities; *development* - what actual teaching technique to be used that requires maximum student participation, what specific things students will actually do during the lesson, and *closure* - how to bring the closure of the lesson, and a summary for the students.

Teaching aids or media - list all the equipment, material and resources to be used by both the teacher and students, and how they will be used.

Assessment/evaluation - describe how to determine the extent to which the students have achieved learning outcomes.

Follow-up activities - indicate how other activities or materials will be used to reinforce and extend this lesson. Include homework, assignments and projects.

Reflections - to be completed after the lesson is completed, addresses the major components of lesson plans, focusing on both the strength and areas of needed improvement. Determines how to plan collecting information that will be useful for future lesson, analyses what the different what is intended and what was achieved. This also involves *before* and *during* planning and developing teaching sequence.

Figure 2.2
Modification of existing format of a Malaysian daily lesson plan

2.3.3 The Teaching Sequence in Didaktik Analysis

According to Mėheut and Psillos (2004), the term *teaching sequence* for didaktik analysis refers to the relationship between the proposed teaching and expected student learning, based on research of a content-oriented sequence. Mėheut and Psillos comment that the teaching sequence is used as an intervention in research activity, and consists of innovations that aim at overcoming students' misunderstandings of specific science content. They also indicate that a teaching learning sequence is an activity in the form of developmental research, educational reconstruction, and a priori epistemological analysis of the content.

Tiberghien (2000) proposes a 'modelling' approach in developing teaching and learning situations. Modelling here involves developing students' skills and abilities along with declarative and procedural knowledge, by considering the relationship between the objects and the theories or models used to explain their behaviour (e.g., an object at rest and the theories of forces acting on it). These approaches help change students' alternative conceptions to become more consistent with intended school science. More specifically, Kansanen and Meri, (1999) refer to the teaching sequence as a teaching-studying-learning process. Using didaktik analysis, the teaching-studying-learning teaching sequence is described as the pedagogical relationship between the students and the teacher, the didaktik relationship between the teacher and the content, and the teacher relationship between the students and content (see Figures 2.3 & 2.4).

Mėheut and Psillos (2004) have drawn upon a variety of teaching learning sequences reported in the literature to draw up a generalised approach to developing teaching sequences (it is on individual learning). Mėheut and Psillos provide guidelines for the planning of science teaching which consist of:

i. grounding the design of teaching sequence on a well structured theoretical framework, learning hypothesis, and students' initial conceptions
ii. using the methodology of a priori and a posteriori analysis (does the previous activity really connected with the next activities, and is the

next one really sufficiently prepared for by the previous activities) for the validation of the teaching sequence, and

iii. recognizing the critical role of the teacher in the teaching sequence.

On the other hand, Leach and Scott (2002) provide a four stage guideline for planning science teaching sequences (it is on social learning) based on didaktik analysis:

i. identify the school science knowledge to be taught
ii. consider how this area of science is conceptualized in the social or everyday language of students knowledge. Investigation of literature reports on why students have difficulties in understanding of scientific concepts that will be used
iii. Identify the 'learning demand' of the content by considering the differences between school science knowledge and scientific knowledge, and
iv. Develop a teaching sequence which incorporates information about progression of ideas and how the activity is presented and mediated with a group of students, through language and other semiotic means.

Leach and Scott (2002) argue that research-based teaching sequences emphasize the teacher's role in 'staging' the sequence of teaching activities, in the social context of the classroom. Three general features of 'staging' or implementing the teaching sequences have been proposed (Savinainen, Scott & Viiri, 2005):

- Focus on qualitative conceptual understanding
- Provide students with plenty of opportunities to explore meanings in group discussion, monitored by the teacher, and
- Use multiple representations (e.g., texts, diagrams, or graphs) and link them throughout the teaching sequence.

Leach and Scott (2002) comment that traditional approaches seem to emphasize the effectiveness of the sequence of teaching activities, but not deal with how to teach a specific content effectively. Thus, Leach and Scott describe the design of a teaching sequence by addressing explicitly the staging of teaching activities: making the scientific story intelligible and plausible by drawing on the 'authoritative' and 'dialogic' functions of texts; monitoring and responding to students' understandings (e.g., whole class questioning and discussion, small group activities, individual writing activities, sharing and challenging particular points in class, offering comments on student written exercise, and discussing issues); and, providing opportunities for students to 'try out' and practise the new ideas for themselves, and to make new ideas 'their own'.

Other than addressing explicitly the stages of the teaching activities, Leach and Scott (2002) also emphasize the role of the teacher in mediating teaching activities through language and other semiotic means (e.g., graphs, algebra, geometrical mathematics & drawings). This is because learning scientific knowledge is influenced by the interactions between a student with his/her peers and students with their teacher, and can only be acquired as a result of deliberate and systematic teaching in an educational setting (Wells, 1994). This type of teaching activities according to Leach and Scott (2002) is based on socio cultural views of learning.

Based on Vygotskian views of internalization of concepts, the student internalises the concepts by making personal sense of the new social language with the active support of the teacher, because this view of learning emphasizes the fundamental importance of social context and language (Leach & Scott, 2000). Vygotsky (1987) notes that learning and teaching has the potential to occur in the Zone of Proximal Development, termed *scaffolding* by a more capable other. Vygotsky suggests this teaching is in relation to the process of students' experiences in learning through the Zone of Proximal Development, moving from teacher's assistance to unassisted competence.

Based on the descriptions above, the teaching sequence starts with a planned conceptual analysis of content, with emphasis on addressing explicitly stages in teaching activities, and the role of the teacher in mediating those activities (Leach & Scott, 2002). This is all guided by analysis of literature on students' alternative conceptions, characteristics of specific physics content, epistemological assumptions, learning perspectives, current pedagogical approaches, and educational context. The pedagogical aids to be used include drawings, pictures, schema, diagrams and graphs. A similar teaching sequence was designed by van Dijk and Kattmann (2007), and was guided by an empirical study on students' alternative conceptions and conceptual analysis of specific content.

2.4 THE PEDAGOGY AND DIDAKTIK APPROACHES

Teacher training programs world wide (at least in English speaking countries) have been dominated by the use of a pedagogy approach to teacher training within the curriculum tradition (Fensham, 2004). As noted above there has been some reservations expressed about how well such regimes actually prepare pre-service teachers for the teaching of science. The researcher believes that it is of great potential significance to consider different approaches to teacher training, in particular the didaktik approach. This is not meant to deny the value and contribution of a long standing teacher education tradition, which typically involves teaching pre-service teachers about various pedagogical approaches. But as Westbury (2000) and Tochon (1999) argue there are striking differences between traditional pedagogy-based and didaktik-based approaches to teacher training. The following section considers the literature on the philosophy of didaktik and its approach to teaching as the core concepts in the development of didaktik, followed by the development of pre-service teachers PCK within the pedagogy approach, and finally looks to show why a didaktik approach is, not only able to complement, but also to enhance the former.

2.4.1 The Philosophy of Didaktik and a Didaktik Approach to Teaching

Historically, didaktik approach has been used as a tool for preparing lessons, enacting and thinking about teaching (Hopmann & Riquarts, 2000), and this can be thought of as an alternative way of thinking about teaching and learning in particular; a philosophy of teaching and thus training. Hopmann and Riquarts (2000) note that Ratichius (1571-1670) and Comenius (1592-1670) used a didaktik approach to inform theories of teaching. Here, for example, Comenius who is considered as the founding father of 'pedagogical' theory, defined didaktik as trying to 'teach everything to everyone', and says it has three elements: knowledge, teacher, and students. In other words teaching requires knowledge about the content to be taught, where it comes from and how it is used. In addition, teaching also needs to consider the progress of learning and the development of the students.

Lastly, teaching has to take into consideration both the content and the students. As long ago as the 18th century, Johann Friedrich Herbart (the most influential didaktik scholar, who developed a theory of education and teaching) argued that the content, the teacher, and the student are intertwined: and that in practice every lesson should follow five formal steps of: preparation, presentation, association, generalization, and application.

From the above short history of educational thinking about teaching, Fensham (2004) notes that the term didaktik is manifestly different to the similar sounding term - didactic, a term understood in the West as teaching via transmitting facts, concepts or principles through lecture or discussion. This linguistic distinction also is highlighted by Hudson (2002) who notes that the comparison of meaning across linguistic boundaries is filled with difficulties, and says that this shows that some ideas from other languages and cultures are not easily articulated in English. The term didaktik has its traditions in Northern and Central Europe, and many of the concepts related to didaktik are not reported in English, but in other languages such as Finnish, German and Swedish (Uljens, 1997). In the European context, didaktik refers variously to: *the art of teaching* or 'how to teach' (Bertrand & Houssaye, 1999; Colomb, 1999); to teach, to be a teacher, to educate or study teaching (Hopmann & Riquarts, 1995, 2000); a tradition of thinking about teaching and learning (Westbury, 2000); what should be taught and learned (Gundem, 2000); and a disciplinary subject matter, or any means of formalising a disciplinary subject matter for learning (Tochon, 1999). Some didaktik scholars argue that in the English language, the term didaktik has no precise equivalent and as noted above it is often confused with didactic (Bertrand & Houssaye, 1999; Colomb, 1999; Duit, Niedderer & Schecker, 2007; Hopmann & Riquarts, 2000).

2.4.2 The Pedagogy Approach to Teacher Training and PCK

A pedagogy approach to teacher training places emphasis on pre-service teachers' ability to *transform* (content of instruction and strategies of instruction) science content knowledge through planning, preparing, and teaching lessons. Shulman (1987) sees this as developing the pre-service teachers' pedagogical content knowledge (PCK), described as:

> Pedagogical content knowledge represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction (Shulman, 1987, p. 8).

According to Shulman PCK is one of a number of knowledge categories that together contribute to a knowledge base for a pre-service teacher. Other categories include his or her: content knowledge; general pedagogical knowledge (i.e., broad principles and strategies of classroom management); curriculum knowledge; knowledge of learners and their characteristics; knowledge of educational contexts (e.g., character of school communities and culture); and knowledge of educational aims, purposes, and values, and their philosophical and historical backgrounds. Hudson (2002) notes that Shulman's (1987) model of pedagogical reasoning and action offers a framework for analysing categories of pre-service teachers' knowledge, and that framework forms the basis of the pedagogy approach. Thus, the PCK of a teacher is distinguished by his or her effectiveness in terms of developing student understanding (Magnusson, Krajcik & Borko, 1999; Van Driel, Verloop & de Vos, 1998).

Kansanen (1999) notes that the nature of PCK is general, and he says it does not focus on school subject and the methods. Likewise Fensham (2004) argues that Shulman's PCK does not spell out the *interaction* between content knowledge and pedagogical knowledge, and he suggests that this interaction should be the focus of any pedagogy-based research into teacher training. The main lacking of a pedagogy-based approach to teacher training is that it does not place emphasis on what is, or should be, going on in science classrooms in terms of a content-specific teaching and learning process (Fensham, 2001; Lijnse, 2000). In teacher training programmes, a pedagogy-based approach separates methods of teaching from developing a specific content knowledge (Fensham, 2004). In other words, such approaches place less emphasis on specific science content analysis when developing teaching methods, and instead focus on understanding learning rather than improving the practices of teaching in terms of developing a specific science content knowledge. As a result, a pedagogy approach seems to focus on understanding learning (which is perhaps good for the teacher, but not necessarily for his or her students), rather than improving the practice of teaching in terms of developing science content (Lijnse, 2000).

2.4.3 Differences in Perspectives Between Didaktik and Pedagogy-Based Approaches to Teaching and Teacher Training

As noted earlier, according to didaktik scholars, there are important differences between didaktik and pedagogy-based approaches to teaching (Kansanen, 2002; Westbury, 2000). Thus, the researcher again reminds the readers that although comparing both approaches may seem to complicate things, it helps to enhance or complement one another in terms of teaching and teacher training. To some extent, perspectives of both approaches appear to be overlapping. Here, the researcher does not support nor argue the argument, but tries to give a broad perspectives on both approaches.

First, Colomb (1999) stresses that didaktik and pedagogy-based approaches are distinguished at the level of epistemology (i.e., the nature of knowledge) where the former is situated in a phylogenetic perspective (where we seek to build up knowledge), and the latter is situated in ontogenetic perspective (which is concerned with the relationship at hand). Although didaktik and pedagogy approaches to teaching are different in terms of epistemology, they are in a synergistic relationship, in which each epistemological way of knowing complements the other, and they seek to achieve a common goal of knowing how to teach and how to learn content knowledge.

Second, Tochon (1999) argues that a didaktik-based approach to teaching is a theory about teaching/studying/learning, which involves research on learning, whereas a pedagogy-based approach tries to take into account the complexity of the classroom events. However, practically speaking a didaktik approach may 'swerve' from its teaching objectives when employed in the classroom (e.g., a teacher may intend as a objective to teach a topic but find students hold alternative conceptions which inhibit teaching), whereas a pedagogy approach will operate within the logic of an open system and adjust to events as they unfold in the classroom. These perspectives thus overlap in the classroom, although the essential features of didaktik and pedagogy-based approaches do not change.

Third, a didaktik-based approach to teaching is different in conceptual terms from a pedagogy-based approach. Differences occur with respect to teaching theory, and how the teacher monitors the construction of meaning within the subject taught (Colomb, 1999). As noted above this is tied to the way teachers think about content within the educational context, and their extra focus on planning, particularly focusing on the learning of specific content, with emphasis on declarative rather than procedural knowledge. Both approaches draw upon cognitive psychology as well as social psychology in the classroom, but probably more so in the case of a didaktik approach (Bertrand & Houssaye, 1999; Colomb, 1999; Tochon, 1999). Westbury (2000) argues that the didaktik-based approach to teaching described above provides us some ideas as to the core tasks of pre-service teacher training; an area he believes has shortcomings in the pedagogy-based approach. Thus, the following paragraphs present different perspectives about teaching training, with some overlapping in both approaches.

The differences between didaktik-based and pedagogy-based approaches are mostly to do with teaching in the German literature the conception of didaktik also is used for preparing lessons. For example, the didaktik approach focuses on the learner's cognitive functioning when she or he learns a given content, and becomes a 'knowing subject' (Bertrand & Houssaye, 1999). On the other hand, conceptions of pedagogy involves 'educational process engineering', that is, overseeing the interactive operations of teaching, and the immediate interaction of classroom teaching as it pertains to educational goals. These operations may be associated with immediate experiences, in synchronic relation with the educational context. There is a focus on practice that focuses on the relationship between the teacher and students, and draws more on social aspects of knowledge in the classroom within the didaktik-based approach (Bertrand & Houssaye, 1999;

Colomb, 1999; Tochon, 1999). Additionally, Bertrand and Houssaye (1999) argue that:

- Didaktik consists of reflection on and planning about education that emphasizes the relationship between a learner and knowledge. It is concerned with analysing the learner's cognitive behaviour (i.e., similar to the pedagogy-based approach)
- Didaktik focuses on a limited set of variables, compared to pedagogy which takes account of the maximum number of variables
- Didaktik concentrates on the knowing subject, and places emphasis on declarative rather than procedural knowledge, and
- Didaktik is derived from cognitive psychology (i.e., happened to be similar to the pedagogy-based approach).

2.4.4 Similarities and Differences Between PCK and Didaktik Analysis

The above literature has focussed on differences in thinking between a didaktik and pedagogy-based approaches to teaching and thereby teacher training. Here the relationship between Shulman's notion of PCK to teaching and training and didaktik analysis is discussed.

Van Driel, Verloop and de Vos (1998) comment that PCK refers to specific content knowledge, and say it is therefore different from a teachers' general knowledge of pedagogy. PCK thus concerns the teaching of specific content knowledge, and therefore differs from, just content knowledge. Van Driel, Verloop and De Vos note that good content knowledge is pre-requisite for the development of a teacher's PCK, and say that the teacher's PCK is mostly developed during the actual teaching practice. However, Magnusson, Krajcik, and Borko (1999) say that "although teachers have some knowledge about students' difficulties, they commonly lack important knowledge necessary to help students overcome those difficulties" (p. 106). This suggests that pre-service teachers and in-service teachers need to continually develop their PCK by *learning from experiences*. However, van Dijk and Kattmann (2007) comment that if teaching experience is essential for the development of PCK, then it follows that pre-service teachers will likely have little or no PCK.

It is interesting to consider how scholars from the didaktik-based approach (e.g., Kansanen & Meri, 1999; van Dijk & Kattmann, 2007) view PCK and its relationship to a didaktik analysis to teaching and teacher training. For example, van Dijk and Kattmann (2007) conducted a substantive review of publications from the didaktik scholars on the conceptualization of PCK. They report that PCK is seen by didaktik scholars as personal and private knowledge. In contrast, didaktik approach including didaktik analysis is seen as a research domain (Lijsne, 2000), a 'scientific' discipline in its own right. To illustrate what this might mean, in the context of this thesis, a didaktik analysis-based approach to physics teaching tries to answer questions about students' prior knowledge and their alternative conceptions, and focuses on the development of appropriate content knowledge in the learner. It is important to note that a didaktik analysis-based application also includes analysis of conceptual change, but this is beyond the scope of this thesis. Van Dijk and Kattmann (2007) also note that if didaktik analysis is considered as a field of science, then the study of PCK could be seen as a research field, among many other fields, within the didaktik research domain.

Some didaktik scholars have argued that there is no clear definition of PCK. In particular it seems there is no distinction between PCK as an educational concept (i.e., an abstract idea used in teacher education and textbooks) and PCK as a subjective representation, that is, an element of teachers' professional knowledge (Kansanen, 1999). However, van Dijk and Kattmann (2007) question Hashweh's (2005) view of PCK as personal and private knowledge, and argue that:

> … it is necessary to, for empirical research on PCK, to distinguish between the educational ideas that concern the integrated area of content and pedagogy that can be used in teacher education and its representation and transformations within a teacher's mind … because … the knowledge that the teacher has acquired during his or her teaching career can differ from the available theoretical concepts within educational fields (van Dijk & Kattmann, 2007, p. 889).

Van Dijk and Kattmann, (2007) go on to say that there seems to be no distinction between PCK as an educational concept and PCK as a domain of teacher knowledge, because in teacher training pre-service teachers can not learn *directly* from experts. Didaktik scholars thus view PCK as a knowledge domain, and not as an educational concept or idea. Kansanen (1999) argues that teacher training programmes that are driven by a desire to develop pre-service teachers' PCK, typically say they focus on the content in the teaching process, but that the focus is not actually on the content itself, "… but on the structural analysis of this content" (p. 30). He further argues that "what is presented is a reflection on what kind of elements there may be in the specific content", something consistent with his view that knowledge is regarded as the "subjective" aspect of content, and content itself is seen as "objective". However, he also suggests that the presentation of content is *formal*, by that he means it focuses on students' attributes such as learning, motivation, and achievement.

Thus as a conclusion, a pedagogy-based approach to pre-service physics teachers' training draws heavily upon PCK, as commonly practiced in Malaysian secondary teacher education programmes. If, as is argued above, pre-service teachers will not easily be able to develop their content knowledge through a pedagogy approach to teacher training, this may mean we need to consider other means of teacher training (Fensham, 2004). As mentioned elsewhere, the researcher incorporated didaktik analysis, as a component of the content in a physics teaching methods course, which forms part of science education programme at the institution involved in the study. The notion of didaktik analysis has been briefly discussed in Section 1.2.2, further elaborated in Section 2.3, and finally a detailed account example of teaching sequence from Newton's third law is presented in Chapter 3.

The actual didaktik analysis used in didaktik approach to teaching and learning depends upon our understanding of the nature of didaktik and this is discussed next.

2.5 THE NATURE OF DIDAKTIK IN TEACHER TRAINING

A didaktik-based approach to teaching and learning is thus quite different in nature to a pedagogy-based approach, and this has implications for teacher training. In order to understand how teachers and pre-service teachers might draw upon the didaktik approach we need to understand more about the nature of didaktik, its epistemological assumptions, its relationship to cognitive psychology and its principles. Specifically, we need to know more about the nature and practice of didaktik with respect to teacher training. These issues are complex and interrelated, and are discussed next.

2.5.1 The Principles of Didaktik

Hudson (2002) notes that didaktik is a 'science' of the teaching, studying and learning process, and the didaktik relationships between the teacher, student and knowledge is described by what he calls the *didaktik triangle* (Colomb, 1999; Kansanen & Meri, 1999; Tiberghein, Jossem & Barojas, 1998). Kansanen and Meri (1999) note that the didaktik triangle is used as a means to understand content, and they point out that content should be treated as a 'whole' although in practice this is probably impossible (e.g., it is probably only practical to look at say the relationship between the student and content, the teacher and content or the teacher and students). Thus, some didaktik scholars (e.g., Kansanen & Meri, 1999; Uljens, 1997) suggest that this triangle can be used in teacher education to explain to pre-service teachers how to prepare lessons (Hopmann & Riquarts, 1995). In other words, teaching requires knowing what the content of instruction should be like, where it comes from, and how it is to be used; teaching is only possible if instruction takes cognisance of the progress of learning and the development of the student. Teaching thus has to be aware of both the content and the student in the classroom.

The pedagogical relationship between the teacher and the students is the most usual approach as a starting point (Figure 2.3). When students are adults, the pedagogical relation between the teacher and the students is either asymmetrical or democratic, but when the students are children or young the asymmetric quality of the relation is substantial (Kansanen & Meri, 1999). The relationship takes into consideration each situation; it is interactive, students cannot be forced into it, and it is not a permanent relationship as students grow and become increasingly independent (Kansanen, 2003). The pedagogical relationship also involves reflection on, and planning about, teaching with an emphasis on the relationship between the student and knowledge or content that is to be taught, and the relationship also involves analysing students' cognitive behaviour (Bertrand & Houssaye, 1999). According to the didaktik triangle, the students' relationship to the content is the key to understanding the teaching process. The relationship between the teacher and the content is also taken into consideration, and the teacher's 'competence' is brought into focus. As teaching in itself does not necessarily result in learning, activities of students are termed as 'studying'. In other words, studying is seen as an integrating factor between teaching and learning (Kansanen, 2003). Thus, it is through studying that the teaching process can be evaluated, and the invisible or latent part of this relationship may be learning. The teacher's role in this relation is that of guiding.

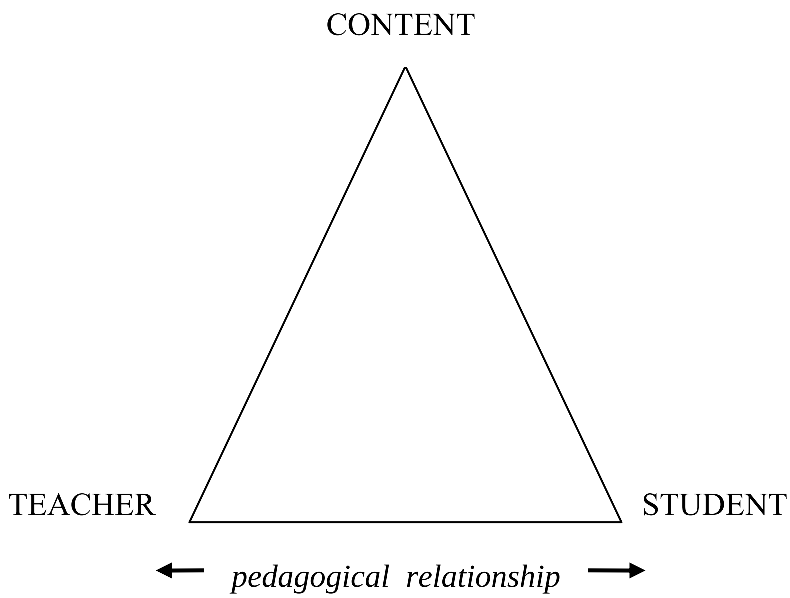


Figure 2.3 Pedagogical relationships in the didaktik triangle
(from Kansanen, 2003, pp.229)

The didaktik 'relationship' is in fact a *set* of relationships, and forms the core of a teacher's professionalism (Figure 2.4). As this set of relationships is complex in any situation, it is difficult for didaktik relationships to be organised universally, or according to some technical rules. As a consequence a teacher's own practical theories and pedagogical thinking become essential if we are to understand the teacher's practices. For example, although reflection-in-action occurs as part of the didaktik relationship, didaktik reflection refers to thinking both *before* and *after* instruction, because it is oriented towards content. In addition, didaktik reflection also should be seen as the way of linking the intentions of the teacher with the curriculum specifications (e.g., Malaysian secondary school curriculum) prior to the preparation for teaching (Hudson, 2002).

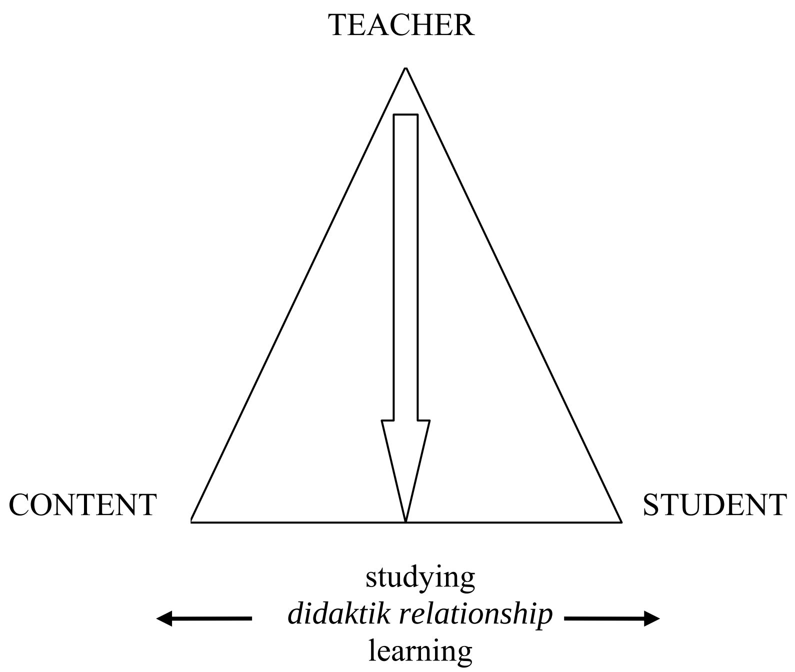


Figure 2.4 Didaktik relationships in the didaktik triangle
(from Kansanen 2003, pp.230)

Bertrand and Houssaye (1999) suggest that didaktik has five major principles: First is that didaktik theory is developed within a disciplinary subject matter. Second, didaktik is underpinned by cognitive psychology. Third, didaktik consists of the explications of principles that ought to guide classroom learning. Fourth, didaktik includes empirical and inductive research studies conducted in the classroom. Finally, didaktik is subdivided into levels (i.e., analytical, applied, empirical, experienced, experimental, general scientific, special, specific, and theoretical didaktik). The first four principles are the most relevant for the present study since they are most relevant to the notion of the relationship between content and the participants (i.e., teachers and students), and are briefly addressed below.

The disciplinary affinity: The didaktik-based approach to disciplinary subject matter uses the word didaktik associated with specific content such as; *physics didaktik*, *biology didaktik*, *chemistry didaktik*, and so on. Thus, any undertaking in didaktik necessarily relates to specific content subject matter, and thus describes *how to teach a given subject*. Bertrand and Houssaye (1999) argue that based on this principle, historically, the didaktik and pedagogy approaches are similar.

Cognitive-psychology underpinnings: Bertrand and Houssaye (1999) cite several ways in which the didaktik approach draws on cognitive psychology. Among them are: Science didaktik aims to facilitate the processes of mastery by considering the objects of the learning process (e.g., concepts, methods, attitudes) and the student's characteristics. However, a naïve conception of didaktik defines the content and teaching procedure separately; the former is seen as a simple reduction of scientific findings, the latter as the simple application of the data produced. The didaktik-based approach is concerned with 'how to teach', and this suggests that new practices are needed in order to understand 'what's going on' in the classroom (in particular, what the various constraints are), and in the student's mind. For example: how does the student learn?, and what conditions could improve his/her learning? This process needs a teacher with certain attitudes and competencies, and an understanding of the content to be taught (whether the content has limitations and is interesting), and the classroom settings. Thus, the 'pedagogical' concern in the didaktik-based approach shifts from a focus of 'how to teach' to a focus on 'how to learn', or obstacles to students' learning (e.g., resistance to conceptual change). Thus, optimal learning varies with the content and with the cognitive skills held by the students. However, in (non-didaktik-based) teaching practice it seems that a teacher often employs a single path for a variety of content, using the only recognized 'pedagogical' style (i.e., a didactic or tramsmission style).

Didaktik consists of the explication of principles that ought to guide classroom learning: The areas of compatibility between pedagogy and didaktik are seen as ‘a model of *didaktik action* founded on observations made by experienced practitioners’ and ‘pedagogy of experience’. A didaktik theory of teaching is thus designed by an expert or someone highly knowledgeable about the content, and includes cognitive planning; such as integration of cognitive, affective, and psychomotor domains, and project work.

An inductive process: An observation process is needed to know what goes on in the classroom (i.e., how the student and teacher function). However, a problem arises as to the role of an observer of teaching practice; both in didaktik and pedagogy: what should he or she do: observe or intervene? Here, although it seems about educational research, but this principle of didaktik relates to teaching and teacher training.

Levels of didaktik: A distinction within the didaktik-based approach is that of levels: *general didaktik* (lessons or manuals), *special didaktik* (the teaching of a discipline), analytical, applied, empirical, experienced, experimental, fundamental, scientific, specific, and theoretical didaktik.

In summary, the researcher suggests here that the didaktik-based approach to teaching and teacher training deals mainly with the teaching and learning of *specific content knowledge*. If this is so, then the didaktik and pedagogy-based approaches are different in terms of epistemology. They are in a synergistic relationship, in which each epistemological way of knowing complements one another, they seek to achieve a common goal of how to teach and how to learn specific content knowledge. From the above we can conclude that a didaktik-based approach if employed in teacher training, overall should seek to help pre-service teachers *learn how to prepare lessons* and deliver.

2.5.2 Didaktik of Physics

If the didaktik approach provides some guidance to decide the core tasks of pre-service teacher training, as Westbury (2000) argues, then Hopmann and Riquarts (1995, 2000) ask some critical questions: What do teachers know about the content they are teaching?, and what do students see and comprehend when they are confronted with that content? To answer these questions, Marton and Ramsden (1988) note that one needs to have a 'subject' didaktik (e.g., physics didaktik). As a result, they conclude that the practice of teaching and learning in the classroom within the didaktik approach can be enhanced. It is from this conclusion that in this study the didaktik of physics becomes important for "it defines the analysis and mapping of the different ways students experience and conceptualize various content domains" (Marton & Ramsden, 1988, p. 283).

According to Marton and Ramsden (1988), the *didaktik of physics* is not the intersection of a teaching physics methods course, educational psychology, and subject matter. It is more a distinctive discipline, a kind of 'science of education', in its own right. It is concerned with how specific content is taught and learned. Didaktik of physics as a discipline in teacher training is thus seen as another field of scientific endeavour. In a similar way, Tochon (1999) defines didaktik of physics as the analysis of, and theorizing about, the phenomena of teaching and learning specific to the content knowledge of physics. Lijnse (2000) simplifies this term as someone who deals with the improvement of physics education through research, curriculum development and teacher training. As noted above, didaktik of physics is a disciplinary subject matter, and van Dijk and Kattmann (2007) view didaktik of physics as a scientific discipline that brings together physics and physics education by studying empirically students' alternative conceptions, their motivation, and the effect of using media methods. According to Tochon (1999), a disciplinary subject matter describes and designs the actualized or virtual learning and teaching relationship between a disciplinary content, students, and a teacher. A disciplinary subject matter then recognizes the diachronic nature of didaktik: it is expressed before and after the interaction similar to Schön's reflection on action.

2.5.3 Some Didaktik Analysis Practices Within the Didaktik Approach

Another key feature of the didaktik approach is the emphasis that is placed upon teaching and teacher training, and this subsequently helps us understand the teaching process. Thus, enacting the didaktik approach through the didaktik analysis of specific content in the way outlined above, could improve the practice of science teaching not only, by focusing on analysing specific science content, but also drawing on the huge body of research findings of students' alternative conceptions (Fensham, 2001 & 2004; Jenkins, 2001). As discussed above, teacher training is thought to play an important role in addressing students' alternative conceptions, by assisting pre-service teachers to develop specific content knowledge. There are relatively few studies in the literature on the improvement of practice in science teaching within the didaktik approach (Leach & Scott, 2002; Lijnse, 1995, 2000), and those studies that are reported are confined to Central and Northern European educational contexts (Lijnse, 2000; Tochon, 1999).

A number of issues related to employing a didaktik analysis to teaching and teacher training have been reported in the literature, for example, developing exemplary practices for the teaching of specific topics using developmental research (Lijnse, 1995, 2000); modelling and semiotic means - the 'degrees of freedom' at the disposal of a teacher to transform an idea being taught (Tiberghien, 2000); and constructing teaching sequences based on the concept of 'learning demand' (Leach & Scott, 2002).

Interestingly, in contrast to many reported interventions (e.g., based on constructivist or learner-centred approaches to teaching), and as noted earlier, Viennot and Rainson (1999) report that a teaching sequence designed from didaktik analysis took less time than their conventional teaching approach, and resulted in consistent year-on-year improvements in learning.

In summary, research suggests that the didaktik approach may be effective in improving the practice of science teaching, and this forms the basis of the intervention used in this thesis.

2.6 CHAPTER SUMMARY

The literature reviewed above suggests that those involved in the training of science teachers have two basic approaches open to them; a pedagogy-based approach in which the core task is to equip pre-service teachers with a number of pedagogies without much link to specific content, and the didaktik-based approach with its strong focus on content analysis and linking pedagogies to that content. Support for the use of the didaktik-based approach comes from the fact that seemingly little progress has been made in addressing student alternative conceptions in Malaysian secondary school physics, suggesting we need to rethink how we teach physics and how we train teachers to teach physics. Further support for considering the didaktik-based approach comes from commentary by authors such as Fensham (2004) and Duit, Niedderer, and Schecker (2007), who argue that traditional teacher training has failed to address the issue of science content, and the importance of addressing the issue of specific physics content. Fensham, in particular, maintains we need to move on from the pedagogy-based approach and accord science content the significance it merits. A key feature of the didaktik-based approach is that it is content specific. Hence, in the next chapter a model for a didaktik-based approach specific to the topics of interest to this thesis is presented; namely, the *didaktik of physics*.

CHAPTER 3

DIDAKTIK OF PHYSICS

CHAPTER OVERVIEW

The literature reviewed in Chapter 2 suggests that a didaktik-based approach to the teaching and learning of science must be content specific. So if we wish to teach physics (or train pre-service teachers to teach physics) then we need to develop an approach that is specific to the content domain of physics. As noted elsewhere, the process of didaktik analysis as used in this study involves: before teaching activities (analysing specific science content from the curriculum specifications and textbooks, analysing literature on students' alternative conceptions, planning lesson plans, and developing teaching sequences); during teaching activities (implementing teaching sequences); and after teaching activities (reflections). Thus, one needs to develop a didaktik of physics *before* tasks of didaktik analysis can be carried out. Some features of a didaktik of physics are the analysis and mapping of the different ways pre-service teachers experience and conceptualize various physics content areas. That is what is presented here through the didaktik analysis of physics, in particular for topics of 'force and motion'; analysis of literature about student alternative conceptions, analysis of the content of 'force and motion' and finally a teaching sequence develops based on specific physics content area (Newton's third law). These are now discussed in turn.

3.1 ANALYSIS OF LITERATURE ON STUDENTS' ALTERNATIVE CONCEPTIONS OF FORCE AND MOTION

3.1.1 Students' Alternative Conceptions in Science

Research in science education has produced many descriptions of secondary school students' understanding of science concepts (Bryce & MacMillan, 2005; Driver, Guesne & Tiberghien, 1985; Herron & Meltzer, 2005; Savinainen, Scott & Viiri, 2005). One of the terms used in descriptions of this understanding is students' 'alternative conceptions' (Clement, 1993; Dekkers & Thijs, 1998; McDermott & Redish, 1999; Palmer, 2001). Alternative conceptions refer to students' conceptions that either differ from scientific knowledge (Driver, 1989; Taber 2001), or represent improper or incorrect conceptual knowledge (Hoz, 1983). In some cases these conceptions have some similarity with scientific concepts they have been taught, but in many cases, there are significant differences between students' 'everyday knowledge', and scientific knowledge (Driver, 1989).

Researchers in the cognitive sciences suggest that 'the building of bridges' between scientific knowledge and students' everyday knowledge may involve the use of: intermediate notions or intermediate conceptions (Driver, 1989; Driver, Asoko, Leach, Mortimer & Scott, 1994); intermediate states (Niedderer, 1992); conceptual maps (Dykstra, Boyle & Monarch, 1992); transitional states (Thornton, 1995); anchoring conceptions (Clement, Brown & Zietsman, 1989); and learning pathways (Duit & Treagust, 2003; Petri & Niedderer, 1998). Likewise, various terms have been used to portray students' everyday knowledge: phenomenological primitives (diSessa, 1988) – such as force as mover or more effort begets more result; ontologies (Chi, Slotta & de Leeuw, 1994) – in students' minds force belongs to the category of matter (i.e., something that can be stored); coordination class (diSessa & Sherin, 1998); initial and synthetic models (Vosniadou, 1994) – affected before and unaffected after teaching, respectively; facets (Minstrell & Stimpson, 1996) – students integrate the concept of force with the concepts of energy and momentum; and concepts (Carey, 1999). Although there are numerous different views of students' learning, a student's everyday knowledge can overall be summarised as fragmented or knowledge 'in pieces' (diSessa, Gillespie & Esterly, 2004; Minstrell, 1992) or coherence (Ioannides & Vosniadou, 2002). These two views of students' knowledge will be used for the specific content knowledge of force in this development of the didaktik analysis of physics.

Here, the researcher reviews one example of the difference between scientific knowledge and students' everyday knowledge about the scientific concepts of Newtonian force and acceleration. An example of a 'conceptual map' given by Dykstra, Boyle and Monarch (1992) is provided in Figure 3.1.

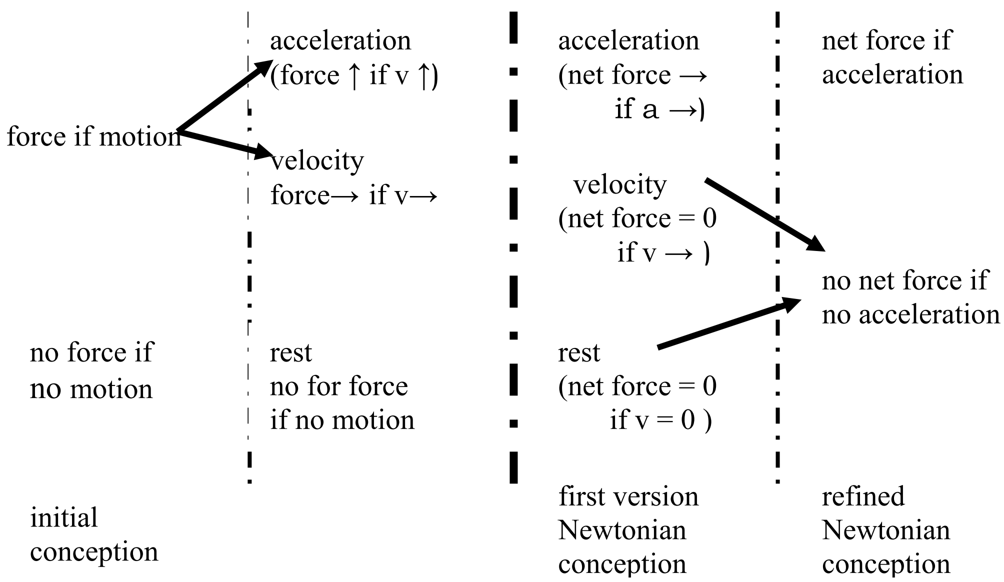


Figure 3.1
Conceptual map of the physics concept of force
after Dykstra et al. (1992)

On the right side of Figure 3.1, are the intended learning outcomes for the scientific concepts of force and acceleration. In between, the lines show two different intermediate states from which students may reach the correct scientific concepts, in two steps. Thus, in order to understand the correct relationship between force and motion, a student's learning is not going from the alternative conception directly to the intended scientific concept, but going through a series of intermediate states.

Research suggests that students conceptual understanding is particularly weak for concepts such as mechanics (Bryce & MacMillan, 2005; Herron & Meltzer, 2005; Savinainen, 2001; Savinainen, Scott & Viiri, 2005), and many studies of students' everyday knowledge seek to explain why physics is difficult to learn for many students (Halloun, 1998). Leach and Scott (2003) argue that research based on cognitive science is not enough to explain how students actually learn in the classroom. For example, factors such as language and culture need to be taken into account, as these can play a role in generating and maintaining alternative conceptions (Leach & Scott, 2003; Warren, Ballenger, Ogonowski, Rosebery & Barnes, 2001). Identifying and addressing alternative conceptions, particularly in topics like mechanics, may help teachers improve classroom teaching more generally (Niedderer, 1992). Therefore, it is important for teachers to develop an understanding of their students' alternative conceptions if they wish to improve teaching science.

3.1.2 Alternative Conceptions and Their Origins

As noted above, the term students' alternative conception refers to differences between students' everyday knowledge and scientific knowledge. These differences may have occurred because students assimilated knowledge incorrectly from formal teaching, or confused terminologies from everyday experiences (Driver & Easley, 1978; Warren et al., 2001), both perceptually and linguistically (Clement, Brown & Zietsman, 1989; Preece, 1984; Warren et al., 2001). In other cases, students, before receiving formal education may have constructed initial, incomplete or naïve notions about a concept which are then not corrected during teaching (Kuiper, 1994). Hammer (1996) also comments that students' alternative conceptions vary according to specific science content.

Preece (1984) suggests that alternative conceptions are in fact not learned from experience, but 'triggered' by experience. In other words, students' alternative conceptions are innate, rather than constructed. This might occur, for example, because of students' lack of reasoning abilities for scientific conceptions. The literature suggests that students' alternative conceptions are deeply rooted in language and culture (diSessa, Gillespie & Esterly, 2004; Ioannides & Vosniadou, 2002; Solomon, 1983; Viennot, 1979; Warren et al., 2001), and what they think of as 'school science' is stored in a different domain of cognitive structure to students' everyday knowledge (Claxton, 1993; diSessa et al., 2004).

Many of the students' alternative conceptions reported in the literature are connected with the teaching of science in the English medium, to English speaking students. Thus, it seems linguistic confusion can occur even when a student is learning a science content in his or her mother tongue. Clearly, when students are learning science in a language other than their first language, the development of alternative conceptions mentioned above may be further exacerbated. The bilingual delivery of physics determines whether students' understanding might be better expressed in their mother tongue or similar to when they express their understanding of scientific concept in English. This factor thus also may play a role in generating alternative conceptions, or not.

3.1.3 Students' Alternative Conceptions in Physics

An extensive review of the literature reports a variety of difficulties experienced by students in their understanding of elementary concepts in mechanics such as, force, motion, velocity, impulse, and acceleration (Duit, 2004; Herron & Meltzer, 2005; Savinainen, 2001). For example, research suggests that the term 'force' has many meanings in students' everyday experiences (Gunstone & Watts, 1985; Ioannides & Vosniadou, 2002). To illustrate, students' conceptions are that 'force always causes motion' (Watts & Zylbersztajn, 1981), and that 'motion implies force' (Clement, 1998; Dykstra, Boyle & Monarch, 1992), and that they 'associate force with velocity' or force depends on velocity instead of acceleration (Viennot, 1979, 2001). The following is a brief analysis of students' conceptions for force.

Watts and Zylbersztajn (1981) comment that many students relate force to motion, and that they believe when two objects interact to produce motion; one is 'stronger' than the other. Such students' alternative conceptions fall under the category of 'force causes motion', and include a view that a constant force acting on an object produces a constant speed, and that increasing a force on an object produces acceleration (Clement, 1982, 1998; Viennot, 2001). These conceptions of 'force causes motion' are termed 'the causal principle of motion' (Dykstra et al., 1992; Halloun, 1998). Students seem to think that a force is needed to keep an object moving, that this force is 'carried' by the object itself, and that the velocity is then proportional to this force (Viennot, 1979, 2001). Hence, in summary, *force is seen as always causing motion*.

Students' alternative conceptions of 'motion implies force' may also mean that there is no force if there is no motion, if there is motion then this is caused by a force in the direction of the motion; that this is the only force (Dykstra, Boyle & Monarch, 1992). Although this view is not taught in schools, it represents a common and self-consistent stock of concepts of what Viennot (1979) has called 'intuitive physics' or 'spontaneous reasoning'. Students' alternative conceptions of 'motion implies force' thus consider that inert or inanimate objects cannot exert forces (Ioannides & Vosniadou, 2002). Students think of forces as being 'things' in themselves, as events, and as properties of objects (Terry & Jones, 1986). For example, students may think that a table does not exert a force on a book lying on it, it is just 'in the way' (Bryce & MacMillan, 2005; Minstrell, 1982).

A number of studies indicate that students are not very consistent in the way in which they apply their conceptions to everyday and contrived situations (e.g., Bryce & MacMillan, 2005; Palmer, 1997; Savinainen & Scott, 2002). For the case of the teaching of Newton' third law, for example, Bao, Zollman and Hogg (2002) report that students appear to have multiple conceptions that are highly context-dependent: velocity, mass, pushing, and acceleration. These conceptions are associated with the dominance principle (Halloun & Hestenes, 1985). For example, for velocity, an object with larger velocity exerts a larger force; for mass, an object with a larger mass exerts a larger force; for pushing, an object that 'pushes', exerts a larger force; and for acceleration, an object that is speeding up, exerts a larger force. Similarly, Terry and Jones (1986) note that beside the words 'action' and 'reaction', the expression 'in the opposite direction' may also cause problems in student unobtrusively (students thought that both terms refer to the same body, and thus in order to cause motion, action must be stronger than reaction). In order to avoid the words action, reaction, and opposite, Hellingman (1989) proposes teaching the third law as being that a force consists of an *interaction* between two bodies, working equally strongly in opposite directions.

Table 3.1
Students' alternative conceptions for mechanics
(from Sequeira & Leite, 1991)

Newtonian ideas	Students' common alternative ideas
• Heavier objects fall with the same acceleration as lighter object.	• Heavier objects fall faster than lighter objects, with increasing velocity.
• In vacuum objects fall with the same acceleration.	• In vacuum objects do not fall
• Gravity is a distance force; it may act at a distance without physical support.	• Gravity needs physical support; it cannot act in vacuum.
• Objects keep on moving with constant velocity, in the absence of an external net force.	• Motion implies a force in the same direction.
• Objects stop due to a force opposite to motion.	• Objects stop because they have used up all the force.
• Motion and rest are similar rule governed stages.	• Motion and rest are different rule governed stages: rest does not require an explanation.
• Constant force implies constant acceleration.	• Constant force implies constant speed.
• Force is proportional to acceleration.	• Force is proportional to velocity.
• Slow down motion is caused by negative acceleration.	• Slow down motion is caused by the decrease of the force in the direction of motion.
• Forces come from interaction between objects.	• Objects have/acquire forces.

3.1.4 Implications of Students' Alternative Conceptions for Teaching within the Pedagogy Approach

The findings of research into student alternative conceptions resulted in researchers in science education research developing teaching strategies for specific science content. Researchers claim that a variety of teaching strategies are effective: bridging analogies (Brown & Clement, 1989; Brown, 1992 & 1994; Bryce & MacMillan, 2005; Clement, 1993 & 1998; Minstrell, 1982); concept maps (Novak, 2002); cognitive conflict strategies (Scott, Asoko & Driver, 1992); modelling (Halloun, 1998); contrastive teaching (Schecker & Niedderer, 1996); and bridging representations (Savinainen, Scott & Viiri, 2005).

To illustrate further, consider the example of the bridging analogy teaching strategy. Minstrell (1982) focused on the extent to which students believed in the existence of the reaction force, and Brown and Clement (1989) used this in the case of situation in which a book is lying on the table - focusing on the idea that there is a force on the book caused by the table. It seems students cannot quite believe that there are any forces on the book caused by the table. The use of springs or soft rubber foam makes this force evident (can be seen), helping student to 'bridge' into the scientific view of force in this rest situation. Briefly, the three of elements involved in the bridging analogy are the anchor, the bridging elements, and the target (see Section 3.3.1).

Finally, the literature also suggests that the function of language in the teaching of science is not to transmit concepts and their meanings from a teacher to students, but as a means of discussing and negotiating differences in constructed meanings between a teacher and students' everyday knowledge (Niedderer, 1992). However, results from research into students' alternative conceptions are important for improving the practice of teaching and learning for pre-service teachers in the classroom (Niedderer, 1992). Through the elicitation of students' prior ideas, their alternative conceptions generated from anchoring, facets, contrastive teaching, concept maps and cognitive conflict can be understood and addressed in teaching strategies.

Fensham (2001) suggests that research on students' alternative conceptions focuses on isolated concepts of science rather than on the contexts and processes of conceptualization. However, the research findings from alternative conceptions research may help in designing a teaching sequence for the pre-service teachers, as part of didaktik analysis. As noted above, by eliciting students' prior ideas through appropriate use of language (e.g., the use of terminology and acronyms), students' alternative conceptions generated from anchoring, facets, contrastive teaching, concept maps and cognitive conflict can be used as a basis for developing teaching strategies. In other words, students' alternative conceptions can be changed using such strategies.

As noted above, there is a huge body of research about students' alternative conceptions, and teaching strategies in physics and in the areas of force and motion in particular, all which seek to improve physics teaching. However, there are *no reports* of specific teaching sequences designed *within the pedagogy approach* which detail better ways of teaching *specific* physics content (Lijnse & Klaassen, 2004; Millar, Leach & Osborne, 2000). Indeed, a review of literature suggests that research in science education does not aim to develop ways to teach *specific* science content better, but to contribute to *general* educational and/or psychological theories (Duit & Treagust, 1998; Lijnse, 2000; Lijnse & Klaassen, 2004; Tiberghien, 2000), and is probably why students continue to construct alternative conceptions when learning.

Some authors argue that the choice of teaching sequence in the pedagogy approach is up to the personal freedom and competence of each individual teacher (Lijnse & Klaassen, 2004). As a consequence it is possible that there is no 'best' way of teaching specific science content. But such a view underestimates the difficulty of using more general theoretical ideas in teaching (Lijnse & Klaassen, 2004). Lijnse and Klaassen (2004) note that whilst other authors may claim that the 'best' way of teaching specific content is 'an illusion', some ways of teaching are better than the others. They conclude that it is worthwhile to search for evidence of how and why a didaktik approach may help improve the practice in science teaching. A large number of studies on alternative conceptions, problem solving and meta-cognition (views of learning) have shown that students, and even physics teachers, still face difficulties in learning science (Eryilmaz, 2002; Herron & Meltzer, 2005; Savinainen, 2001; Vosniadou, 2001).

Halloun (1998) summarises a large body of research on student alternative conceptions in physics, and concludes that students' are typically unable to: realise how physics concepts or principles relate to the real world; differentiate among different concepts; relate individual concepts to each other; develop appropriate procedures for applying a concept or a principle to real world situation; and, express themselves correctly when trying to engage in scientific discourse.

Lijnse (1995) argues that theory-practice gap is as serious as it is long-lasting. The researcher therefore concludes that the literature on analysis of students' alternative conceptions, analysis of the content of specific physics content and the design of teaching sequences based on specific physics content area employed in the 'pedagogy approach' also can be part of the didaktik analysis of physics. In other words it is incumbent upon the researcher or teacher to consider the relationship between specific content and pedagogy. Hence the next section consists of an analysis of some specific physics content. The researcher has chosen the concepts of force and motion since the alternative conceptions research described above suggest this is of prime importance to the understanding of physics, and that it is an area students find difficult to understand.

3.2 CONCEPTUAL ANALYSIS OF FORCE AND MOTION

3.2.1 History of Mechanics

One feature of the conceptual analysis of specific content in didaktik analysis is to look at the historical background of the discipline, mechanics in the case of this study (Gundem, 2000). Galili and Hazan (2001) believe that using history and philosophy of science helps facilitate students' construction of a deeper and genuine conceptual understanding of the content knowledge embedded in introductory physics. Other authors likewise suggest that the study of the history and philosophy of a specific topic in science led them to gain insight into how it might be more effectively taught and learned in school (e.g., McGinnis & Oliver, 1998).

A brief outline of major historical developments for mechanics follows. Galileo Galilei (1564-1642) – discovered patterns in the behavior of freely falling bodies. Johannes Kepler (1571-1630) – observed the motion of the planets, and designed several experimental laws to describe their behaviour. Isaac Newton (1642-1727) – starting with Galileo's and Kepler's laws and adding some experimental work of his own, stated the fundamental laws of mechanics. His classical mechanics is known as Newtonian mechanics. The three laws of Newton, stated approximately in the language he used, are as follows:

i. Every body continues in the state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it

ii. The change of motion is proportional to the motive force impressed and is made in the direction of the right line in which the force is impressed, and

iii. To every action there is always opposed an equal reaction; or, the mutual actions of two bodies upon each other are always equal and directed to contrary parts.

3.2.2 Conceptual Models for Newtonian Concepts of Force and Motion

Here the researcher considers the concepts of force and motion, drawn from the broad area of mechanics. Specifically an attempt is made by the researcher to develop science content suitable for teaching and learning in the particular context in which the research for this thesis was under taken (i.e., Malaysian secondary classrooms at age 16 years old or Form 4). In particular the researcher drew upon his own teaching exercises, and took cognisance of the didaktik analysis model proposed by Klafki (2000). First and foremost in the teaching of force and motion, like many topics in physics, we are dealing with the teaching of a series of conceptual models; these are used in physics teaching, and serve as a template and as a guide for planning and evaluating learning outcomes (Bryce & MacMillan, 2005; Halloun, 1996; Savinainen, Scott & Viiri, 2005).

Halloun (1996) notes that conceptual models are often subjective, idiosyncratic and not necessarily coherently structured, but through appropriate teaching they become relatively objective and coherently structured. For example, a physical object in motion can be studied using models from Newtonian mechanics. Of the two types of Newtonian models (particle and rigid bodies), only one will be discussed in this study: the particle model. The particle model refers to physical objects, the internal structure of which can be ignored when they are in 'translation' without rotation or precession, in a specific reference system. The content of each basic particle model consists of a single, dimensionless object: 'a particle'. Of four basic particle models, only two are used for this thesis as both can be used to describe (kinematic – not involving forces), explain (dynamics – involving forces), or to predict the motion of an object:

- Free Particle: This model refers to physical objects subject to zero net force ($\sum \mathbf{F}_i = 0$) in linear translation with constant velocity or at rest.
- Uniformly Accelerated Particle: This model refers to physical objects subject to a net constant force ($\sum \mathbf{F}_i$ = constant), moving with constant acceleration in a linear path in the direction of the net force.

Conceptual models consist of four dimensions: domain, composition, structure, and organization (Halloun, 1996, 1998). The composition and structure 'define' the model, whereas the domain and organization situate the model within the broader theory to which it belongs (in this case mechanics). Each of these is now described in turn.

Domain: The domain of a model consists of a set of physical systems and phenomena which help us to describe, explain and/or predict the motion of an object, both approximately and precisely. In the case of a uniformly accelerated particle, this includes all physical systems that are in translation with constant acceleration in inertial reference systems. Each system is interacting with one or many physical agents that exert on it a net constant force.

Composition: The composition of a model consists of content, environment, object descriptors, and interaction descriptors (Figure 3.2). In other words, it has conceptual objects and agents, and respective properties or descriptors.

- The content of a model consists of objects representing physical objects inside a set of physical systems. A physical system can be 'simple', if it consists of only one object, or 'composite' if it consists of more than one object. For example, a particle model of Newtonian mechanics is a simple model consisting of a single object, and depicted by a geometric point in a given coordinate system.

- The environment of a model consists of 'agents' (object-concepts) representing physical entities outside the physical systems that interact with entities inside. For example, every object on Earth is physically attracted by celestial objects such as the Sun, the stars and planets (Earth is not included). However, terrestrial objects (physical objects on Earth) are considered only attracted by the Earth, and the Earth is the only celestial object that is represented by an agent in the environment of model referring to terrestrial objects. Thus, it is important to identify 'agents' acting on an object, how to specify the corresponding forces, and how to draw appropriate force diagrams. There are two types of agents: interaction at-a-distance, and contact-interaction.

- Object descriptors refer to characteristic features of a given physical object. These features can be intrinsic or state properties (state-dependent) of the physical object. An intrinsic descriptor or parameter represents a physical property that is assumed to be constant (e.g., the mass of an object). Only one intrinsic property is accounted for in any particle model: the mass of an object. A state descriptor or variable represents a physical property that can vary in time. State properties are the kinematical properties of the object: position, displacement, velocity, acceleration, kinetic energy, and so on. As an agent, like an object, also has intrinsic and state properties which often are limited to quantification of the interaction between the agent and respective object/s, and this is discussed next.

- Interaction descriptors refer to physical interactions between an entity inside a physical system of the model and one outside (e.g., force). Only the force imparted by an agent on an object is considered; the one exerted by the object on the agent is ignored. Forces exerted on the particle by its agents are depicted by arrows in a force diagram (Figure3.2); Two-way arrows indicate interaction between two objects (O's), while one-way arrows depict interaction between agents (A's) and objects, and no interaction is shown between an object and itself, or among agents. It is important to note that a particle model is not isomorphic with any physical object. Not every physical entity needs to be represented in a particle model representing it. This is applied for intrinsic or state properties of the physical object. However, every object in a particle model must correspond to at least one entity inside its physical systems, and every agent, to at least one entity outside. Similarly, every descriptor in a particle model must correspond to a specific physical property of object.

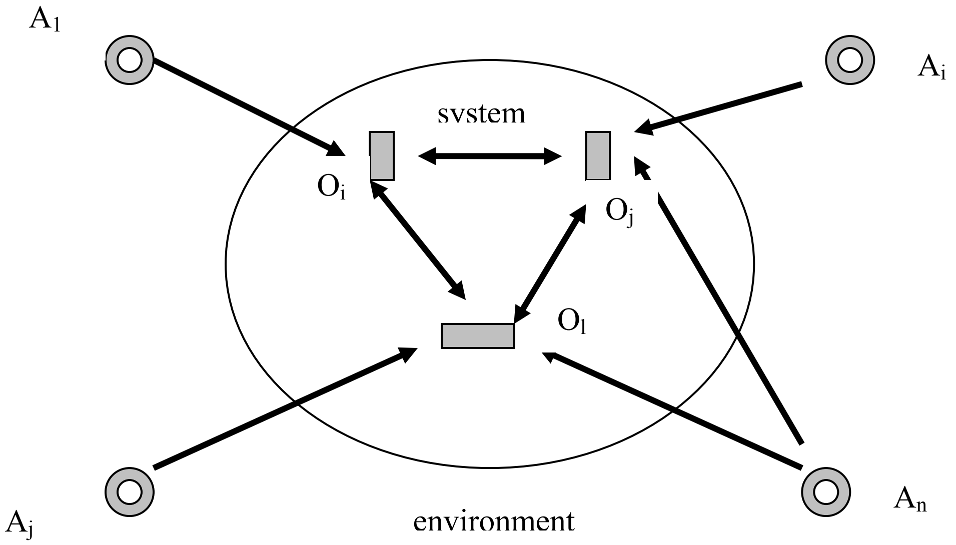


Figure 3.2
Schematic representation of the composition of force using the particle model

Structure: the structure of a model consists of relationships among the descriptors of different entities, and various relationships. There are three types of structure; geometric, interactive and behavioural. Geometric structure refers to the spatial configuration of objects and agents, and often expressed in terms of the *position* of the individual objects and agents and/or of *non-temporal* relationships between the relative positions of the various parts of individual entities. Interactive structure refers to *non-temporal* relationships expressed in interaction laws between an interaction descriptor and object descriptors of the respective object and agent (e.g., Newton's law of universal gravitation). Geometric and interactive structures are called internal when they relate descriptors of various objects in the content of a model to each other but not to those of agents in its environment. The opposite case of structures is external. Behavioural structure refers to *spatiotemporal* relationships in terms of direction, conservation, and location, and expressed in two types of law; state and causal. State laws express relationships between object properties of a single object, and describe the change of state of a particular object (e.g., Newton's first law and kinematic laws of motion referred to in textbooks as equations of motion). Causal laws express relationships between an interaction property and state properties of an object, and explain the change of state of an object (e.g., Newton's laws of dynamics). It is important to note that a particle model is *descriptive* if it does not have an interactive structure, and its behavioural structure is expressed only in terms of state laws but not causal laws. A particle model is *explanatory* if it does not have an interactive structure, and/or its behavioural structure is expressed only in terms of causal laws and but not state laws.

Organization: the organization of a model refers to its relationship to other models in a given scientific theory. Every theory provides classification of various models such as those mentioned above, the families of basic models in classical mechanics: particle models and rigid body models. A basic model is one with simple composition (i.e., consisting of one object) and simple structure (i.e., describing and/or explaining one elementary phenomenon). Every theory contains organization laws and rules that specify how models relate to each other and how to combine different models. Discussions of organization laws and rules are omitted in this thesis as they involve both models; particle, and rigid body.

Based on the conceptual models above, the following is a description of individual concepts in physics. There are three types of concepts in physics: object concepts, property concepts, and operational concepts. Object concepts refer to physical objects in the real world, for example, the concept of a particle in mechanics. Property concepts, for example, concepts like speed or force, refer to physical properties that are particular to a given physical object (e.g., speed) or that characterize its interaction with other physical object (e.g., force). In this thesis, the researcher refers to property concepts as concepts or descriptors. As mentioned above, there are two types of descriptors: object or individual descriptors, and interaction descriptors. Operational concepts are logico-mathematical concepts that are used to process object and property concepts, for example, vector addition. Finally, from the model analysis, the schematic dimensions of a model (called as knowledge and complemented by some procedural knowledge), and individual concepts discussed above. Halloun (1998) defines scientific concepts in five schematic dimensions: domain, organization, quantification, expression, and employment.

Force Domain: The domain of the concept of force consists of all couples of interacting physical objects, namely an object and agent. The conditions and limitations of applicability of the descriptor to its physical systems can be formulated in a set of correspondence rules. There are two types of interaction: interaction at-a-distance, and contact-interaction. Some correspondence rules for the Newtonian concept of force are:

- The domain of the concept of force consists of two physical objects that interact; the object, and the agent
- An object can not interact with itself. Every force must have an external agent. Unless a distinct agent exists that interacts in a specific way with a given object, the concept of force cannot be used
- The concept of force is explanatory. It is a concept of dynamics and not kinematics; it explains the change in the momentum (or velocity) of an object
- The existence of interaction, thus requires the concept of force, and can be recognised from the kinematical state of an object: a free particle does not require interaction with any agent to maintain its constant momentum (or velocity); however any change in its momentum requires an interaction with one or many agents
- A single force represents one side of the interaction, the action of an agent on an object, or the action of an object on the agent.
- Forces come in pairs: the two opposite forces exchanged by an object and an agent are simultaneous, and both are involved in any interaction, and
- No intermediary between an object and an agent is needed for them to interact (this is true at the macroscopic level but not necessarily at the microscopic level).

Organization: A concept is always related to other concepts in scientific theory through axioms, definitions, and laws, the network of which make up the organization of the concept. Two types of concepts are prime, and derived. Prime concepts are those that cannot be derived from other concepts. Derived concepts are those that are commonly defined explicitly in terms of prime concepts and other derived concepts. The concept of force is a prime concept, whereas the concept of work (being a combination of force and displacement) is a derived concept.

A prime concept is commonly defined axiomatically, that is implicitly through a given set of axioms or laws. The Newtonian concept of force is defined axiomatically through the entire set of Newton's laws of dynamics, sometimes these laws called as *axioms of force*. Newton's second law is a law, not a definition of the concept of force. Newton's second law is a causal law that explains the change of state of an object (as defined by its momentum or velocity). A 'definition' relates concepts of the same nature, for example, the definition of velocity in terms of position, or of work in terms of force.

Force Quantification: A descriptor has to be quantifiable, and quantification of a descriptor or a concept is done according to laws and following rules that are set by the theory to which the concept belongs. Quantification laws set the quantitative nature of a concept, the operations that can be undertaken with it, and the assumptions underlying its measurement. Quantification rules specify how to practically measure the concept and determine the respective limits of approximation and precision. Some quantification laws and rules for the Newtonian concept of force are below.

a. Quantification laws:

- Force is a vectorial concept (as opposed to scalar, like the concepts of mass or temperature) and thus its measurement requires the specification of a direction, a magnitude, and a unit which is the Newton in the SI unit system
- Force is an extensive concept (as opposed to an intensive concept, like temperature), for example, a single force of magnitude zero indicates no net interaction

- Force is an additive concept (as opposed to a non-additive concept, like temperature); two or more forces can be added vectorially following the superposition principle (the law of composition)
- Force is a proportional concept (as opposed to an ordinal concept, like temperature); two forces can be compared by a ratio, and
- A force is indirectly measured physically; there are no direct means for comparing a given force to a standard force in the same way. A force is always measured through its effect on a given object, like stretching or compressing a spring.

Thus, there are some assumptions underlying the measurement of a force. For example, changing the strength of an interaction between an object and an agent is assumed to induce a proportional change in a given state property of the object. Two forces are then axiomatically said to have equal magnitudes if they produce the same effect on the same object (which further assumes that after each measurement, the object can be brought back exactly to the same initial conditions).

b. Quantification rules:

- How to set the dimension of a force (the set of all units by which the physical quantity is expressed), is given symbolically by:

$$[\text{ force }] = \frac{[\text{ mass }] \times [\text{ length }]}{[\text{ time }]^2}$$

- How to convert from the SI unit of force to a derived unit:

$$1 \text{ N} = 1 \text{ kgms}^{-2}$$

- How to determine the characteristics of a force exerted by a given agent
- How to measure a force physically using appropriate force probes (for example, spring scales), and establish the correspondence between 'reading' an effect and the magnitude of the force that causes it, and
- How to estimate errors in an experimental setting.

Force Expression: Each concept of physics is expressed by the means of forms such as: identification, symbols, labels, pictorial depictions, and mathematical representations, along with corresponding semantics for interpreting the various forms of expression. Expression means and semantics for the Newtonian concept of force are below.

Means of expression include:

- Identification of the concept, for example, force and the name of its unit (Newton or N/kgms^{-2}), all of which are particular for this concept, and not shared by other concepts
- Symbolic labels such as specific characters that can denote the concept or its units instead of their names, and the appropriate style: e.g., **F,** or F
- Pictorial depictions such as geometric figures that can depict the concept: a force is depicted by a vector, a labelled arrow, in an appropriate coordinate system. Specific assumptions underlie the point of application of this vector, depending on whether or not the object is particle-like, and
- Mathematical representations, including equations, graphs, and geometric diagrams representing the concept, and its relation to other concepts.

Semantics specify:

- What each form of expression denotes, especially that each form can denote specific features of a concept but never all its features: a normal letter labels the magnitude of a force, whereas the bold letter labels it as a directional quantity as well, and
- How to interpret each form of expression, and establish the appropriate correspondence to the real world.

The magnitude and direction of interaction between a physical object and agent can be determined appropriately from the corresponding force vector.

The equality in $\mathbf{F} = m\mathbf{a}$ relates a force F exerted by an agent to its effect **a** on an object of mass m, and expresses a different relationship from the one expressed, say, in $\mathbf{a} = dv/dt$ for defining the acceleration of an object in terms of its own velocity.

- How different forms of expression relate to, and complement, each other in specific respects: a force vector can only depict a force at a given instant. Changes in its direction and magnitude may be better represented by appropriate diagrams such as field lines, graphs and/or equations.

Force Employment: the employment of any concept is guided by appropriate rules that stem from the above four schematic dimensions and that are set by the theory to which it belongs. Guidelines for employing the concept of force in basic particle models indicate what to do when studying particle interactions:

- Set convenient system boundaries in a conveniently chosen inertial reference system, so that every system can be represented by a particle model
- Depict the reference system using a convenient system, and the particle by a point in this system
- Identify agents, remembering that, except for the earth, no physical entity can be an agent unless it is in contact with a given object
- Identify the force exerted by each agent on a given object
- Depict every force by an appropriate arrow in a force diagram, with the tails of all arrows coinciding at the point depicting the particle
- Resolve a force vector into appropriate components
- Compose many force vectors following the superposition principle
- Match various mathematical representations of a force, and conduct appropriate operations with those representations
- Match the resultant force on an object with the acceleration of the object, and
- Choose between Newton's laws and the work-energy principle to relate the resultant force to its effect on a given object.

This didaktik analysis of physics content for the mechanics concepts of force and motion considered both *domain* and *organizational* aspects. The symbolic and quantification rules are a key outcome of this analysis. This analysis formed the basis of the intervention in the following teaching sequence.

3.3 TEACHING SEQUENCE FOR PHYSICS TEACHING

This section reviews the development of a teaching sequence, and aims at enhancing the practice of teaching and learning of physics in the Malaysian Form 4 physics classroom (e.g., Year 10 students about 16 years old), which seeks to answer research question four (Chapter 1) as well as provide evidence for the success of a didaktik-based analysis teaching sequence. As mentioned in Section 2.3.3, the process of constructing a teaching sequence from didaktik analysis involves a theoretical framework (epistemology, psychology & didaktik), learning hypothesis, students' prior knowledge, a 'priori' and a 'posteriori' analysis (does the previous activity really connected with the next activities, and is the next one really sufficiently prepared for by the previous activities), the teacher's role, classroom, materials and resources, motivation, consistency, and feasibility in the educational system (Buty, Tiberghien & Maréchal, 2004; Mėheut & Psillos, 2004). According to Buty et al. (2004), the researcher utilizes a theoretical framework to develop a teaching sequence and this may result in either constraints or provide useful hints for teaching. The core activity is not to understand learning, but to improve the practice of teaching and learning of physics. Its emphasis is on the teaching and learning of the content, and other particularities of physics as a subject (Lijnse, 2000). The particularities of physics deal with aspects of physics knowledge, particularly concerning physical quantities, their relationships and their meaning in the framework of physics (Tiberghien, 1994).

Areas of the didaktik of physics related to a teaching sequence start by taking cognisance of the literature on students' learning, which includes empirical investigations of students' alternative conceptions for the specific content area, empirical studies of learning processes or pathways of learning (i.e., from initial alternative conceptions to a more scientific view), theoretical investigations about physics learning from a constructivist view, and research about development of a teaching sequence (Bryce & MacMillan, 2005; Niedderer, 1992). Duit, Niedderer and Schecker (2007) note that about 64 % of the above empirical studies documented are carried out in physics.

As an example of how this process works, van Dijk and Kattmann (2007) in an attempt to integrate didaktik of science with PCK development based on a pedagogy approach in the curriculum tradition, started with conceptual analysis of specific content and analysis of literature on students' alternative conceptions. At the same time, they also focused on empirical research on student's alternative conceptions and empirical research on teachers' PCK, and these in turn led to the process of designing a teaching sequence. According to Lijnse (2000) and Niedderer (1992), as each specific content area involves steps of learning, then a teaching sequence involves content-specific teaching/learning processes.

As mentioned in Chapter 2, there are a variety of designed teaching sequences reported in the literature, such as bridging analogies (Brown & Clement, 1989; Brown, 1992 & 1994; Bryce & MacMillan, 2005; Clement, 1993 & 1998; Minstrell, 1982; Niedderer 1992), concept mapping (Novak, 1996 & 2002), cognitive conflict strategies, modelling (Tiberghien, 2000), contrastive teaching (Schecker & Niedderer, 1996), and bridging representations (Savinainen, Scott & Viiri, 2005). At first sight these might look like pedagogies, but as we shall see below their use in the classroom requires a carefully enacted teaching sequence. Three of these are reviewed here because they are didaktik in origin, and have been reported as being successful in enhancing students' learning. The first one is the bridging analogy, the second is contrastive teaching, and the third is the bridging representation; these are now described in turn.

3.3.1 Teaching Sequence Using a Bridging Analogy for Newton's Third Law

This strategy of a teaching sequence aims at developing and building on students' alternative conceptions, moving them towards the scientific view. The term bridging analogies is described as a series of related analogies, from an everyday base analogy to the target situation, via a series of intermediate analogies between 'close' and 'far analogies' in order to make the transition to the target more obvious to students (Bryce & MacMillan, 2005). Bryce and MacMillan (2005) note that the use of analogies in the teaching sequence assists students to develop an understanding of abstract phenomena because they successfully use more concrete examples. This strategy also known as bridging strategy and it has three elements: the anchor; the bridging elements; and the target. The example used is Newton's third law for a book on a table (at rest condition) – see Figure 3.3.

According to Brown and Clement (1989), this strategy has four main stages: students' alternative conceptions on specific content are made explicit by using target questions (e.g., forces acting on a book on a table); the teacher then introduces another situation as an analogy. This analogy is known as the anchoring analogy (e.g., a hand pushing down on a spring); next the teacher asks the students to compare the 'anchoring analogy example' (between the anchor & target) to the real situation; if the students do not understand the example, the teacher then try a series of bridging analogies (e.g., a book on top of a spring & then on top of a noticeably flexible board). The bridging analogy is thus a 'bridge' situation between the anchoring example, and the actual situation or target.

In the case of a book on a table, generally the students only see one force, the force of gravity acting on the book but not the force from the table on the book. The students can only see the second force through the analogous anchor of a finger pressing on a spring. Students can see both forces from this example because in their alternative conceptions of 'force', forces are exerted only from active and moving objects (a finger and a spring).

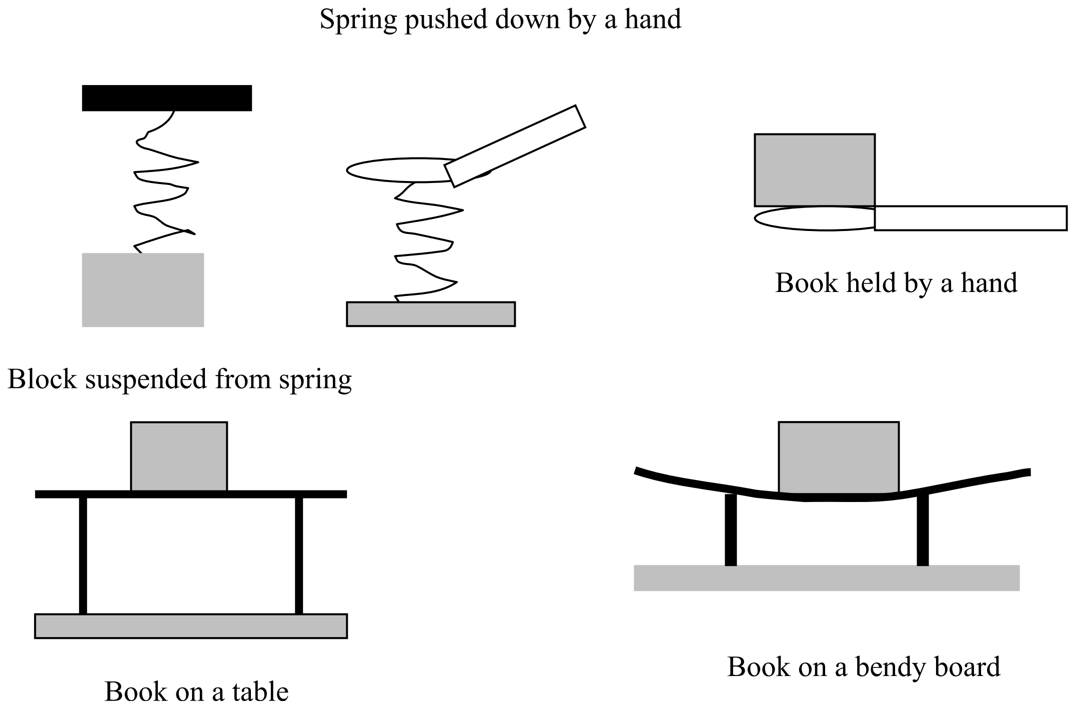


Figure 3.3 Bridging Analogies
from Bryce & MacMillan, 2005

Niedderer (1992) claims that a teaching sequence with bridging analogies has four important features: an explanation within a microscopic model seems to be more scientific than other explanations, and knowledge seems to be the true or real for the students; additional experiments are required to explain and demonstrate the two forces; teaching behaviour such as asking questions to the students like ‘does that make sense to you?’, ‘How does this kind of picture or this force make sense to you?’ and finally the extensive use of thought experiments. Although this teaching sequence seems developed and built on students’ alternative conceptions, in the context of this thesis, secondary school students learn through their existing experience and beliefs, and these experiences make sense to them. Then, students are able to accept new knowledge provided that they themselves understand. In other words, as Lijsne (2000) claims that students come to see the point of extending their existing conceptual knowledge, experiences and beliefs systems in a certain direction.

3.3.2 A Teaching Sequence for Newton's Third Law Involving Contrastive Teaching

The description of the following contrastive teaching sequence is based on work by Schecker and Niedderer, (1996). The authors use the term 'contrastive teaching' drawing on its parallel with 'contrastive grammar', a linguistics method for teaching and learning a foreign language. Here, grammatical features of the target language are introduced by comparing them explicitly with related structures of the mother tongue. Thus, in contrastive teaching, the students' intuitive ideas about scientific knowledge correspond to the mother tongue, whereas the scientific view and concepts correspond to the target language. In contrastive teaching, the emphasis is on qualitative understanding, ways of handling students' alternative conceptions, attention to students' ideas about physics teaching, and appreciation of students' ideas. According to the authors, contrastive teaching was designed mainly for secondary students (16 to 19 years old), and involves six stages:

- *preparation* – conventional teaching with demonstration experiments and teacher-dominated presentation of concepts is carried out - or textbook problems with calculations are posed
- *initiation* – the teacher introduces a new topic by; sketching a broad framework for students' activities, offering a set of apparatus for free experimentation, and demonstrating an initial experiment without explanation. An open-ended question is posed. The students form groups, elaborate their own ideas or work out questions and hypothesis for their own investigation; *performance* – the students formulating questions or hypotheses, planning and performing experiments, making observations, theoretical discussions, and formulation of findings on their own words. The teacher stays in background, working as facilitator on demand, and does not interfere with students' discussion

- *discussion of findings* – the groups present their results in a whole-class forum. The teacher writes these on the whiteboard or blackboard using the students' words. The teacher challenges students' views by indicating inconsistencies or suggesting additional experiments. The students defend their notions and often modify them slightly, but they do not change their ideas immediately

- *comparison with scientific theory* – the scientifically accepted explanation (concepts, principles and laws) is offered as an alternative view and compared with the students' ideas, but not as the 'truth'. Commonalities and differences are made explicit. The advantages of scientific theory for universal application and precise prediction in a controllable setting are shown. Intuitive conceptions are described as more appropriate and better suited for everyday communication about specific single events. In addition, class findings are compared with similar historical theories or modern ideas as well as differences are stated and possible reasons for those differences are discussed. However, this stage implies chances and risks such as a guided comparison helps students to see differences between their conceptions and scientific theory as well as specific differences, and a confrontation with completely different physical concepts may disappoint students and make them look upon their own efforts as useless, and

- *reflection* – students are encouraged to look back on the process and their performance, and to consider particular questions or difficulties in their problem finding and problem solving processes which arose. Findings from the philosophy of science about the different structure of everyday life thinking can help to students to notice and accept any differences.

In an evaluation of contrastive teaching, Schecker and Niedderer (1996) report that students from the class taught using a contrastive teaching-based teaching sequence gained significantly higher scores in a questionnaire on conceptual understanding for mechanics compared with others taught via conventional teaching (measuring problem solving and quantitative formal reasoning).

3.3.3 A Teaching Sequence for Newton's Third Law Using a Bridging Representation

This description of a teaching sequence incorporating the notion of a bridging representation (Savinainen, Scott & Viiri, 2005) is mainly derived from the bridging analogy mentioned above. Here rather than utilizing a physical system as a bridge in a bridging analogy (see Section 3.3.1), a diagrammatic representation is used as a bridge, and is termed the symbolic representation of interaction (SRI). This involves a diagram which shows mechanical interaction between pairs of objects that are identified explicitly, and this provides a bridge linking of concrete physical situations with the more abstract free-body diagram involving vector notation and the equations of Newton's laws. This contrasts with the normal free-diagram body that concentrates on forces acting on one target object, and subsequently does not make the concepts of interaction explicit to students. The authors argue that the pedagogic function of the SRI diagram lies in providing a bridge, and they termed this a bridging representation (Figure 3.4). This teaching sequence was developed within the context of Newtons' third law, drew upon conceptual change theory, the concepts of bridging analogy, and bridging representations. Bridging analogies and bridging representations are intended to promote conceptual change. In the context of Malaysian Form 4 physics classroom both are used, not only, to guide students to make sense but also to construct scientific knowledge. In other words, as Lijsne and Klaassen (2004) argue that construction of scientific knowledge can serve practically (learning to cope with everyday life), theoretically (learning to understand nature), technically (learning to design artefacts or industrial products), and societally (learning about science and society).

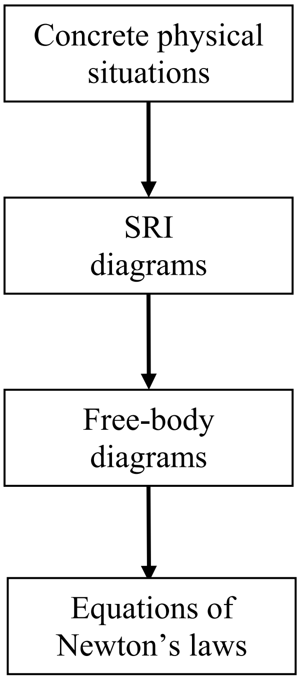


Figure 3.4
The SRI diagram acts as a bridge linking concrete physical situations with free body diagrams and the equations of Newton's laws

Developing this teaching sequence started with analysis of conceptual change theories and literature on students' alternative conceptions, and also considered the role of the teacher in mediating teaching activities. The researcher first discussed learning Newtonian mechanics from the conceptual change literature, whereas the teaching activities were informed by social perspective on conceptual change (Leach & Scott, 2003). This perspective illustrates teaching and learning as a process where students are introduced to new ways of thinking and talking about the natural world. The teacher has the critical role in introducing physics language to students, and guiding them to use it independently. First, conceptual analysis was done through an analysis of curriculum specifications and textbooks presentations (i.e., to identify the school science knowledge to be taught), and how this knowledge is conceptualised in the everyday language of students. From both documents, the teacher identified the differences between students' everyday knowledge and scientific knowledge that was to be taught. According to Leach and Scott (1995), the nature of any differences may be due to the conceptual tools used, ontological assumptions, and the epistemological underpinnings of the content.

Savinainen and Scott (2002) outline three general features of a bridging representation: *conceptual* focus – here class discussions of concepts focus more on qualitative understanding before considering *problem solving*; exploring meaning in carefully framed peer discussion monitored by the teacher – here the role of the teacher is to promote discussion among the students to use and make their construction explicit; and using *multiple representations* and linking between such representations. For example, the teaching of the terms force and motion starts by giving examples of a variety of forces and motion, and posing interesting questions to stimulate curiosity. This includes an object at rest; equilibrium rules for forces and moments, levers and inclined plane; forces on moving objects; Newton's first law; general rules that forces result from interactions between pairs of objects; accelerated objects and that motion can be explained by Newton's second and third laws. To illustrate further, teaching activities involved the students discussing conceptual exercises in pairs. As group discussion takes place, the teacher moves around to monitor understanding of the questions posed. The pairs compare their answers and follow this by comparing their explanations with the explanation provided by the teacher. This was done through demonstration and experiments because both become sources of conceptual questions, and serve as a basis for verbal conceptual exercises.

Again at first sight, the features mentioned above seem to represent constructivist-based science teaching and are nothing new, but the concepts of force (often not clear to students and hidden) are made explicit. In other words, the concept of interaction between pairs of objects is made explicit to students.

Initially the concepts of force were introduced in the context of 'contact interaction', then the students were asked to press down on a table with their thumbs and to observe what happened. This touching was characterised as an interaction between thumb and table. They were also asked to press textbooks and notebooks to see if they too were deformed. This made it easier to believe that the table does deform in an interaction with other objects. Then, the students were asked to press the table gently, and then hard, and to observe if there were any changes in the deformation of their thumb. This simple activity gave them a sense that the strength of an interaction can vary, and at this point, 'force' was defined as a measure of the strength of interaction. An ordinary scale and a spring balance were used to measure the strengths of interaction. These activities sought to build on the students' existing ideas and extend them to new situations in the spirit of a bridging analogy.

Next the SRI diagram was introduced as a tool used to represent interactions. Double-sided arrows show interaction between two objects, and double-headed arrows indicate interactions that are always symmetrical, and their interactions are all explicated in a diagram (see Figure 3.5). It was emphasized that both objects mutually interact, and that the interaction is symmetrical. For example, "the interaction between the hand and the block is symmetrical, thus the force exerted by the hand on the block has the same magnitude as the force exerted by the block on the hand, but the opposite direction." The same SRI diagram represents the situation in which the block remains at rest (friction would be static or resistance to motion).

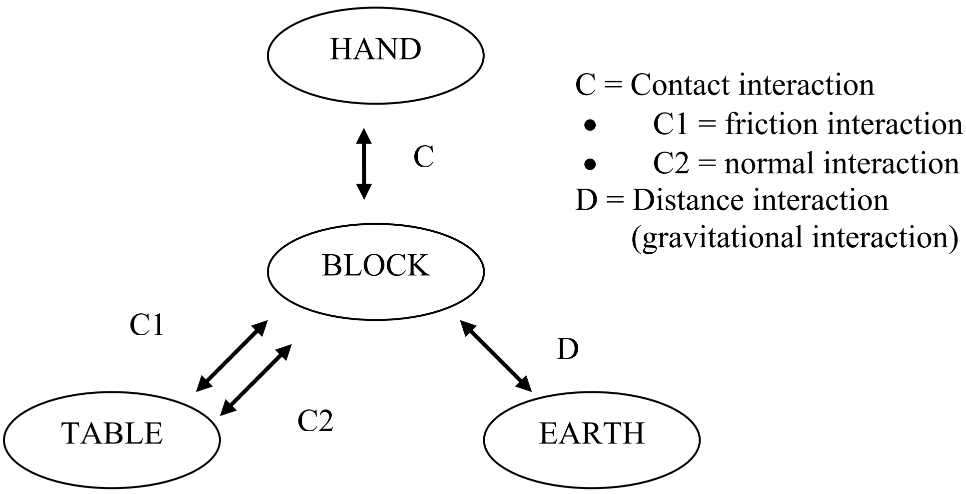


Figure 3.5
A SRI diagram of a block sliding on a table.
(from Savinainen, Scott & Viiri, 2005)

In addition, it is not possible to tell whether the block is accelerating or not. Thus, the students were then asked to draw SRI diagrams representing the block moving at constant velocity, and when decreasing or increasing in velocity. At this point, some students realised that there was no difference in the SRI diagrams, and this indicated that it was crucial to consider the same concept from a number of different, but related, perspectives. The SRI diagram does not show the magnitudes of the forces, whereas free-body diagrams show the magnitude of interactions via the length of force vectors, as well as allows in determining the direction of possible acceleration from the sum of force vectors (the net force). The students were then required to draw both SRI and free-body diagrams for multiple situations, and were asked to compare their diagrams in peer discussions. This approach provided many opportunities for the students to explore meaning together. Once they reached a consensus on both diagrams and their verbal explanations, the teacher provided his or her explanations and checked how many of the students' solutions and explanations were correct in the sense of scientific knowledge.

The authors claim that the SRI diagram not only addresses all aspects of conceptual learning, but also provides visualization tools for identifying and representing interactions between objects, and these in turn help students to perceive forces as the property of an *interaction* instead of a property of an *object* (i.e., addressing the ontological aspect). Addressing the conceptual aspect involved the use of the double-headed arrows, showing the interaction between two objects is symmetrical, whereas applying the SRI diagram in a variety of situations helped the students to realise that Newton's third law is valid in all situations regardless of contextual features (i.e., addressing the epistemological aspect).

As the force is a measure of the interaction, the same amount of force is necessarily exerted on both objects. Figure 3.5 illustrates the situation of a hand pushing a block on the horizontal surface of the table. Here, the block is located at the centre because it is the target object in this example. Figure 3.6 illustrates a possible corresponding free-body diagram. The perpendicular and parallel components of contact interactions are identified, to facilitate a better corresponding with free-body diagram. Although the division between contact and distance forces is not justified in the context of modern physics, it is a useful distinction in introductory mechanics.

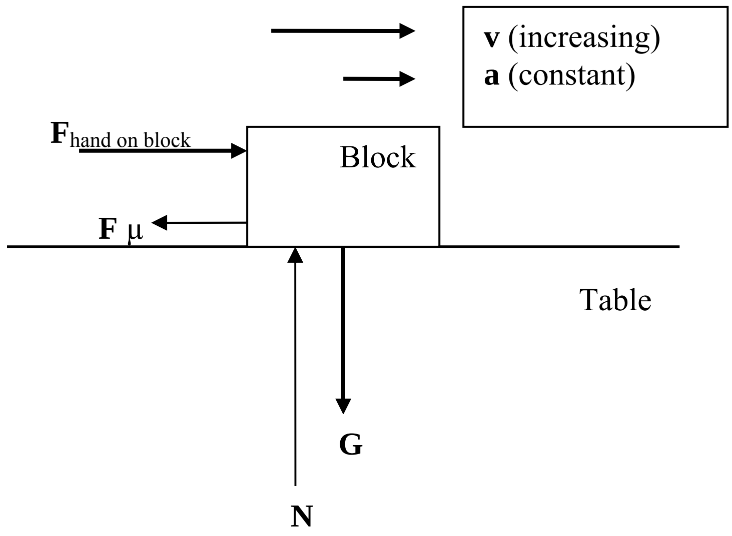


Figure 3.6
A free-body diagram showing a block sliding on a table with constant acceleration used in a teaching sequence based on a bridging representation

Evaluation indicates that this teaching sequence is successful in promoting contextual understanding of Newton's third law, at least at the level of identification: the students could identify the correct answers from non-Newtonian alternatives and justify their reasoning.

3.4 CHAPTER SUMMARY

The strengths of the teaching sequence for Newton's third laws are the careful attention to detail required by the principles for developing a teaching sequence, and the didaktik analysis developed in specific areas of physics content. Furthermore, the variety of theoretical perspectives drawn upon in developing these teaching sequences enhanced learning outcomes in the classroom.

This chapter has thus presented two key aspects of didaktik analysis. A key underlying notion is that didaktik analysis is *content specific*. Hence, in this chapter the researcher has presented didaktik analysis of physics using the mechanics concepts of force and motion as an illustration. This analysis consisted of a review of the students' alternative conceptions literature for the concepts of force and motion, along with content analysis of the concepts of 'force and motion', and descriptions of some teaching sequences based on this specific physics content area (Newton's third law).

The above content analysis of concept of force and motion, in combination with an analysis of literature reports of student alternative conceptions and developed teaching sequences based on specific physics content area (Newton's third law), were subsequently used to guide the training of pre-service physics teachers at the institution that formed the context for this study. The theoretical basis to this thesis, and how the above analysis was incorporated into an intervention, is the subject of Chapter 4 which follows.

CHAPTER 4

THEORETICAL UNDERPINNINGS OF THE THESIS

CHAPTER OVERVIEW

The description of the literature on the use of didaktik analysis in science education and for a particular domain of physics presented in previous chapters is based on the research questions set out in Chapter 1. This chapter seeks to draw five dimensions that together form the theoretical underpinnings for the thesis. The first dimension of the theoretical underpinnings is the *physics dimension* including an analysis of literature on students' alternative conceptions generally in the domain of physics, and particularly the physics concepts of force and motion. This is presented in the previous chapter that concerned the didaktik of physics. The researcher now draws on Chapter 3 to present here three additional dimensions: a *teaching dimension* (Chapter 2 and this chapter), a *learning dimension*, and a *personal dimension*. Key issues for these dimensions discussed in this chapter are pre-service physics teachers' concepts, beliefs, attitudes and self-efficacy, the connection of these with their knowledge and practices of teaching physics, and the researcher as a student, physics teacher and physics educator. These dimensions are linked with the researcher's philosophy of knowledge and knowledge acquisition, and these together inform the *research dimension* (the 5th dimension) which is presented in Chapter 5 as part of the research methodology. The theoretical underpinnings for the thesis are shown in Figure 4.1.

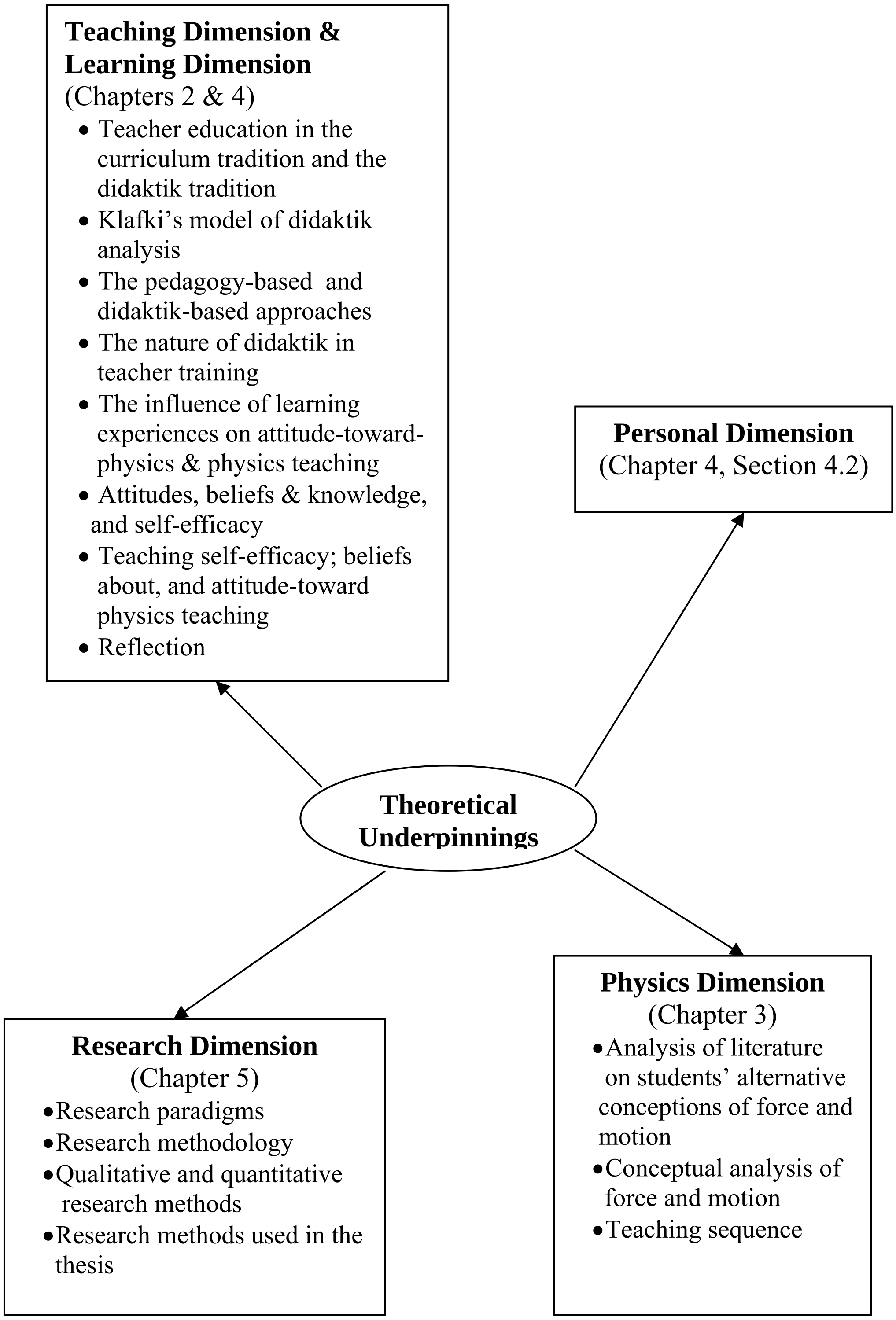


Figure 4.1
Theoretical underpinnings for the thesis

4.1 TEACHING AND LEARNING DIMENSIONS

Although a didaktik-based analysis approach to teaching and learning inherits its thinking of teaching and learning from a different tradition (the didaktik tradition), it shares ideas of teaching and learning with conventional pedagogical approach to teaching and learning. The details of didaktik-based analysis theory of learning refer to "*Bildung*" (Fensham, 2004, p. 147), a concept Fensham (2004) notes, is problematic in terms of translation. Fensham (2004) comments that the use of metaphor helps our understanding "*the formation of a learner as an individual character or whole personality*" [original emphasis](p. 147). Other writers, such as Klafki (1995), effectively seek to interpret *Bildung*, but key themes to emerge are the importance of educational context and sociological factors. Thus, the theoretical basis for didaktik-based analysis approach to teaching and learning is consistent with social constructivism and indeed socio-cultural theory of teaching and learning is based on Vygotskian's perspective (Hodson & Hodson, 1998). According to Hodson and Hodson (1998), this theory for teacher training is likely to be inquiry oriented, personalised and collaborative, and conducted in accordance with the norms and values of the community of practitioners.

Thus, the teaching dimension and learning dimension consider literature about pre-service physics teachers' beliefs, knowledge and practices, physics teaching self-efficacy and attitudes towards physics teaching. Prior to describing pre-service physics teachers' beliefs about, and attitudes towards physics teaching; their learning experience at secondary school and tertiary, attitudes-toward-physics and learning, physics teaching self-efficacy, and conceptual understanding of specific secondary school physics content, are reviewed. The major reason for these reviews is the didaktik analysis that has been included in the physics teaching methods course content. The move to incorporate these aspects of didaktik analysis into the synopsis of the course is because they have implications for pre-service physics teachers' beliefs which were involved in their practicum. Pre-service physics teachers involved in didaktik analysis come to the practice of it with their own beliefs and attitudes. Knowledge of such beliefs and attitudes are essential because the success or failure of introducing didaktik analysis depends on the actions of the pre-service teachers concerned. Pre-service physics teachers' ability to reflect is another issue and this also is explored in this chapter. This discussion considers whether or not the pre-service physics teachers' engagement in reflection is driven by an assignment on didaktik analysis, and on their teaching practice both in the microteaching and practicum.

The literature about the teaching dimension and learning dimension is presented in five sections. Section 4.1.1 reviews literature on learning experiences of pre-service physics teachers at the secondary and tertiary levels. This is followed by looking at definitions of attitudes, beliefs and knowledge; and self-efficacy beliefs in section 4.1.2. Their theoretical basis draws on the work of Bandura (1986). Conceptual differences between the definitions and self-efficacy beliefs are also explained. Section 4.1.3 then discusses literature on pre-service teachers' attitudes towards science, their physics teaching self-efficacy beliefs, and their beliefs about, and attitudes towards, physics teaching. Section 4.1.4 reviews the literature on reflection in terms of definitions and form, both from the perspective of a pedagogy approach and didaktik approach. Key literature on the teaching dimension and learning dimension in teaching training programmes are then summarised in section 4.1.5.

4.1.1 The Influence of Pre-service Teachers' Learning Experiences on Attitude-toward-Physics and Physics Teaching

This section reviews the factors influenced by learning experiences on pre-service teachers' attitude-toward-physics and learning, and on physics teaching self-efficacy beliefs. The literature suggests that, not surprisingly, negative learning experiences are related to a negative attitude towards physics, a subject which is seen as being difficult to understand, and uninteresting (Angell, Guttersrud, Henrikson & Isnes, 2004; Carlone, 2003; Nolen, 2003; Osborne & Collins, 2001). In contrast positive learning experiences result in physics being seen as stimulating and challenging, enjoyable, and resulting in satisfaction. Such factors, negative or positive learning experiences, seem to be interrelated or intertwint and Pajares (1996) comments that what an individual chooses to attend to, is influenced by his or her attitudes and beliefs about his or her experiences. Nespor (1987) says such learning experiences are critical because they "produce a highly detailed episodic memory which later serves the student as an inspiration and template for his or her own teaching practice" (p. 320). In particular for pre-service physics teachers, it seems that they tend to believe that their own learning "experience is the best teacher" (Richardson, 1996, p. 108).

Angell et al. (2004) report on learning experiences about physics among students in upper secondary schools and physics teachers in Norway. Their findings seem suggest that the pre-service teachers see the particular nature of physics as the main reason that learning experiences are either positive or negative (Duit, Niedderer & Schecker, 2007). From the researcher's experience in the physics teaching methods course, Angell et al.'s (2004) conclusions also apply to the pre-service teachers in that:

- The subject is regarded as difficult, with a higher workload, a faster progression and being more conceptually demanding but interesting, and the teaching is often good. Although difficult, in physics sound understanding is essential
- The subject is seen as theoretical and abstract, but still strongly related to real world
- The language of physics is mathematics and mathematics is a useful tool for shedding light on physical processes and phenomena
- Good achievement is associated with teaching 'physics content and basic laws' whereas low achievement is directly related to teaching 'history, context, and processes of physics'
- Doing experiments is interesting as the aim is showing the theory in practice, that is, having theoretical background in place, before doing the experiment or watching a demonstration, and
- Experiments can help in making physics concepts clear, whereas teacher demonstrations may not.

Attitude-toward-physics and learning and self-efficacy beliefs of pre-service teachers are reported to affect their teaching (Bryan & Atwater, 2002; Haney, Lumpe & Czerniak, 2002; Pajares, 2002). Particular aspects of physics learning, experienced at the secondary (see e.g., Hăussler & Hoffman, 2000) and tertiary levels, and reported in the literature can be divided into three categories: teacher, student, and the class environment (Haladyna, Olsen & Shaughnessy, 1982; Myers & Fouts, 1992). Experiences from all these three categories each impact upon pre-service teachers' beliefs, and result in either their positive or negative attitudes towards physics teaching. Haladyna et al. (1982) say that the most important variable affecting students' attitude is the type of science *teaching* they experienced. Specifically, Myers and Fouts (1992) report that the positive classroom learning experiences are associated with high levels of involvement, very high levels of personal support, strong positive relationships with classmates, the use of a variety of teaching strategies, and unusual learning activities.

Woolnough (1994) reports common aspects of physics teaching that he identified to be effective: a supply of well qualified teachers, enthusiastic science teachers, who not only have a good spread of expertise across content but who also have individual subject loyalty. Good teaching was characterized as a teacher being enthusiastic about his or her subject, setting the subject in everyday contexts, and running well ordered, and stimulating science lessons. A good teacher also is characterized as being sympathetic and willing to spend time, both in and out of classroom, talking with the students about science, careers and individual problems.

These reports suggest that pre-service teachers who are positive about their teachers are positive about physics teaching. For example, research of pre-service teachers' views about the competency of their physics teachers, suggest it forms an important component of successful learning experiences, and it seems that the competency of their teachers affects their attitude and their willingness to teach in the classroom (Barros & Elia, 1998). Pre-service teachers are influenced by how they were taught and they tend to follow in the same footstep when teaching their own students (Barros & Elia, 1998).

As might be expected, it seems teachers are very focused on covering the curriculum (Sadler & Thai, 2001) in order for their students to do well in examinations (Angell et al., 2004), and Osborne and Collins (2001) note that emphasis on achievement in national examinations may result in declining interest in the subject. These types of learning experiences with their teachers appear to influence pre-service teachers' attitude-toward-physics and learning and consequently their teaching self-efficacy beliefs. For example, negative experiences serve as a barrier to a desire to teach physics whereas positive experiences are likely to promote an intention to teach physics (Zacharia, 2003). In addition, the attitude of teachers towards the subject - such as amount of time they devote to clarifying content, how prepared they are to explain things and provide enjoyable learning opportunities, whether or not they have good rapport or relationships with students and if they provide opportunities for students to raise questions and discuss aspects of science, if they have good humour, and pace learning well – all appear strongly associated with a perception of positive learning experiences (Bencze & Hodson, 1999; Nolen, 2003; Osborne & Collins, 2001; Sadler & Thai, 2001; Zacharia, 2003). Thus, positive attitudes and higher self-efficacy beliefs towards teaching have been found to be enhanced through good learning experiences (Haladyna, Olsen & Shaughnessy, 1982; Myers & Fouts, 1992).

Particular pre-service teachers' learning experiences with their teacher's teaching approaches reported in the literature include: lectures and note taking, the use of textbooks, teacher demonstrations and experiments, and problem-solving exercises (Nolen, 2003; Osborne & Collins, 2001; Sadler & Thai, 2001). Angell et al. (2004) explored the connections between different teaching methods and student learning outcomes and engagement of students. They suggest that to give students a good impression about physics and expose them to positive learning experiences, the following may help:

- Make the subject less demanding or work-intensive compared with other subjects, by, for example, reducing the number of topics covered
- Emphasise science knowledge in context
- Use more qualitative/conceptual discussion and demonstrations
- Make the role of experiments clear
- Integrate mathematics in the physics course, and
- Use a variety of teaching methods.

These types of pre-service teachers' learning experiences with their teachers at the secondary and tertiary levels; teaching approaches, lectures, use of textbooks, experiment and teacher demonstrations, and problem solving are to be discussed in turn, next.

4.1.1.1 Learning Experiences - Teaching Approaches

Secondary School Level: Physics like most science subjects is a subject that is probably impossible to learn on one's own, meaning students depend heavily on the teacher to explain (Angell et al., 2004), and this points to the importance of the role of the teacher (Carlone, 2003). Although new teaching approaches have received increasing attention in science education research of late (Fensham, 2004; Savinainen, Scott & Viiri, 2005), the literature suggests they have not been that successful, and that much teaching still involves science content being transmitted as a set of facts, data, and laws (Barros & Elia, 1998; Magnusson, Krajcik & Borko, 1999). Such an approach is thus still teacher-centred and dominated by 'chalk and talk', termed 'didactic' (Angell et al., 2004), despite teachers being encouraged to shift to more student-centred approaches (Angell et al., 2004; Cuban, 1990).

A teacher-centred emphasis tends to emphasise terminology (Gallagher, 1991), with students reciting information they have memorised; with the teacher doing most of the talking (Cuban, 1990). A common reason teachers rely on such information-transmission approaches is they may be teaching outside their own subject specialisations (Hacker & Rowe, 1985; Hashweh, 1987).

Such 'chalk-and talk' classroom experiences are seen as boring by students as they involve students learning passively; copying teacher notes, focusing on facts, and involving repetition, with little discussion, and much time devoted to revision (Osborne & Collins, 2001). In comparison to other topics, physics teaching typically involves more manipulation of mathematical problems than conceptual learning because homework and examinations involve many problems that require students to use formulae (Hoff, 2003). Such learning experiences have been reported to adversely affect attitudes of pre-service teacher towards teaching physics (Bencze & Hodson, 1999). Barros and Elia (1998) identified three negative attitudes towards teaching physics that deal with the teacher-centred approach:

- Teacher's lack of confidence due to poor conceptual understanding of physics
- Most of the time teachers act as information providers with few characteristics of spontaneity, and teachers believe that all students are identical and ready to follow the same type of instruction, and
- Physics teachers have a tacit understanding, similar to students that the important aspects of physics have to do with manipulation of mathematical symbols.

Experience of physics teaching methods, either in the classroom (Nolen, 2003) or in the laboratory (Hofstein & Lunetta, 2004), varies from one pre-service teacher to another. It seems some pre-service teachers prefer variation in teaching methods (Angell et al. 2004; Kempa & Diaz, 1990; Sadler & Thai, 2001) with some preferring student-centred approaches with emphasis on qualitative and conceptual understanding (Angell et al. 2004). Apparently explaining problems in several different ways is seen as useful (Sadler & Thai, 2001), and a key factor in generating interest in science education (Piburn, 1993). These experiences of teaching methods either in the classroom or in the laboratory are summarized based on Magnusson, Krajcik & Borko's (1999) orientations of teaching science (see Table 4.1). For example, the goal of a didactic orientation to teaching is to transmit the facts of science. In this orientation, the role of the teacher is to tell students the knowledge, or transfer a body of knowledge to the students who receive it passively. The role of the students is to listen to the teacher and 'learn' the facts provided. Students are seen as a 'vessel to fill' (Cuban, 1990; Gallagher, 1991; Grayson, 1996).

On the other hand, the goal of *discovery orientation* is "to provide opportunities for students, on their own, to discover targeted science concepts" (Magnusson et al., 1999, p. 100). There are a number of discovery teaching methods such as inductive and deductive reasoning and coming to understand academic rigour. Discovery teaching methods concentrate upon closure for some important process, fact, principle, or law which is required by the science curriculum. It appears to focus on end products.

Some authors (see, e.g., Coble & Koballa, 1996) report that a *science process* approach emphasizes the 12 learning processes of: observing, classifying, measuring and using numbers, making inference, prediction, communication, using space/time relationship, interpreting data, defining operationally, controlling variables, making hypothesis and experimenting. This line of inquiry has important implications for teaching the content of the lesson, given that findings can be used to emulate scientists' work as distinct from learning about scientific facts and phenomena.

Table 4.1
Orientation of Teaching
(from Magnusson, Krajcik & Borko, 1999, pp. 100-101)

Orientation	Goal of teaching science	Characteristics of science instruction
Academic Rigour	Represent a particular body of knowledge	Students are challenged with difficult problems and activities. Laboratory work and demonstrations are used to verify science concepts by demonstrating the relationship between particular concepts and phenomena.
Process	Help students develop the 'science process skills'	Teacher introduces students to the thinking processes employed by scientist to acquire new knowledge. Students engage in activities to develop thinking process and integrated thinking skills
Didactic	Transmits the facts of science	The teacher presents information, generally through lecture or discussion, and questions directed to students are to hold them accountable for knowing the facts produced by science
Discovery	Provide opportunities for students on their own to discover targeted science concepts	Student-centred. Student explores the natural world following their own interests and discover pattern of how the world works during their exploration

A great effort has been made in Malaysia to make secondary school physics teaching more interactive and inquiry-based through the development of constructivist-oriented teaching. This is intended to involve things such as: interactive teaching, generative teaching, concept maps, conceptual change, cognitive conflict, Science, Technology and Society (STS), learning cycle, cooperative learning, and inquiry (Kementerian Pendidikan Malaysia, 1991, 2001, 2004). However, Lilia and Subahan (2002) report Malaysian secondary school teachers rely heavily on verbal explanations, and that the changes employed by experienced Malaysian science teachers were simply to teach at a slower pace, to leave out difficult topics, and give more detailed notes. The reasons for these changes according to Lilia and Subahan were due to teacher perceptions of student lack of interest in physics and their poor mathematical competency.

Tertiary Level: Compared to the growing body of research on teaching experiences at secondary level, it is interesting to note that there is little reported research on learning experiences at the tertiary level. However, overall it seems that traditional teaching is still the prevalent way - although there are some signs of change. Dalgety, Coll, and Jones (2003), for example, report that the nature of the tertiary level teaching experiences depends on the situation, with, for example, tutorial classes seen more positively and as more beneficial in helping students prepare for tests and examinations. Dickinson and Flick (1998) say that overall tertiary physics teaching again focused on solving algorithmic problems, with emphasis on procedures rather than conceptual understanding.

4.1.1.2 Learning Experiences - Lectures

Yager (1983) suggests that some secondary school science teachers teach science via lectures and use question and answer techniques. He comments that such lectures and question/answer periods are based upon information that exists in textbooks. Yager concludes that when science teachers rely so heavily on textbooks, the textbook becomes a *de facto* course outline, and sets the framework, and parameters of the student learning experience, which will be dominated by testing, and which portrays a certain world view of science.

Osborne and Collins (2001) note that the lecture teaching method at tertiary level taken from texts promotes passive learning, the problems developed in the tutorial classes lead to algorithmic, and repetitive solutions, and fail to stimulate the reasoning skills needed to approach new situations, and laboratory work is restricted to mere verification. The lecturers had notes and sample problems prepared earlier to be used in the lecture hall. They demonstrated problems either on overhead projector, PowerPoint presentation or writing on the rolling blackboard together with lectures to illustrate concepts of physics. They have correctly solved an example problems list just to be copied onto an overhead projector, and written on the rolling blackboard or PowerPoint presentations.

4.1.1.3 Learning Experiences – Use of Textbooks

Science textbooks are a primary resource in physics teaching (Baker, 1991; McCarthy, 2005; Shymansky & Kyle, 1992; Wheatley, 1991; Yager, 1992). Peacock and Gates (2000) comment that the main uses of textbook are: for the teacher's own learning and preparation; as starting points or triggers for new topics; to guide students to do practical activities; and when practical activities are seen as inappropriate. However, Baker (1991) says that using the textbook is less effective than other methods of instruction. Such teaching may be regarded as an effective way of covering a detailed syllabus, of providing the activities for use in the classrooms and/or laboratory (Whiteley, 1996; Yager, 1992). However, a textbook is content-driven, and science teaching tends to end up being based on lectures, and question and answer sessions (Stinner, 1995). Sadler and Thai (2001) suggest that using no textbook at all, or reading it less, can improve students' achievement and in turn generate interest. This is consistent with the view of Yager (1983) who says that textbooks appear to 'imprison' science teachers. There are a variety of reasons why science teachers depend so heavily on textbooks (Shymansky and Kyle, 1992; Yager, 1983):

- Most physics teaching is based on the information present in a textbook
- A textbook is used as the 'answer place' for teacher questions; both those used in discussions, and those used in examinations
- The teaching sequence employed in the classroom is often dictated by a textbook. Such typical sequence is assign, recite, test, and discuss test
- Teachers' questions tend to focus on information in the textbook
- The laboratory is used to provide deductive verification of ideas presented in the textbook, and
- A lack of equipment and supplies for other teaching methods.

Overall, learning experiences that rely on textbooks result in learning consisting of the memorization of large amounts of information and regurgitating this back in tests and examinations.

4.1.1.4 Learning Experiences - Experiments and Teacher Demonstrations

Kang and Wallace (2005) say that the role of laboratory work in teaching is "to prove the verity of scientific knowledge; to provide the opportunity to apply the concepts; to motivate students; to provide first-hand experience to assist learning; to train students in the scientific way of thinking, and to prove the exploratory power of scientific theories" (p. 9). Overall, teaching using experiments and demonstrations of physics knowledge is seen as more rewarding, attractive and entertaining for students (Angell et al., 2004; Sadler & Thai, 2001). Although the use of laboratory work in physics teaching has received considerable research attention in the past decade or so, little attention has been paid to attitudes towards physics and self-efficacy beliefs that may develop from experiences of laboratory work (Freedman, 1997; Zacharia, 2003). Although the use of an experiment does not necessarily bring about gains in general reasoning, it seems it does help equip students with laboratory or technical skills (Baker, 1991; Laws, 1996), which may result in greater interest, sense of ownership, and fun.

Science teaching, other than lectures, is still heavily dependent on laboratory work (Laws, 1996; Jenkins, 1998). Angell et al. (2004) say that demonstrations to illustrate concepts or phenomena are quite frequent, and experimental work is often taken from textbooks, and not designed by the students. Because of this, some authors argue that teacher demonstrations are as important as students doing their experiments themselves (Hofstein & Lunetta, 2004; Hodson, 1993; Lock, 1988). This is because scientific concepts are more accessible and more easily retained even if the teacher experiment or demonstration produces incorrect results (Osborne & Collins, 2001). Although Hodson (1993) says 'experimentation' is central to science, and central to physics teaching (Lucas & Roth, 1996), he mostly sees it as 'a means to an end', the 'end' being better understanding of content learning and learning about the procedures of scientific enquiry (Lubben & Millar, 1996).

4.1.1.5 Learning Experiences – Problem-Solving

Research on learning experiences involving problem-solving consists mostly of work at the tertiary level, where it is reported that lack of mathematical skills is the main contributing factor to the lack of physics understanding (see, e.g., Orton & Roper, 2000). It seems that the 'translation' from a physical situation to the formalized language of mathematics is what students find most challenging (De Lazano & Cardenas, 2002) along with poor preparation in mathematics (Orton & Roper, 2000). In addition, Angell et al. (2004) comment that physics seems difficult because it requires learners to cope with a range of different forms of representation (illustrations, examples, models, analogies, experiments, graphs, mathematical symbols, verbal descriptions, etc.) simultaneously, and to manage the transformation between these different representations. A key difficulty is that associated with the mathematical aspect of physics - through the extensive use of equations and formulae (Osborne & Collins, 2001). Again, the researcher's experience with pre-service teachers seems apply to them.

4.1.2 Pre-service Teachers' Attitude, Beliefs and Knowledge, and Self-Efficacy, Toward Physics and Physics Teaching

If we wish to train pre-service teachers to become competent physics teachers who are positive about teaching physics we then need to consider what factors influence their attitudes and beliefs about physics and physics teaching. The literature reviewed above suggests that pre-service teachers' own learning experiences influence their attitude-toward physics and physics teaching, and these in turn influence their self-efficacy beliefs. Here literature about other factors that influence attitudes and beliefs about physics and physics teaching is reviewed.

The literature contains many definitions of attitude, beliefs and knowledge, and self-efficacy beliefs. These are now discussed in turn.

4.1.2.1 Towards an Understanding of Attitude

The notion of attitude has three components: the affective, cognitive, and conative (or action) components (Richardson, 1996). Ajzen and Fishbein (1980) argue that attitude, arises from either a positive or negative assessment of a psychological object, and that beliefs are non-evaluative. They comment that two individuals could have the same beliefs about a particular object, but could evaluate that belief differently, with one regarding it as a good thing, and the other as a bad thing. For example, two individuals might agree that physics is difficult, but one may see this as a negative attribute of physics (perhaps because he/she had bad physics learning experiences), while the other might regard it as a positive attribute (perhaps because he/she had enjoyable physics learning experiences).

Aiken (1997) describes attitude as consisting of cognitive (knowledge or intellective), affective (emotional and motivational), and performance (behavioural or action) components. However, there seems to be broad consensus that attitude has a greater affective and lesser cognitive content than beliefs (Lumpe, Haney & Czerniak, 2000; Pajares, 1992).

A definition of attitudes that is related to the study of pre-service teachers chosen here is based on Aiken's definition: "A learned predisposition to respond positively and negatively to a specific object, situation, institution, or person" (Aiken, 1997, p. 251). In other words, a positive or negative evaluation arises from beliefs of pre-service teachers about physics, about their confidence to teach physics and about physics teaching. In addition, for the purpose of this research, the common features of attitudes as described by Anderson (1994) are adopted. They are:

- Attitude is commonly associated with feelings. It can be categorised as an affective characteristic which includes emotions whether they are positive, negative or somewhere in between. In this context, the researcher attempts to interpret and to generalise how pre-service physics teachers feel about physics learning experiences, and
- Attitude is associated with feelings, but it is often in the form of an abstract idea. These feelings are directed toward or away from some target. The targets involve objectives which are associated with the specific subject. When attitudes are favourably directed toward the target, they are said to be positive. When attitudes are unfavourably toward the target, they are said to be negative. However, attitudes also involve intensity. This can be seen when some feelings are more intense than others in terms of experience and expression.

4.1.2.2 Beliefs and Knowledge

The literature likewise contains many definitions of 'knowledge' and 'beliefs', their relationship, and their relative influence on teaching (see, e.g., Koballa, 1992; Richardson, 1996; Tobin, Tippins & Gallard, 1994). Pajares (1992) classifies beliefs as: "Attitudes, values, judgements, axioms, opinions, ideology, perceptions, conceptions, dispositions, implicit theories, explicit theories, personal theories, internal mental processes, action strategies, rules of practice, practice principle, perspectives, repertoires of understanding, and social strategy" (p. 309). He further notes that clusters of beliefs form attitudes, and dictate action to be taken. Some beliefs may be explicit, but many beliefs are implicit which an individual is unable or unwilling to express. But all beliefs are highly personal and context-specific, serving to filter and interpret new phenomena.

The conceptual difference between knowledge and beliefs is not always clear, and some researchers use the terms synonymously (e.g., Kagan, 1990; Tobin et al. 1994). However, Lumpe, Haney and Czerniak (2000) say that beliefs are synonymous with knowledge, attitudes, and personal conviction - or an individual's acceptance or rejection of a proposition. Kagan (1990) similarly argues beliefs are similar to knowledge, as individual's knowledge is subjective and gained through experience, which is both tacit and contextual (Clandinin & Connelly, 1987; Lumpe et al., 2000).

Others see beliefs are distinct from knowledge (e.g., Pajares, 1992; Richardson, 1996). Nespor (1987) termed beliefs as existential presumption, alternative, affective and effective loading, and episodic structure. Existential presumption refers to an assumption about the existent or non-existence of an entity that may be seen as immutable and beyond individual control or knowledge. Pajares (1992) observes: "People believe them because, like Mount Everest, they are there" (p. 309). Alternative beliefs refer to the creation of ideals or situations that may differ from reality. In this respect, beliefs serve as a means of defining tasks and goals. Affective and effective loading beliefs refer to feelings, moods, or subjective evaluations based on personal preferences. Finally, episodic structure beliefs refer to memories derived from personal experiences.

Richardson (1996) observes that a belief is a psychological concept: This 'concept' then describes a proposition that is accepted as 'true' by the individual. On the other hand, Hollingworth, Dybdahl and Minarik (1993) argue that practical knowledge is not synonymous with belief, as knowledge is embodied within the whole person, and not only in the mind. This knowledge cannot be separated from, for example, the classroom practice and it is similar to Schön's (1987) notion of knowledge-in-action. Knowledge can be seen as evidential, dynamic, emotionally-neutral, internally structured, and something that develops with age and experience (Alexander, Schallert & Hare, 1991). Nespor (1987) argues that beliefs are far more influential than knowledge in terms of how an individual frames problems and organizes tasks, and this suggests they are stronger predictors of behaviour.

Richardson's (1996) reports the origins of pre-service teachers' beliefs and knowledge as being influenced by three types of experiences: personal, schooling and instruction, and formal knowledge. In support of this, recent work on an introductory university chemistry course suggest that undergraduates' prior experiences about learning and science were predominantly influenced by their teachers at secondary schools and lecturers at university (Dalgety, Coll & Jones, 2003).

4.1.2.3 Beliefs and Their Relationship to Teaching Practice

Richardson (1996) says that beliefs and practice are considered to have an interactive relationship, with beliefs being the driving force of one's action or practice. However, experiences and reflection-on-action also may lead to changes in and/or additions to beliefs. According to Richardson, beliefs are personal cognitive constructs that are important in pre-service teachers' practice, and are frequently connected to practice in the classroom. Practices or actions are considered to consist of 'knowing-in-action' to use Schön's (1983) term. In other words, pre-service teachers practice what they believe (Cronin-Jones, 1991; Haney, Lumpe & Czerniak, 2002). Hashweh (1996) sees beliefs and practice as interdependent, but others (e.g., Roehrig, 2004) say that beliefs must change before practice can change. For example, Cronin-Jones (1991) reports that beliefs about the relative importance of content, influences curriculum implementation. Kagan (1992) comments that pre-service teachers' beliefs are a form of situated knowledge found in the *context* (knowledge related to students); in the *content* (knowledge related to particular academic subjects), and in the *person* (the knowledge embedded within the pre-service teacher's unique, personalised belief system).

4.1.2.4 The Relationship between Self-efficacy and Attitudes, Beliefs and Knowledge

The literature suggests that the life experiences of pre-service teachers influence their perceived capability of whether or not they can accomplish a task – based on the knowledge and skill they have. These 'self-efficacy' beliefs according to Pajares (2002) emerged from Bandura's (1986) social cognitive theory. Based on this theory, Pajares (2002) notes that an individual possesses a self-system that enables him or her to exercise a measure of control over his or her thoughts, feelings, motivation, and actions. Self-efficacy is then an individual's perception of his or her ability to undertake a specific task, and to achieve specific results (Dalgety, Coll & Jones, 2003; Pajares, 1996). However, Roehrig (2004) maintains that self-efficacy is an individual's beliefs about their confidence to achieve a task.

Pajares (2002) identifies four sources of self-efficacy beliefs: mastery experience, vicarious experience, social persuasion, and physiological states and indexes. Mastery experience is thought to be the most influential, as it comes from practical *personal* experience. Vicarious experiences, are experiences resulting from observing colleagues engaged in the activity. In the case of pre-service teachers this might be observing comparable peers trying out their teaching ideas in the classroom. The thinking here is that if pre-service physics teachers' see others they consider to be of comparable ability to them succeeding, then they may then think that they also may be successful. Social persuasion comes from the influence of teachers and lecturers, for example, when a teacher trainer visits pre-service physics teachers in the school and receives positive (or negative) commentary on their teaching practice.

An important component of Bandura's (1986) social cognitive theory is the individual's beliefs of their personal competence to achieve designated types of performance, and achieve specific results (Pajares, 2002). First, an individual is motivated to perform a task if the task bears a favourable result. This is called the outcome expectancy – an individual learning experience determines whether or not a task is performed successfully. Second, is if the individual is confident about performing a task successfully. This is the self-efficacy expectation – in which an individual believes in his/her ability to perform a task. Ajzen (1985) argues that the belief of an individual ultimately determines his/her behaviour, because connections are formed among these clusters of beliefs. The resulting attitudes become action agendas, because each individual takes action based on what s/he believes.

4.1.3 Pre-service Teachers' Attitude-Toward-Science, Teaching Self-Efficacy, Beliefs About, and Attitude-Toward Physics Teaching

This section presents a review of the literature studies about the nature of pre-service teachers' attitude-toward-science, their teaching self-efficacy beliefs, their beliefs about and attitudes towards *physics teaching*. Pre-service teachers' beliefs about and attitudes towards science teaching can be examined using Bandura's (1986) social cognitive theory. Bandura notes that beliefs are thought to be the best indicators of the decisions an individual makes. Most researchers in science education believe that attitude-toward-science and beliefs about science teaching are very influential in determining pre-service teachers' classroom practice (see, e.g., Tosun, 2000) and in their subsequent teaching behaviour (Richardson, 1996).

Beliefs act as a filter through which practices are changed (see e.g, Czerniak & Lumpe, 1996). However, it is also difficult to change beliefs (see e.g., Richardson, 1996), held by pre-service teachers when they enter a university training programme, as they hold established beliefs about teaching very tenaciously (Shireen Desouza & Czerniak, 2003). What might this mean? The literature suggests pre-service teachers often resort to teaching in the ways in which they themselves were taught (Bryan & Atwater, 2002; Munby, Russell & Martin, 2001).

Pre-service teachers' beliefs also may determine whether or not they hold positive or negative attitudes towards teaching (see, e.g., Lederman, 1999), and research on 'how to teach' has emphasized the importance of teachers' beliefs on their practice (e.g., Gunstone & White, 1998; Pajares, 1992; Veal, 2004). It is argued that research on teachers' beliefs can inform how pre-service teachers' lessons on 'how to teach' in teacher training are enacted by them in the classroom. Views of 'how to teach' also are influenced by pre-service teachers' beliefs and their background about specific content knowledge (Barros & Elia, 1998; Veal, 2004).

In other words, pre-service teachers learn both specific content knowledge and what they see as a related, appropriate pedagogy. However, Tobin, Tippins and Gallard (1994) caution that pre-service teachers' beliefs may not always be reflected in their subsequent teaching practice, for a variety of logistical reasons. Work on pre-service teachers by Gustafson and Rowell (1995) supports this, and suggests that teaching and learning of science are influenced by pre-service teachers' learning preferences, science education courses, and a variety of personal experiences.

4.1.3.1 Attitude-Toward-Science

Attitude-toward-science is different from the similar sounding scientific attitude. Osborne, Simon and Collins (2003) categorise attitude-toward-science as a set of affective behaviours, namely:

- The manifestation of favourable attitudes towards science and scientists
- The acceptance of scientific enquiry as a way of thought
- The adoption of 'scientific attitudes'
- The enjoyment of science learning experiences
- The development of interests in science and science-related activities, and
- The development of interest in pursuing a career in science or science related work. (pp. 1053)

Osborne, Simon and Collins (2003) see attitude-toward-science as affective in nature, which according to them comprises feelings, beliefs, and values held by individual about the enterprise of science, school science, the impact of science on society or scientists. These attitudes may be derived from pre-service teachers' own learning experiences - favourable or unfavourable - their anxiety, their perceptions, and interest in a pursuing a career in science teaching. To illustrate, if a pre-service teachers' learning experiences in physics were difficult, then his or her perceptions of becoming a science teacher may be negative (Zacharia, 2003).

The literature suggests attitude-toward-science is difficult to measure, since it is a complex and multidimensional construct (Gardner, 1995; Osborne et al., 2003). Another difficulty in measuring attitude-toward-science is that it is a measure of how an individual expresses her/his preferences and feelings towards an object (Ramsden, 1988). As a result, Osborne et al. (2003) list a number of constructs of attitude-toward-science that needs to be taken into account when trying to measure 'attitude-toward-science' (or indeed for a specific science discipline like physics):

- The perception of science teacher
- Anxiety toward science
- The value of science
- Self-esteem at science
- Motivation towards science
- Enjoyment of science
- Attitudes of peers and friends towards science
- Attitudes of parents towards science
- The nature of the classroom environment
- Achievement in science, and
- Fear of failure on course.

Ramsden (1998) in her study concludes that many students' attitudes-toward-science are:

- Science is difficult and not relevant to the lives of most people
- Science causes social and environmental problems
- Science is more attractive to males than females
- A loss in interest in science decreases over the years of secondary schooling, and
- More negative views are associated with the physical sciences than the biological sciences.

A list of attitude-toward-science as presented above is the main focus in this study, particularly on pre-service teachers' learning experiences. The researcher attempts to examine whether pre-service teachers are favourable or unfavourable towards physics as a result of their prior physics learning experiences. These preferences can be positive - such as seeing science and physics in particular as enjoyable, interesting, stimulating and challenging, motivating and satisfying, or negative - such as seeing science and physics as being difficult to understand, theoretical and abstract, and boring. Although attitude-toward-science noted above is a measure an individual's preferences and affective in nature, this may not necessarily be related to behaviour exhibited by an individual (Osborne, Simon & Collins, 2003). In such cases, behaviour becomes dominant over attitude. In other words, rather than focusing on attitudes towards *science*, attitudes towards *science teaching* (i.e., the action component) may be better predictor of individual's behaviour.

4.1.3.2 Teaching Self-Efficacy Beliefs

The above literature review suggests that attitude-toward-science and beliefs about teaching are factors that contribute to science teaching self-efficacy (Bleicher & Lindgren, 2005; Rice & Roychoudhury, 2003; Tosun, 2000). Self-efficacy is then regarded as a useful predictor of behaviour and is context specific (Pajares, 2002) – in this case teaching secondary school physics. Self-efficacy emerges from social cognitive theory, and has two factors: life experiences (outcome expectancy), and personal beliefs about ability to cope (self-efficacy).

This makes sense, according to Dalgety, Coll and Jones (2003) and Richardson (1996), because students' learning experiences in secondary school influence their attitude- and self-efficacy beliefs toward science and science teaching. Bleicher and Lindgren (2005) likewise argue that pre-service teachers' self-efficacy beliefs are also influenced by their science conceptual understanding of the content knowledge they are expected to teach. Pre-service teachers, in turn will be more confident about teaching science if they have personal success in the learning of science. It seems then that pre-service teachers' attitude-toward-science (or physics) is influential in their views about the subject and subsequently their own ability to deliver when teaching the subject. This then begs the question as to the relationship between attitude and confidence with respect to teaching and, according to Koballa and Crawley (1985), attitude is a general and enduring positive or negative feeling about science, whereas confidence is more to do with self-image as a teacher (Bohning & Hale, 1998). This 'confidence' (or otherwise) about teaching is more commonly reported as self-efficacy in the literature. Self-efficacy is thus more contexts specific than confidence, and, for example, here would be seen as related to pre-service teachers' beliefs specifically about their own ability to teach physics.

Conceptual frameworks related to beliefs and attitudes can be derived from Ajzen and Fishbein's (1980) *Theory of Reasoned Action* (TRA) and Ajzen and Madden's (1986) revised *Theory of Planned Behaviour* (TPB). The theory of reasoned action has two independent sources, a personal and a social motivator (along with their associated beliefs), as mediated by behavioural intention. This theory could, for example, focus on the distinction between attitude-toward-physics and attitude-toward-physics teaching. Here, the TRA would then represent a relationship between attitude, intention, and behaviour. Intention determines behaviour, and this forms attitudes towards the behaviour and the subjective norm - beliefs about how other people would regard one's performance of, or engagement in, the behaviour (Figure 4.2).

The theory of planned behaviour has an independent antecedent of behaviour - perceived behavioural control (PBC). Here the researcher assumes physics teaching self-efficacy is considered to be an antecedent of perceived behavioural control (Figure 4.2). Here a pre-service teacher can be said to have a control belief if s/he believes that s/he does not have an ability, confidence and/or interest to teach secondary physics due to the lack of conceptual understanding of content knowledge. This physics teaching self-efficacy of pre-service teacher derived from control beliefs may result in a perceived barrier towards teaching secondary school physics. Lack of interest can also be a barrier to teaching physics. For example, a pre-service teacher who is not that interested in physics may perceive that physics content as difficult. This theory of behaviour prediction has two factors: life experiences (outcome expectancy), and personal beliefs about ability to cope (self-efficacy). However, Bandura (1977) argues that a teacher's overall level of self-efficacy may not properly reflect the individual's beliefs about his/her ability to implement effective programmes in specific subjects, for example, in the case of this thesis, the intention to teach secondary physics.

These theories all assume that humans usually behave in a rational manner and make systematic use of the information available to them before they decide to engage or not to engage in a given behaviour. Based on these theories, pre-service teachers' beliefs could be investigated in terms of predicting their behaviour, using three variables (Figure 4.2):

- Attitude toward the behaviour (AB)
- Subjective norm (SN) – see below, and
- Perceived behavioural control (PBC).

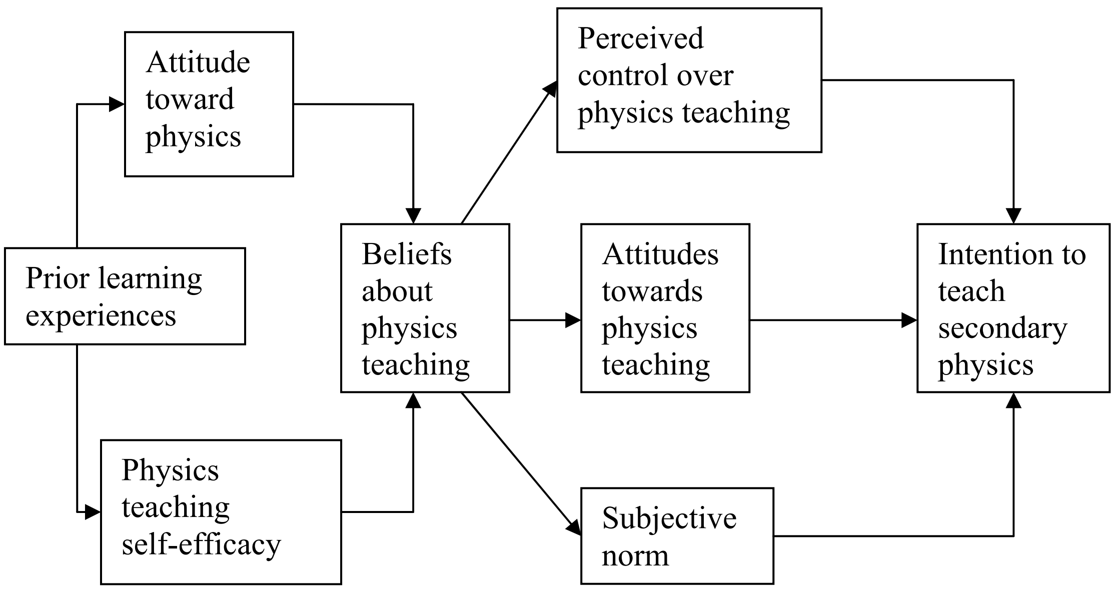


Figure 4.2
Antecedents of intention to teach secondary physics

Attitude toward the behaviour (AB) depends on an individual's perceived consequences of performing the behaviour (personal beliefs) and on an individual's evaluation of each of the consequences (outcome evaluations). In other words, AB represents what an individual believes will lead to desirable consequences. Subjective norm (SN) measures the extent to which an individual believes that most of his/her 'important others' (e.g., peers, immediate relative, and teachers) think that a behaviour either favourable or not should or should not be performed. Perceived behavioural control (PBC) is a measure of "an individual's beliefs as to how easy or difficult the behaviour is likely to be based" (Shireen Desouza & Czerniak, 2003, p. 4) on external (e.g., time) and internal (e.g., knowledge or persistence) factors. PBC the opportunistic component, represents an individual's assessment of the presence or absence of resources or opportunities that will influence his/her ability to perform the behaviour, that is, the perceived likelihood of behavioural goal achievement.

Based on TPB theory, Enochs and Riggs (1990) developed a specific instrument for pre-service teachers - the Elementary Science Teaching Efficacy Beliefs Instrument (STEBI-B). This instrument has two components: personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE). The first component refers to pre-service teachers' ability or beliefs about their ability to perform science teaching in the classroom, and the latter reflects pre-service teachers' ability or beliefs whether or not they think they can improve their students' learning. Although Riggs employed the term 'science-teaching efficacy', here the term 'physics-teaching self-efficacy' is confined to one aspect of 'science-teaching efficacy': Personal Science Teaching Efficacy (PSTE). As the researcher only modified Enochs and Riggs' (1990) instrument (STEBI-B) derived from the TPB theory, thus PSTE and STOE are not shown in Figure 4.2 but only physics teaching self-efficcay. For example, pre-service teachers who believe they have weak science content background tend to have significantly lower self-efficacy towards teaching science than pre-service teachers with strong science content background, and this results in the avoidance of teaching science (Enochs, Scharmann & Riggs, 1995).

4.1.4 Reflection

This section considers literature on 'reflection' in education and science education research as it is part of the didaktik analysis. There are three types of reflection reported in the literature: reflection on practice; reflection on theory; and reflection on the theory of science (Uljens, 1997).

Reflection is commonly seen in terms of reflective teaching (Zeichner & Liston, 1996), reflective practice (Westbury, Hopmann & Riquarts, 2000), the teacher as a researcher (Roth, 2007), reflective thinking (Bengston, 1995), inquiry-oriented teacher education (Carr & Kemmis, 1986; Tabachnich & Zeichner, 1991), reflection-*in*-action (Schön, 1983, 1987), and the teacher as a professional (Calderhead, 1992). The literature suggests that pre-service teachers need practice to develop reflection skills (Schön, 1987; Shireen Desouza & Czerniak, 2003; Valli, 1993). One of the reflective practice techniques needed by pre-service teachers is the ability to make distinctions between cognitive and behavioural psychology (Valli, 1993). According to Kennedy (1989) a reflective practitioner can be characterised as an individual who analyses his or her practice from various frames of reference. That is, someone, who is deliberative and who combines personal experience, values, and beliefs with theory and research. This is consistent with the views of Calderhead and Gates (1993), who suggest that reflective teachers are those "who are able to analyse their own practice and the context in which it occurs; who are expected to be able to stand back from their own teaching, evaluate their situation and take responsibility for their own future action" (p. 9).

According to Wallace and Louden (2000) encouraging reflection is one way we can help pre-service teachers learn, but they note, that learning to become a reflective practitioner takes time. It seems reflection is most effective when its target is not well-defined, but rather when the individual reflects on situations and events that are out of the ordinary (Coble & Koballa, 1996).

4.1.4.1 Definitions of Reflection

Reflection is thinking about one's experiences (Bengston, 1995; Uljens, 1997) and in the case of teacher education thinking about teaching practice. Loughran (1999) sees reflection in pre-service teacher education as a deliberate, purposeful act by teachers to help their students learn meaningfully, and goes on to say that to make reflection happens, one needs attitudes such as open-mindedness, whole-heartedness, and responsibility. Loughran refers to these concepts as attitudes of pre-service teachers to their experiences. Based on these attitudes, reflection consists of five phases:

- Suggestions, ideas or possibilities when one encounters a puzzling situation
- Problem identification, seeing 'the whole picture', recognizing the real cause for concern, understanding the perplexity of a situation more precisely so that next course of action can be thought of thoroughly
- Hypothesis formation, when a suggestion is reconsidered in terms of what can be done with it or how it can be used
- Reasoning, the linking of information, ideas, and previous experiences allows one to expand on suggestions, hypotheses and tests, to extend the thinking about and knowledge of the subject, and
- Testing, when the hypothesized end result may be tested and in so doing, the consequences of the testing can be used to corroborate or negate the conjectural idea.

Teacher education can facilitate pre-service teachers in learning about teaching, and learning about reflection. Zeichner and Liston (1996) argue that not all thinking about teaching constitutes reflection and results in reflective teaching. Teaching that is reflective includes a teacher that:

- Examines, frames, and attempts to solve the dilemmas of classroom practice
- Is aware of and questions the assumptions and values he or she brings to teaching

- Is attentive to the institutional and cultural contexts in which he/she teaches
- Takes part and is involved in school change efforts, and
- Takes responsibility for his/her own professional development.

4.1.4.2 Forms of Reflection

A conceptual account of teacher's reflection provides two themes: interests and forms (Wallace & Louden, 2000). *Interests* refer to the goal of an act of reflection, either, and the goal of reflection inclined to some theory or practice. This interest seeks to develop a deeper and clearer personal understanding, of professional problem solving and critique of the conditions of professional actions. On the other hand, *forms* refer to the characteristics of the teaching act which can be: a matter of introspection, of thinking or feeling; of replaying or rehearsing professional action; of systematic inquiry into action; or of spontaneous action. Although these categories of reflection are different, they complement each other. So a specific act of reflection, or set of reflective acts, may have different interests and forms. In other words, as Wallace and Louden (2000) note, interests are inquiries in the empirical-analytic sciences, the hermeneutic-historical sciences, and the critical sciences and they seem related to research paradigms (more detail is in Section 5.1). These forms of inquiry are associated with a cognitive interest: the empirical with technical control by discovering rule-like regularities in objective world; the hermeneutic with practical control through understanding and communication; and the critical with emancipation through critical reflection on the condition of social life.

Briefly, interests in teacher's reflections can be technical, practical, and critical. *Technical* interest seeks to 'control' the world by attending to rule-like regularities. They stand behind quantitative research into effective teachers, and competency-based teacher evaluation. Key issues in technical reflection include fidelity of teachers' practice to some set of empirically or theoretically derived models, and the development of the technical skills of teaching. Practical interest consists of two categories: personal interest, and problem-solving interest. Wallace and Louden (2000) note that *personal* interest places emphasis on the personal meaning of situations, or the connecting of experience with ones understanding of his of her life (i.e., biography). The *problem-solving* interest emphasises resolution of practical problems encountered in professional work, similar to Schön's (1987) notion of reflection-on-action. From Schön's perspective, problem-solving is concerned with problems outside the established technical knowledge of a profession; for example, cases which are not in 'book' but situations which are uncertain, unique or conflicted. This problem-solving may take place as informal experiments either Schön's reflection-*in*-action (for which it is thought possible to alter the outcomes of action), or Schön's reflection-*on*-action (i.e., after the event or one's continuous experiences during action). In either case, Schön's interest is with the situations that learners or practitioners already see as problem-solving in nature: occasions where people are surprised by what happens, and are moved to rethink and reflect on their professional practice. Thus, this type of reflection can appear in either reflection-*in*-action, or reflection-*on*-action. Finally, critical interest involves questioning taken-for-granted thoughts, feelings, and actions. It begins with the assumption that reality is constructed and that people can act to influence the conditions in which they find themselves (Carr & Kemmis, 1986). So in terms of teaching, critical reflection involves considering who benefits from current practices, how these practices might be changed, and what personal action might be needed to secure changes in the classroom (Wallace & Louden, 2000).

The four 'interests' (technical, personal, problem-solving, and critical) of reflection account for a range of reasons pre-service teachers might have for reflection; but they do not necessarily help elaborate the range of ways in which changes in understanding and action actually take place. From the various terms of reflection mentioned above, it can be concluded that reflection seems to be something that occurs or takes place in a moment of action, a kind of cognitive activity or a process of thinking or feeling separated from action, and in between there is thought and action - tacit and explicit knowledge (Bengston, 1995; Uljens, 1997; Wallace & Louden, 2000).

On the other hand, forms of teacher's reflections can be seen as variation along introspection and spoantaneous action. At one end, reflection is seen as *introspection*: reflection involving thinking and feeling (reflection also may involve conscious processes conducted at some distance from the stream of action). This notion of reflection is also seen as self-reflection, in that one evaluates and alters his or her thinking or feelings, from reflection on experience (Bandura, 1986; Bengston, 1995; Uljens, 1997). In addition, reflection also means contemplation or meditation, thinking, cogitation, and intellectual activities (Wallace & Louden, 2000). This type of reflection is related to some phenomenon one is subjected to thorough consideration, thoughts in which one dwells for a long period of time on an object in order to get a better and deeper understanding of it. This involves looking 'inwards' and reconsidering one's thoughts and feelings about some issues. The object of reflection can be one's own activity, any kind of object or one's own profession – but this differs from one's own professional activity because it is limited to individual practice (Bengston, 1995). Thinking, however, is a recurring activity, and this differs from how a pre-service teacher acts and perceives in the practice of his or her profession.

At the other end, is *spontaneity*, where reflection is bound up in the 'moment of action', in which there is no conscious awareness of thinking about the action. This process of learning through moments of experience involves tacit reflection which takes place within the stream of experience. So in the midst of action, one 'seizes the moment' and changes the direction of his or her action.

Two intermediate categories of reflection are *replay and rehearsal*, and *inquiry*. Replay and rehearsal reflection involves a pre-service teacher thinking or talking about events that have happened or that might happen in the future. For example, as a teacher talks to colleagues or writes about their work, they try to make sense of surprising classroom events, draw provisional generalizations which may inform their future practice, make plans for action, and affirm their values. This sort of reflection is one step closer to action than introspection, but still distant from the movement between action and reflection which characterizes inquiry. Replay and rehearsal, and introspection take place some distance from action, in contrast inquiry reflection involves both action and discourse about action (Wallace & Louden, 2000). In addition, inquiry reflection involves a process of deliberate movement between action and discourse - as typically occurs in action research. This sort of reflection may also be undertaken in conjunction with technical, personal, and problem-solving interests. Thus, a single interest is connected with a single form of reflection such as critical interest and inquiry.

Others have a single interest with a range of forms of reflection such as reflection-*in*-action and reflection-*on*-action which are represented in all four forms of reflection, with each form of reflection associated with the problem-solving interest. Introspection is more often associated with personal interest, whereas replay and rehearsal, inquiry and spontaneity are associated with problem-solving interests. There are also critical interests through inspection, replay and rehearsal, and spontaneity.

The process of reflection for pre-service teachers begins when they experience a difficulty, troublesome event, or experience that cannot be immediately resolved (Shireen Desouza & Czerniak, 2003; Zeichner & Liston, 1996). Action taken to analyse such experiences might occur during the action, or after the action is completed. There are actions that are routine, and actions that are reflective. Routine actions are those guided by impulse, tradition, and authority (Zeichner & Liston, 1996). While, reflective actions involve active, persistent, and careful consideration of any belief or practice in the light of the reasons that support it – it also involves considering the further consequences to which it leads. This involves intuition, emotion, and passion, and is not something that can be seen as a 'set of techniques' for pre-service teachers to use. What is important here in reflective actions for pre-service teachers is to have open-mindedness, responsibility, and wholeheartedness.

An assignment on didaktik analysis was used in the intervention in this thesis to help promote reflective practice amongst the participant pre-service physics teachers. In the context of this thesis, in order for pre-service teachers to become reflective practitioners, they should be able to ask questions about the assignment of didaktik analysis and their teaching practice, and seek answers for such questions in a systematic way. In this course, pre-service teachers were encouraged to reflect on their teaching, not only on content knowledge, but also on their students' prior knowledge (both are from the assignment of didaktik analysis). In terms of content knowledge, science courses at the School of Science should cover what is needed to enable pre-service teachers to become capable (content-wise) in their science related discipline.

An investigation of pre-service teachers' beliefs and attitudes toward didaktik analysis as required in their assignment may then help determine whether or not they in fact engaged in reflection, and if so, in what form. To assist in the development of reflection, the assignment on didaktik analysis required conceptual analysis of Form 4 physics, analysis of textbook, analysis of literature on students' alternative conceptions and lesson plans, and for the microteaching and practicum experiences.

4.1.5 Summary of the Teaching Dimension and Learning Dimension

It is evident from the above discussion that the teaching dimension and learning diemension is a multi-faceted, holistic, and complex topic. Pre-service teachers' views of learning result from a variety of antecedents. Their beliefs, knowledge, prior experiences and practices of science teaching all are influential, and these in turn influence their attitude-toward-physics, and their self-efficacy towards physics teaching. It is proposed here that such factors may influence pre-service teachers' intentions to engage in certain target behaviours, namely the use of didaktik analysis of physics in their microteaching and subsequently in the teaching practicum. Such factors also may be influential in the pre-service teachers' developing into reflective teaching practitioners.

A further factor influential in pre-service teachers practice is the personal dimension and this is considered next.

4.2 THE PERSONAL DIMENSION

This section presents assumptions and ideas that influenced the researcher's thinking about the didaktik analysis of physics reported in this thesis; that is, it is concerned with the *personal* dimension of this research. The intention here is that by providing details of some personal experiences, as an experienced physics teacher, and physics education researcher, the reader may be helped to 'map' the ways in which this research on didaktik analysis has developed.

Since enrolling in a PhD at the University of Waikato, the researcher has been exposed to different views concerning didaktik-based approach. As a consequence, his view towards the didaktik-based approach to teaching and teacher training is now considerably different from ideas that he held initially. Study of the theory of didaktik made an impression on his way of thinking about educational research as a whole. Differences between the researcher's prior perceptions of teacher training based on the pedagogy-based approach, and his new perceptions developed as his understanding of the didaktik-based approach grew, and led him to think about how to improve the practice of teaching and learning of pre-service physics teachers within the didaktik tradition. This new direction was subsequently incorporated into a physics teaching methods course in the School of Education at the University of Malaysia Sabah. This development prompted a desire to investigate potential factors influencing the effectiveness of introducing this didaktik-based approach during the pre-service teachers' coursework training, which in turn influenced the researcher's perceptions of the microteaching and practicum.

During secondary school days, the researcher underwent physics learning experiences that were based on the 1976 Malaysian New Modern Physics Curriculum. Learning physics was based on the use of textbooks and laboratory experiences. When he became a secondary school physics teacher, the researcher continued using this curriculum until the New Physics Revised Curriculum was introduced in 1992. Aspects emphasized in the 1992 curriculum included the introduction of constructivism as the basis for the teaching and learning of physics. Almost a decade later, another revised physics curriculum was introduced. The main aim of this new curriculum was to provide students with knowledge and skills in science and technology which would enable them to solve problems, and make decisions from everyday life based on scientific attitudes and 'noble values' (Kementerian Pendidikan Malaysia, 2001). In addition to constructivism, educational approaches such as inquiry, Science, Technology and Society (STS), contextual, and mastery learning were given emphasis in this version of the curriculum. Thus, the researcher has had experiences in the teaching of physics under the umbrella of two curricula: the Malaysian Modern Physics syllabus (1971-1990); and the Integrated Secondary School Curriculum (1990-2000). Subsequently in 2002, the Malaysian Prime Minister announced that science and mathematics were to be taught in English. As a consequence, the national Curriculum Development Centre (Kementerian Pendidikan Malaysia, 2004) once again produced a revised physics curriculum, this time in English. This was first implemented in 2006 (see below for more discussion of this issue). Although a great effort has been made nationally to make physics teaching more interactive and inquiry-based through the development of constructivist-oriented teaching and other relevant instructional materials, in the researcher's experience, in most cases, physics teaching in Malaysian schools is still highly teacher-centred, and dominated by 'chalk and talk'.

The researcher had thus experienced teaching secondary school physics for nearly 13 years before joining the University of Malaysia Sabah in July 2002. During his time as a teacher at a number of secondary schools of different types, in different locations and with very different students, the researcher employed a variety of pedagogical strategies when teaching physics. At the University of Malaysia Sabah, one of the courses the researcher taught was a physics teaching methods course. The researcher changed the mode of presentation of his content for the course each semester. Feedback from the school principals, mentor teachers, secondary physics students as well as pre-service teachers, resulted in the researcher reflecting on how this course might best help pre-service teachers develop physics knowledge and skills in their students. The proportion of secondary physics students passing the national examinations was more than 90% every year. However, in the view of the researcher this very high pass rate does not necessarily provide a good indicator that those who enter teaching profession will therefore become good physics teachers.

Physics education involves a teacher and his or her students. Here the researcher is most interested in students' understanding of physics conceptions: their understanding of specific scientific knowledge. Some teachers or education researchers might think that students' performance in physics learning is related to the students' reasoning abilities or intuitive understanding and grasping of scientific concepts. However, students' conceptions that have arisen from their learning experiences may, or may not, be compatible with the views held by physicists. An important factor here is that the physics knowledge is ultimately derived from physicists. However, 'school physics', that is, the physics presented by teachers of physics, may not actually be in accordance with physics knowledge held by physicists. This may be the scenario encountered especially in some Malaysian secondary schools in rural areas, since in such locations physics is often taught by non-specialists, with little background knowledge of physics content (e.g., graduates from chemistry, or biology or other science disciplines). A national shortage of qualified physics teachers in secondary school contributes to this phenomenon. If the role of the teachers is to help those students gain scientific knowledge similar to or accepted by physicists, then a lack of content knowledge would likely inhibit this process.

Thus, development of a *didaktik of physics* is a pre-requisite *before* tasks of didaktik analysis can be carried out in the intervention into a teacher education program in the School of Education; specifically in a physics teaching methods course to the third and fourth years of pre-service physics teachers. In practical terms this consisted of helping the pre-service teacher trainees to understand how to teach physics by developing a didaktik of physics, and subsequently drawing on didaktik analysis. The teaching practices in the microteaching and during practicum, that the pre-service physics teachers were engaged in as part of the intervention, helped them to reflect on the assignment of didaktik analysis and informed their decision to teach secondary school physics.

In the experience of the researcher, some teachers do not teach according to the intentions of the curriculum developers. For example, it is common to teach only theoretical aspects of physics instead of working with students in laboratories, and only doing physics demonstrations. The researcher thus observed in his years of teaching, that teaching and learning of physics in Malaysian schools are typically based on lectures and note taking, reading of textbooks, with little emphasis on doing experiments/demonstrations, and problem-solving. Textbooks are a major referent for both students and teachers. As a consequence of using these rather 'dry' resources somewhat divorced from the human dimension of physics, insights about the beauty and power of physics is lost. The researcher feels that other available teaching materials that require significant work by the teacher, tempt teachers to focus more on demonstration and rote memorisation. These features of the Malaysian physics teaching scene combine to drive teachers to engage in a didactic approach (notably different from 'didaktik'!), with a strong focuses on the content of science, and which seems to portray scientific knowledge as absolute and unproblematic (Millar & Driver, 1987). It is noteworthy that this occurs despite a strong emphasis on student-centred teaching and learning by the Curriculum Development Centre (CDC) and as expressed in the curriculum specifications.

In a similar manner, the researcher's experiences as a trainer of physics teachers suggest that preparing and equipping teachers with pedagogical strategies in teacher training represents a significant challenge. While some pre-service teachers have sound physics knowledge, many others in the same teacher training institution may lack understanding of physics conceptions, or have difficulty in teaching physics using English as a medium of instruction. Further, in his role as a teacher trainer, the researcher routinely received complaints from schools that some pre-service teachers were not able to teach satisfactorily in terms of developing sound content knowledge in their students, and that this occurred even when they had good content knowledge in physics.

The rather ad hoc implementation of the teaching science and mathematics in the English language medium introduced early in 2003 at Form 1, and subsequently at Form 4 in 2006, meant that Malaysian secondary school students were exposed to learning science and mathematics in English, despite the fact that most teachers' own physics learning experiences occurred in the Malay language. The pressure on teachers arising from the change of the medium of instruction into English may affect the linguistic use of scientific terms amongst physics teachers. It could be that teachers learning the English language during their schooling years, and using inappropriate terms or switching between English and Malay to explain some physics phenomena might influence student understanding of physics. It also is interesting to note that in the current situation for secondary school teaching in Malaysia is that there is a proposition being considered by the Malaysian Education Ministry to exclude certain subjects from national examinations. Perceptions of a crowded curriculum are of concern at the Ministry, and it has been suggested that sciences, such as physics and chemistry may be excluded from the national examinations at SPM (Malaysian School Certificate) level. The intention of this move is to see if students' understanding and attitudes toward physics learning can be enhanced, without the 'pressures' of external examinations. Such moves would no doubt require secondary physics teacher training programmes to be substantially revised, and teacher trainers may have to look for new directions in fulfilling national educational needs (what ever they might be).

The purpose of this 'personal dimension' discussion, is nicely captured by Wellington and Osborne (2001), who note the importance of the role of the teachers in mediating conceptions of science for secondary school students (see Chapter 1). This in the mind of the researcher is the core of the didaktik analysis of physics, which drives this thesis.

4.3 CHAPTER SUMMARY

This chapter has presented key aspects of theoretical underpinnings for this thesis. Hence, in this chapter the researcher has presented part of the theoretical underpinings; the teacher dimension and personal dimension. The research dimension is discussed next under the umbrella of research methodology, and is presented in Chapter 5.

CHAPTER 5

RESEARCH METHODOLOGY

CHAPTER OVERVIEW

This chapter presents the methodology, research design and methods used in this thesis. This research is influenced by contemporary research methodologies for investigating aspects of the practice of teaching training of pre-service physics teachers. The researcher sought to employ a research methodology under an appropriate paradigm to provide explanations relevant to the context in which the research was conducted. Specific research methods used included a combination of qualitative and quantitative data collection tools. The research design is based on the theoretical underpinnings presented in Chapter 4.

There are six sections in this chapter. Section 5.1 discusses the three main research paradigms - explaining the meaning of each and identifying that deemed most appropriate for this thesis. Section 5.2 outlines the research methodology adopted in this thesis, and used to examine the educational implications of the use of a didaktik-based approach in a teacher training programme. This is followed by a short outline of quantitative and qualitative research, and Section 5.3 discusses in detail qualitative research methods and qualitative research methodology in general. Section 5.4 describes quantitative research methods and the quantitative research methodology, and Section 5.5 describes research methods used in the thesis - quantitative and qualitative methods. Steps taken to minimize the threats to objectivity and to enhance credibility or internal validity, transferability (external validity or generalizability), dependability or reliability, confirmability, subjectivity, trustworthiness and authenticity, triangulation along with ethical considerations are included here. The chapter concludes with Section 5.6, which provides a chapter summary.

5.1 RESEARCH PARADIGMS

This section discusses prevalent research paradigms reported in the educational literature. The term paradigm is given a variety of meanings in the literature (Guba, 1990; Lincoln & Guba, 2003), including the worldviews, perspectives, or ways of breaking down the complexity of the real world (Lee & Yarger, 1996; Patton, 1990). In this thesis, the meaning ascribed paradigm by Guba (1990), and Denzin and Lincoln (2003) is used; that is, a composition of ontology, epistemology and methodology; each informing the other (see also Creswell, 1994; Guba, 1990; Patton, 1990). The researcher's starting point in analyzing paradigms derives from Guba (1990) who identifies three paradigms in educational research: *empirical-positivist*, *interpretive*, and *critical theory*. Table 5.1 also shows a general set of paradigm assumptions based on ontology, epistemology and methodology. Discussions of these three major paradigms follow in the next three sections respectively. Each paradigm is distinguished by certain ontological assumptions which in turn give rise to epistemological assumptions, and these, in turn, result in methodological assumptions and ultimately methods of inquiry (Cohen, Manion & Morrison, 2000). Thus, the proposition here is that research paradigms for educational research should comprise ontology, epistemology and methodology that are compatible and all linked to research questions, and an appropriate conceptual framework.

Ontology is described as the study of how individuals' view the outside world, what kind of being is the individual, or what is the nature of reality? (e.g., how they look from within to the outside). A *realist* ontology sees reality as absolute and based on facts, while a *relativist* ontology holds that reality is an individual's construction. Epistemology is the study of how individuals' view their knowledge; that is looking inward and making qualitative judgments and commitments about various theories or conceptions they might have. In other words, epistemology is concerned with the relationship between the individual and knowledge, or between the inquirer and the known. Distinctions between an individual's views about reality and the relationship between the researcher and that researched, emerges as a framework, that comprises methodology. A methodology is then the entire process of the research study or how the researcher goes about finding things out (Creswell, 1994; Denzin & Lincoln, 2003; Guba, 1990).

Table 5.1
Empirical-positivist, interpretive and critical theory paradigm assumptions
(from Creswell,1994, pp. 23, and Lincoln and Guba, 2003, pp. 256)

Assumption	Empirical-Positivist	Interpretive	Critical Theory
Ontology: What is the form or nature of reality or what is there?	Naïve realism – 'real' reality but apprehended.	Critical realism – 'real' reality but only imperfectly and probabilistically apprehended. Relativism – local and specific constructed realities	Historical realism – virtual reality shaped by social, political, cultural, economic, ethnic and gender values. Crystallized over time.
	Reality is objective and singular, apart from the researcher	Reality is subjective and multiple as seen by individuals	Reality is subjective and multiple as seen by individuals
Epistemology: What is the relationship of the researcher to that researched?	Dualist/objectivist (findings true).	Modified dualist/ objectivist (findings probably true). Transactional / subjectivist (created findings).	Transactional/ subjectivist (value- mediated findings).
	Researcher is independent from that being researched.	Researcher interacts with that being researched.	Researcher interacts with that being researched, takes into account the role of values.
Methodology: What is the process of research or how to go	Experimental/ manipulative.	Modified experimental/ manipulative. Hermeneutical/ dialectical.	Dialogic/ dialectical.
about in finding out things?	Verification of hypotheses established as facts, principles or laws.	Falsification of hypotheses.	Structural/ historical insights.
	Mainly quantitative methods.	May include qualitative method	
	Deductive process	Inductive process	Transformative.

In the empirical-positivist paradigm a realist ontological view of reality as 'objective', 'out there' and independent of the researcher is taken. The epistemological assumption here sees the role of the researcher as an observer who remains distant from that being researched. An individual who commits to a realist ontology typically commits to an objectivist epistemology in that he or she believes that the individual and the knowledge are independent of each other. Consequently, the methodology concerns different methods of measuring reality, and as a consequence, realist-objectivists typically employ an interventionist methodology and attempt to control for bias, select a systematic sample, and seek to be 'objective' in assessing a situation. This typically involves using questionnaires or similar instruments and experimentation based on a deductive process, (Cohen, Manion & Morrison, 2000; Creswell, 1994; Guba, 1990). This 'scientific method' approach to educational research is discussed further in Section 5.1.2.

In contrast to the empirical-positivist stance, in the interpretive paradigm a relativist ontological assumption views reality as subjective and multiple-constructed by individuals whether the researcher, respondents or others involved - all of whom interpret the study. Here the epistemological assumption concerns the involvement of the researcher *with* the respondents, and in contrast to the empirical-positivist stance researchers try to *minimize* the distance between themselves and the respondents. An individual who commits to a relativist ontology also typically commits to a subjectivist epistemology in that he or she believes that knowledge is constructed by individuals. The resulting methodological assumption involves various research techniques in order to take into account the complexity and subjectivity of the process. For example, relativist-subjectivists typically use a hermeneutic methodology in which the researcher seeks to understand and interpret situation through the 'eyes' of the respondents. Therefore, a hermeneutic researcher attempts to understand a situation by interpreting different data sources such as interviews, observations, an experiments but these are used in an inductive process to identify common themes (Cohen et al., 2000; Creswell, 1994; Guba, 1990). This 'non-statistical' approach is discussed in more detail in Section 5.1.3.

Finally, in the critical theory paradigm the ontological assumption is similar to the case of the interpretive paradigm; but the epistemological assumption concerns not only the researcher's involvement with respondents but the *values* she or he brings to a study. An individual who subscribes to a realist ontology commonly subscribes to subjectivist epistemology, in that he or she likely believes that research is closely connected with the values of the researcher. Hence, here the methodological assumption is concerned with a specific technique. For example, critical theorists typically use a dialogic methodology in which the researcher seeks to eliminate 'false consciousness', striving to bring about a more just and egalitarian society. Thus, the critical theory researcher attempts to transform an individual to achieve *social democracy* (Cohen, Manion & Morrison, 2000; Guba, 1990). These 'ideology critiques' and a common critical theory approach, that of 'action research', are discussed in Section 5.1.4. The next section discusses the nature of research paradigms in more detail.

5.1.1 Nature of Research Paradigms

The two dominant research paradigms in educational research are empirical-positivist and interpretive (Lee & Yarger, 1996; Lincoln & Guba, 2003), however growing in importance, the critical theory paradigm also is included in this discussion for the sake of completeness. There have been a number of debates about various paradigm issues reported in the literature. These include the philosophical and epistemological differences between the paradigms, and the hegemony, dominance or supremacy of paradigms (Guba & Lincoln, 1994). Also of interest is the accommodation (compatibility or incompatibility) between the paradigms at both the epistemological or methodological levels (Behrens & Smith, 1996; Firestone, 1987). Specific research issues or quality criteria for the paradigms such as credibility (internal validity), transferability (external validity or generalizability), dependability (reliability), confirmability, objectivity and subjectivity, trustworthiness and authenticity (Lincoln & Guba, 2003; Patton, 1990), also are of interest. Authors also have commented on the links between the aim of inquiry; the nature of knowledge; the way knowledge is accumulated; values; ethics; voice; training; axiology; action; control; foundations of truth and knowledge; reflexivity; and postmodern textual representation (Lincoln & Guba, 2003).

There are several detailed discussions about paradigms debates reported in monographs or major reviews of in educational research, for example, Patton (1990), Firestone (1987), Lincoln and Guba (2003), and Shulman (1997). The principal findings from this literature are outlined for the three main paradigms in Tables 5.1 and 5.2.

Table 5.2
Three contrasting paradigms
(from Cohen, Manion and Morrison, 2000, and Lincoln and Guba, 2003)

Empirical-Positivist	Interpretive	Critical Theory
Society 'objectivity'	The individual 'subjectivity'	Society, groups, individual 'collectivity'
Model of natural sciences	Non-statistical	Ideology critique and action research
Research conducted from the outside	Personal involvement of the researcher	Participant researchers, researchers & facilitator
Generalizing from the specific	Interpreting the specific	Critiquing the specific
Explaining behavior/ seeking causes	Prediction and control; Understanding actions/ meanings rather than causes. Individual reconstruction	Understanding, interrogating, critiquing and transforming actions and interests (emancipation)
Assuming the taken-for-granted	Investigating the taken-for-granted	Interrogating and critiquing the taken-for-granted
Macro-concepts: society, institutions, norms, positions, roles, expectations	Micro-concepts: individual perspective, personal constructs, negotiated meanings, definitions of situations	Macro- and micro-concepts: political and ideological interest, operations of power
Structuralists	Phenomenologists, symbolic interactionists, ethno-methodologies	Critical theorists, action researchers, practitioner researchers
Technical interest	Practical interest	Emancipatory interest
Internal and external validity reliability and objectivity	Internal and external validity, reliability and objectivity; trustworthiness, credibility, transferability, confirmability, authenticity	Historical situatedness, erosion of ignorance and misapprehensions, action stimulus
Commensurable	Some commensurable and some incommensurable	Incommensurable

5.1.2 Empirical-Positivist Paradigm

The empirical-positivist paradigm also is sometimes termed the *scientific* paradigm – and tries to draw upon an empirical-inductivist view common in science (Creswell, 2002; Patton, 1990). The roots are thus in a scientific ontology, epistemology and methodology. The argument is, if the 'scientific method' has been successfully applied to solve problems for natural phenomena, then it equally could help to solve the problems for social phenomena (Cohen, Manion & Morrison, 2000). The application of 'the scientific method' to study the behavior of individuals and social groups also is sometimes called the *normative* approach. This is the underlying idea of positivism which states that there is no difference in principle between scientific explanations of natural phenomena, and scientific explanations of human phenomena.

In order to understand fully the application of the scientific method in explaining human behavior, we need to know four assumptions that underpin the empirical-positivist paradigm (Cohen et al., 2000):

- The assumption of belief called *determinism*. It is believed that by identifying and interrelating variables, the specific behaviour within the system can be known (or determined). This means simply that events have causes, that events are determined by other circumstances. Causality is used to define relationships among empirical variables on a cause-and-effect basis that can be explained or manipulated to produce conditionally predictable outcomes. If X occurs, then Y will be the effect. However, the notion of a system of variables provides a specific meaning of causation. For example, in the behavioural sciences, there are multiple causations and it is likely impossible to control all the factors in such a way as to be able to identify conclusively the causal factor or factors. In which case formulating laws can be expressed in terms of probability of occurrence: prediction and control.
- The assumption belief called *empiricism*. This means that certain kinds of reliable knowledge can only originate in experience. Begin with observations of the particular, then generalise the findings. Thus, concepts are reordered into specific variables that can be measured concretely. The

variables become units that are comparable, 'independent and dependent variables', to identify how one variable influences others, and how manipulation of one variable can produce 'effects' upon other variables. The comparison and manipulation of variables is to confirm or falsify hypotheses as they relate to the development of theory.

- The assumption belief called the principle of *parsimony* which is adopted from the work of scientists. This means phenomena are explained in the best, most simple way.
- The assumption of *generality* which is related to both deductive and inductive methods of reasoning. Through observation of the natural world, scientists seek to generalize their findings about the inanimate world, while the human scientists generalize their findings but with great caution about larger human populations.

The empirical-positivist paradigm in terms of methodological assumptions says we should employ a random and representative sample of the population under study, and holds that certain individual phenomena can only originate in experience, while theories and hypothesis are tested in terms of cause and effect. Concepts, variables and hypotheses are chosen *before* the study begins, and *remain fixed* throughout the study. The questions are usually stated in propositional form and translated into a more precise operational definition, with each variable specified in some measurable way. The proposition is then further translated into a quantitative form so that the research design can be analysed using statistical analysis. The selection of a particular design is based on certain criteria in such a way that assumptions underlying the statistical techniques to be employed can be met. The aim of the study is thus to develop generalizations that will contribute to theory, and enable the researcher to predict, explain and understand a phenomenon or phenomena (Cohen, Manion & Morrison, 2000; Creswell, 1994). This methodological approach characterizes the procedures and methods used to discover general laws. The next step in implementing the chosen research instrument, means the researcher must put questions directly 'to nature' and have the capability of recording nature's direct answers. Thus, paper-and-pencil instruments are commonly used because they are deemed to be independently standardised and normalised (Guba & Lincoln, 1989). There is no direct interaction between the researcher and respondents, and this is deliberate intended to help the researcher receive responses without any 'distortion' of the instrument.

5.1.3 Interpretive Paradigm

Educational research in an interpretive paradigm draws from the disciplinary fields of psychology, philosophy, sociology, humanistic psychology, and social psychology. For example, theoretical approaches drawn from psychology and philosophy involve phenomenology, those from philosophy use hermeneutics, those from sociology use grounded theory and ethno-methodology, those from humanistic psychology use heuristics, and those from social psychology use symbolic interactionism. It is important to note that although each of these theoretical approaches within an interpretive paradigm may employ the same 'methods', those 'methods' may be used for different purposes; asking different questions, and the results interpreted from different frameworks (Patton, 1990). Here the term 'methods' is not referring to what kind of data to collect (i.e., qualitative or quantitative or some combination thereof) but to specific *instruments* for collecting data. This point is discussed in more detail in Section 5.2.

The interpretive paradigm also is often termed *naturalistic*, in that it occurs in the research setting where individuals' behaviour and events or programs occur (Guba, 1990; Patton, 1990). Some events or occurrences cannot be observed directly; such as an individual's past experience. Hence, a researcher can only rely on written information or a person's recall of past events. This written information is considered more subjective because attitudes, interests, opinions, views, perceptions, and knowledge are not open to inspection. A researcher here can only make subjective interpretations of events or occurrences based on verbal or written information (Verma & Beard, 1981).

Interpretivism *emphasizes the subjective experience* of the individuals, and tries to recognise the necessity of interpreting the meaning they bring to the experience (Cohen, Manion & Morrison, 2000). The interpretation of the data or findings depends on the 'subjectivity' of the researcher, as the researcher is the instrument of both data collection and data interpretation, and she or he has personal contact with and gets close to the individuals and situation under study (Patton, 1990). In addition, the researcher also tries to understand the situation from the perspective of the actual individuals; including what they think and feel. In this case, the meaning of the individual's expression is context-bound (Cohen et al., 2000). In other words, the researcher needs to understand the context, in order to understand the individual expressions and this leads to patterns or categories that help explain a phenomenon.

As each individual has a variety of view points and perceptions derived from his or her particular interests, purposes and attitudes, then his or her intentions, motives and stated reasons, and causal explanations may be revealed from his or her own words (Cohen et al., 2000; Odman, 1988). In other words, data or findings *emerge* from the study in descriptive form; findings are thus reported in words rather than numbers (i.e., non-statistical data). In addition, meanings and interpretations are *negotiated* with individuals because they represent multiple realities. The attempt is therefore to reconstruct and understand each of these realities (Guba & Lincoln, 1989; Patton, 1990). In this case, attention is paid to particular individuals and the viewpoints of individuals are interpreted with regard to that particular individual. This methodological assumption characterizes the behavior of individuals, and is termed idiographic interpretation, or interpreting the specific (Cohen et al., 2000; Patton, 1990).

Another aspect of interpretive paradigm is the fundamental assumption of the theoretical approaches, namely, symbolic interactionism, phenomenology and ethno-methodology. These theoretical approaches are not adequate to study either the formal structure of social institutions or to survey the effects of institutions in terms predefined by the researcher (Cohen et al., 2000). For example, Patton (1990) sees phenomenology as the study of how individuals describe things and experience them through their senses, ethno-methodology he sees as an effort to understand taken-for-granted realities or situations in a program in which meaning is problematic, and symbolic interactionists are seen as individuals acting toward things on the basis of the meanings they have for them. These theoretical approaches and others mentioned above are discussed in more detail in Section 5.2.2.

5.1.4 The Critical Theory Paradigm

If empirical-positivist and interpretive paradigms are concerned with the understanding of social phenomena, then the critical theory paradigm is concerned not only to understand social phenomena, but also to *question*, *change* or *act* on this (Cohen et al., 2000; Guba, 1990). The critical theory paradigm consists of both objective and subjective realities, which are termed 'collectivity'. Objective realities are the institutions and roles created in history, while subjective realities are the individual who makes sense of his or her experience. Due to the critical theory paradigm involves an individual's constructions, then this paradigm applies ideology critique in order to understand, and attempts to change groups or individuals. According to Guba (1990), this is done through:

- False consciousness in that it describes how a group's understandings are false or incoherent and contribute to that group's victimization
- Crisis in that it specifies the conditions under which reduction of false consciousness is possible
- Education in that it prescribes how to enlighten and overcome false consciousness, and
- Transformative action in that it clarifies the social condition that must be changed to accomplish the group's liberation.

In other words, the critical theory paradigm attempts to raise individual's 'false consciousness' (i.e., their lack of awareness of the 'real' situation) to the level of 'true consciousness' (Guba, 1990). A combination of critical realist ontology and subjectivist epistemology thus becomes the critical theory paradigm, and the epistemological assumption is clearly subjectivist because the researcher tries to take into account the role of values.

The critical theory paradigm conceptualises interests in terms of the emancipation of individuals and freedom. The emancipatory interest is concerned with praxis: that is, action that is informed by reflection. As interests are socially-constructed, then their purposes are to expose the operation of power, and to bring about social justice as domination and repression are seen to act to prevent the full existential realization of individual and social freedoms (Cohen, Manion & Morrison, 2000).

5.1.5 Paradigm Adopted for the Thesis

Interpretive paradigm has been adopted to answer questions rooted in aspects of ontology, epistemology and methodology. The paradigm the researcher puts forward in this thesis is based on argument presented about the personal dimension: what the researcher experienced as a student, physics teacher and teacher educator (see Section 4.2). As a student at the secondary and tertiary levels, the researcher considers he ascribed to a realist ontology. This realist ontological assumption shifted to become a dualist-objectivist epistemological assumption when the researcher became a physics teacher and teacher educator. In addition, since engaging in this PhD, the researcher's perceptions of teacher education were shaped by personal experiences. As a teacher educator teaching pre-service teachers in their first year undergraduate study, the researcher came to appreciate the importance of the context of an inquiry, and developed awareness, knowledge and sensitivity to many of the issues encountered as a teacher and teacher educator when working with pre-service teachers. Therefore the researcher now considers himself as holding a subjectivist epistemology as described by von Glasersfeld (2002) (note that Guba, 1990 and Patton, 1990 consider this epistemological assumption or constructivism to be 'a paradigm'). The researcher believes that individual constructs knowledge based on his or her own experience. In other words, data that emerge are *constructed* by indivduals rather than gathered from them. The researcher here then attempts to *reconstruct* data from his insights and 'experience' or involvement in the work reported in this thesis. Hence, the researcher blends his own interpretation with the data, in accord with Patton (1990), who asserts that the researcher himself acts as 'the instrument'. The researcher is responsible for his data, and thus it is also essential to include his experiences and perceptions in the data analyses. Based on these ontological and epistemological assumptions, the researcher employed a hermeneutic and dialectic methodology. Individuals' constructions were elicited through interpreting text, questioning it, taking into account the researcher's situation, and elucidating the context of the individuals. These constructions, then were compared and contrasted in 'on-going meetings' and interviews between the researcher and individuals (in this case, pre-service physics teachers). This, in turn, sought to increase trustworthiness and authenticity of the data and findings (Lincoln & Guba, 2003). Thus, as this research involves teacher education, the paradigm adopted in this thesis is based on research questions, conceptual frameworks, research paradigms as presented above, and the research methodology which is discussed in the following section.

5.2 RESEARCH METHODOLOGY: AN OVERVIEW

There is often confusion in the literature between methods and methodology (Cohen, Manion & Morrison, 2000; Guba, 1990; Shulman, 1997). The confusion between methods and methodology according to Coll (1999) arises as a result of difference in beliefs or assumptions about paradigms: differences may be about tools, techniques or instruments, rather than differences about ideology or beliefs that involve ontological, epistemological, and methodological assumptions. Here the methods mean the specific techniques, tools or instruments used for gathering or analyzing data, such as interviews and observations (Cohen et al., 2000; Guba & Lincoln, 1989). Methodology, however, is seen as the theory of knowledge, an ideology or set of beliefs, or disciplined inquiry, based on the theoretical underpinnings that guide the particular research (Guba & Lincoln, 1989; Shulman, 1997). Coll (1999) adds that although researchers may employ the same method, their ontological and epistemological assumptions may be different. As noted in Section 5.1, this definition is consistent with paradigm assumptions, where the notion of methodology is also defined as the process of inquiry from research questions through data collection techniques and analysis (Cohen et al., 2000;

Creswell, 2002). One of the reasons why research methodology in education is different from research methods is that, as Shulman (1997) observes education is *field of study*, and it is not a field or discipline in its own right. In other words, educational researchers need to bring to bear the issues of other disciplines (such as psychology, sociology, and philosophy) on their educational problems, by modifying these disciplinary perspectives such as concepts, methods, and procedures. Shulman's views seem similar to the didaktik tradition (Bertrand & Houssaye, 1999). Each discipline has different principles about reality, the relationship of the researcher to that researched, and the process of research (see Table 5.1).

There also is the issue of quantitative and qualitative methodologies presented in the literature (Guba, 1990; Lee & Yarger, 1996). As noted above, quantitative methodologies employ the use of mathematical and statistical analyses of causal relationships between variables. As a consequence a quantitative research methodology is typically found within an empirical-positivist paradigm. In contrast qualitative methodologies involve emphasis on the qualities of entities, processes and meanings, which are not experimentally examined or measured in terms of quantity, amount, intensity or frequency (see, e.g., Denzin & Lincoln, 2003). Some authors use 'qualitative' as an umbrella term to encapsulate a variety of interpretive paradigm-based approaches (e.g., phenomenology, hermeneutics, grounded theory, ethno-methodology, heuristics, and symbolic interactionists) as well as critical theory (Patton, 1990). Or in contrast simply to mean techniques employed to gather and analyze data such as personal experience, interviews and observation – that is methods (Cohen, Manion & Morrison, 2000; Denzin & Lincoln, 2003; Guba, 1990). Lincoln and Guba (2003) believe that a qualitative research methodology is most consistent with an interpretive and critical theory paradigm.

Some researchers (e.g., Creswell, 2002; Firestone, 1987) argue that qualitative and quantitative methods are incompatible (i.e., qualitative methods belong to a qualitative research methodology; quantitative methods belong to a quantitative research methodology) since their origins lie in different paradigms. In other words, qualitative and quantitative methods, and their paradigms should not be mixed. From this viewpoint, qualitative research methods are consistent with the assumptions of an interpretive paradigm: A process of inquiry to understand social problems from the respondents' perspectives; that reality is socially-constructed through individual; based on building a complex, holistic picture; formed with words; reporting detailed views of respondents in describing things and experiencing them through their senses; and conducted in a natural setting where the researcher becomes immersed. In turn, quantitative research methods are consistent with the assumptions of empirical-positivist paradigm: A process of inquiry into social problems, where there are social facts with an objective reality apart from the beliefs of individuals; based on either testing a theory; employ experimental or correlation design composed of variables that seek to explain the causes of changes in social facts – aims at reducing error and bias as the researcher is detached; measured with numbers, and analysed with statistical procedures, in order to determine whether predictive generalisations of a theory hold true.

Distinctions between qualitative and quantitative research methods also rely on assumptions about the methodology of the research. Although both qualitative and quantitative methods are concerned with the individual's point of view, qualitative researchers argue that they have an intimate relationship with the individuals in terms of securing views by interviewing and by observation of the individuals. They point out that quantitative methods are seldom able to capture individual's views, as these views are gathered remotely and employ inferential empirical methods. In contrast, researchers that chose quantitative method may regard research data produced in qualitative methods as unreliable, impressionistic and lacking in objectivity (Denzin & Lincoln, 2003). As a conclusion, differences between quantitative and qualitative researchers concern: facts versus values; outcomes rather than process or inductive (builds abstractions, concepts, hypotheses, and theories from details); objectivity versus subjectivity or descriptive (process, meaning, and understanding gained through words or texts); the outsider's perspectives versus insider's perspectives; causal explanation versus understanding or meaning; and a static reality versus fluid reality or fieldwork (people, setting, and institution).

In contrast to the above discussion, some authors believe qualitative and quantitative methods are compatible with more than one paradigm, be that phenomenological or empirical-positivist, since each method provides a certain type of understanding of the educational issue of interest (Lincoln & Guba, 2003; Patton, 1990). However, Firestone (1987) believes that both types of methods should be associated with the attributes of either the interpretive or empirical-positivist paradigms. In other words, qualitative and quantitative methods should be linked to paradigms, as there remains an association - although the connection between research methods and paradigms may not be consistent (Creswell, 1994). The researcher agrees with Firestone (1987), and Lincoln and Guba (2003) that the division of the research methods by paradigm creates a false dichotomy, that they should be seen as complementary rather than rival. In other words, the researcher agrees that qualitative and quantitative methods can be used simultaneously in a given study. From this viewpoint a combination or mixed-methods approach may help researchers to achieve a deeper understanding of an educational issue. Discussions about mix-methods or integrated approach to educational research are discussed in Section 5.5.

According to Johnson and Christensen (2000) a potential benefit of using a combination of methods is that researchers are less likely to make a ‘mistake’ and place too much weight on a particular research finding. In addition, mixed-methods help to improve the quality of research because different methods each have different strengths and different weaknesses. The literature on research methods, in education suggests that specific methods employed should be based on the aims of the study. The researcher thus accepts that a mixture of quantitative and qualitative methods is the most useful in conducting the study, consistent with Denzin and Lincoln (2000) who note:

> Both qualitative and quantitative researchers are concerned with the individual’s point of view. However, qualitative investigators think they can get closer to the actor’s perspectives through detailed interviewing and observation. They argue that quantitative researchers are seldom able to capture their subjects’ perspectives because they have to rely on more remote, inferential empirical methods and materials (p. 10).

Other than the 'point of view' and 'perspective' notions mentioned in the citation above, the researcher employs the notion of 'lived experience' of the individual being studied. According to Silverman (2004), this notion reveals the origins of the individual's viewpoint or the process of how the individual gets the experience which in turn lead to the conception of inner meaning.

The next two sections presents more detailed about qualitative and quantitative research.

5.2.1 Quantitative Research Methodology

The empirical-positivist paradigm is consistent with the methodological assumptions of quantitative research or traditional quantitative research (Guba & Lincoln, 1989). The characteristics nature of quantitative research have been discussed above, here the researcher presents a general overview of this approach. Quantitative researchers believe that there is a reality 'out there' to be studied, that is apart from the beliefs of individuals, and that can be captured and understood (Denzin & Lincoln, 2003). Quantitative research involves mainly assumptions of meaning for the phenomenon, and the examination of the distribution of its occurrence by asking specific, narrow questions and collecting numerical data. The causes of an occurrence are explained through objective measurement and analyzing the distribution of it occurrence using statistics (Creswell, 2005; Johnson & Christensen, 2000). The validity and reliability of results are derived from the careful design of data collection, in an unbiased, objective manner, and selecting a representative sample from the population. It aims to isolate causes and effects, operationalizing theoretical relations, measuring, quantifying phenomena, developing the generalization of findings about human behaviour that will enable greater levels of prediction and control (Denzin & Lincoln, 2003; Firestone, 1987). The specific methods for data collection and analysis associated with quantitative research are discussed in detail in Section 5.4.

5.2.2 Qualitative Research Methodology

Historically, qualitative research was associated less with the empirical-positivist (as discussed in Section 5.1.2) and more with the interpretive paradigm and this form the focus of this discussion (Denzin & Lincoln, 2003). In an interpretive paradigm, reality can never be fully apprehended, only approximated (Guba, 1990). This is because the researcher relies on the views of individuals, asks broad, general questions and data collection consists largely of words or texts, describes and analyses these words or texts for themes; conducted in a subjective, attempt to reduce bias (Creswell, 2005). Because of this it often relies on multiple methods as a way of capturing the socially-constructed nature of reality, the relationship between the researcher and individuals, and constraints in the situations of interest (Denzin & Lincoln, 2003). Such a view of the nature of qualitative research emphasizes its value-laden nature. In addition, qualitative research can emphasize the discoveries and verification of theories, takes into account internal and external validity, and utilizes methods that lend themselves to structured analysis or sometimes statistical analysis. This deductive methodology approach is normally conducted within the empirical-positivist paradigm, and also leads to use of inductive methodology if used in the interpretive paradigm (Flick, 2006). This latter approach can employ things such as computer-assisted methods to calculate frequency, tabulations, and statistical analysis different to that of quantitative research, which typically uses more complex statistical measures (Denzin & Lincoln, 2003).

Qualitative research within a critical theory paradigm, however, generally rejects the use of quantitative methods. Members of the critical theory paradigm argue that empirical-positivist and interpretive paradigms produce only certain kinds of 'science', a science that silences too many voices (Denzin & Lincoln, 2003). In addition, this paradigm stresses that "there are no objective observation, only observations socially situated in the worlds of – and between - the observer and the observed" (Denzin & Lincoln, 2003, pp. 31).

Some of the overall characteristics of qualitative research listed by Janesick (2003) are:

- It is holistic. It looks at larger picture and begins with search for understanding of the whole. It is not constructed to prove something or to control individuals
- It looks at relationships within systems
- It is concerned with the individual, face-to-face, and immediate
- It is focused on understanding given social settings, not necessarily making predictions about those settings
- It demands the researcher to stay in the setting over time
- It demands time in analysis equal to the time in the field
- It requires the researcher to become the research instrument. In other words, the researcher must have the ability to observe behaviour and must sharpen the skills necessary for observation and face-to-face interviewing
- It incorporates informed consent decisions and is responsible to ethical concerns
- It incorporates room for description of the role of the researcher as well as description of the researcher's own biases and paradigm adopted
- It requires the construction of an authentic and compelling narrative of what occurred in the study and the various views of the individuals involved, and
- It requires *ongoing* analysis of the data.

Creswell (1998) mentions five types of qualitative research: *biography*, *phenomenology*, *grounded theory*, *ethnography*, and *case study*. Of those five, the researcher here focuses on phenomenology, as it is of most relevance to this study. Although it has been noted in Section 5.1.3 that symbolic interactionism (which focuses on subjective meanings and individual meaning making), and ethno-methodology (which focuses on everyday life experiences) have their own theoretical assumptions in qualitative research, discussions of those assumptions are embedded in phenomenology which is discussed next.

Phenomenology

Phenomenology refers to descriptions of one or more individuals' meanings and experiences about a concept or phenomenon (Creswell, 1998; Johnson & Christensen, 2000; Patton, 1990). Creswell, and Johnson and Christensen note that the central purpose of phenomenology is to obtain a participant's views of his/her world (i.e., an individual's inner world of immediate experience), and to understand the experience of a concept or phenomenon of his/her personal meanings constructed from his/her lived experiences. In other words, phenomenology focuses on the unique characteristics of an individual's experience of something or the "viewpoint of the subject" (Flick, 2006, p. 21).

Johnson and Christensen (2000) note that phenomenology generally assumes that there is some commonality in human experiences. This commonality of experience is called an *essence* or invariant structure (a part of the experience that is common or consistent across the research participants). An essence is an essential characteristic of an experience (Creswell, 2005; Flick, 2006), and according to Creswell (1998), insight experiences can take the form of memory, image, and meaning. Creswell (2005), and Johnson and Christensen (2000) note that an essence is universal, and is present in particular instances of a phenomenon. Creswell (2005) stresses that participants must be individuals who have experienced the phenomenon and can articulate their conscious experiences. Flick (2006) summarizes three basics assumptions of phenomenology in qualitative research: individuals act toward things on the basis of meanings that the things have for them; the meanings of such things are derived from social interaction; and meanings are handled in, and modified through an interpretative process. Hence for phenomenologist studies, purposeful sampling strategy, that of criterion sampling is more suitable.

The next two sections, Sections 5.3 and 5.4 discuss specific *methods* for data collection; including qualitative and quantitative research methods. Data analysis procedures applicable to each research methods also are described.

5.3 QUALITATIVE RESEARCH METHODS

This section discusses the specific methods for data collection and analysis associated with qualitative research, with particular focus on phenomenology. Diverse data collection is used in qualitative research, mainly focusing on verbal discourse and texts; interviews, reported documents, and observations as key tools (Cohen, Manion & Morrison, 2000; Creswell, 2005; Flick, 2006; Johnson & Christensen, 2000). Data from these sources are subsequently transformed into patterns, categories and basic descriptive units (Patton, 1990); codes and themes in a simultaneous part of process – see Figure 5.1 (Cohen et al., 2000); or through pattern coding (Miles & Huberman, 1994). This inductive process occurs throughout the duration of data collection and analysis: collecting, sorting into categories, formatting into a story, and writing qualitative text. At the same time, the process is also iterative or interim, in that it involves cycling back and forth between data collection and analysis – see Figure 5.1 (Creswell, 2005; Johnson & Christensen, 2000). During this iterative approach, the researcher may generate ideas or insights gained by reflecting on data, and recording these ideas as 'written memos' or 'head notes' (Johnson & Christensen, 2000). Memos or notes are thus reflective notes written from the data: these notes can be thought of as emerging concepts, themes or patterns found in the data, or a comparison that needs to be made within the data. Early written reflective notes tend to be more speculative, whereas memos or notes written later tend to be more focused and conclusive. This general view of data collection and analysis process within qualitative research approach is shown in Figure 5.1. Discussions of data analysis in phenomenology are discussed in detail in Section 5.3.5.

The next section discusses data collection methods such as interviews, examinations of reported documents, observation and validity quality, and in section data analysis includes theoretical coding and content analysis in phenomenology.

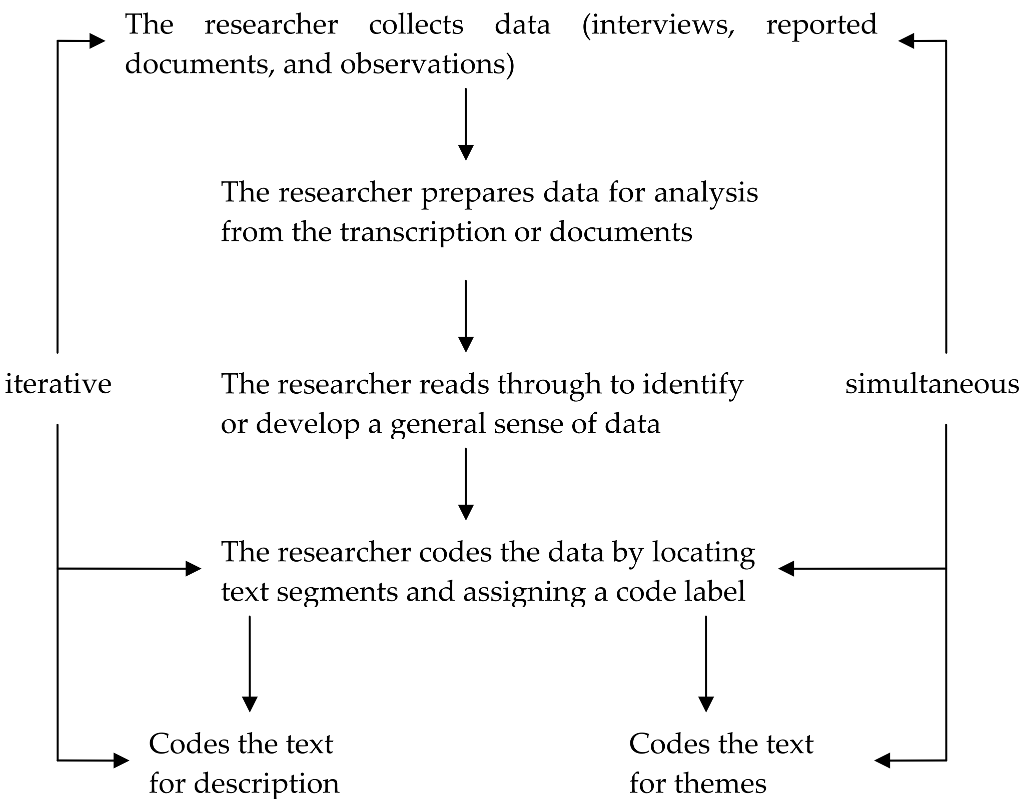


Figure 5.1
The process of data analysis
(from Creswell, 2005, pp. 231)

5.3.1 Interviews

There are a wide variety of ways to conduct interviews (Creswell, 2005; Silverman, 2004). Creswell (2002, 2005) identifies four types of interviews: one-on-one interviews; focus group interviews; telephone interviews; and e-mail interviews. Of those four, the first two are discussed in some detail because of their relevance to the study; one-on-one interviews, and focus group interviews – and these are discussed in turn.

The *one-on-one interview* as the name suggests involves only one participant and the researcher. This approach works well if the participant is not hesitant to speak, is articulate and can share ideas comfortably. However, a *focus group interview* involving several individuals, typically four to six, usually means the time taken to collect information is reduced. The interviewees are generally similar in background, cooperative with each other in discussion and can share their ideas, beliefs and attitudes, and experiences (Creswell, 2005; Johnson & Christensen, 2000; Wilkinson, 2004). It is this sharing that creates socially-constructed interaction experiences necessary for understanding by the researcher. The researcher asks a small number of general questions and elicits responses from all individuals in the group. Through a focus group interview, all individuals are encouraged to talk and to contribute, and it seems some find the experience more gratifying and stimulating than one-on-one interviews (Wilkinson, 2004). Commonly, each individual at the beginning of interview is asked to mention his or her name, to ensure that the voices of individuals in the group can be identified.

In order to make sure the issues of interest are all covered the researcher often employs an interview protocol; a form designed in advance by the researcher which contains the instructions for the process of the interview and the questions to be asked. The use of interview protocols enables the researcher to take notes during the interviews about the responses of the interviewee. The protocols also help the researcher to organize thoughts on items such as headings, information about starting the interview, concluding ideas, information on ending the interview, and thanking the respondent (Creswell, 1998; Flick, 2006). Creswell (1998) provides some helpful guidelines for developing an interview protocol:

- Use a header to record essential information about the project and as reminder to go over the purpose of the study with the interviewee. The heading might also include information about confidentiality and address aspects included in the consent form
- Place space between the questions in the protocol form. Recognize that an individual may not always respond directly to the questions being asked. Be prepared to write notes to all of the questions as the interviewee speaks
- Memorize the questions and their order to minimise losing eye contact. Provide appropriate verbal transitions from one question to the next, and
- Write out the closing comments that thank the individual for the interview and request follow-up information, if needed, from them.

Interview Structure. Interviews can take a variety of forms based on the degree of structure: structured, semi-structured or unstructured (Cohen, Manion & Morrison, 2000; Fontana & Frey, 2003; Johnson & Christensen, 2000). Structured interviews are prepared by the interviewer in advance, interviewees respond to the same series of defined questions in a standardised and straightforward manner, and there is very little flexibility in the way questions are asked or answered. They often elicit rational or reasoning responses. The interviewer plays a neutral role, does not interject his or her opinion of interviewee's answers, tries to establish a balanced rapport – being casual and friendly as well as directive and impersonal, and perfects a style of 'interested listening' – stimulating the interviewee's participation but not evaluating responses.

However, there are three response effects or errors that need to be taken into consideration during interviews (Fontana & Frey, 2003):

- The interviewee may deliberately try to please the interviewer by embellishing the response, giving 'a socially desirable' response or omitting certain relevant information
- The interviewee may error due to faulty memory as a result of the way the interview is conducted, or as a result of the sequence or wording of the questions, and
- Interviewer's error or effects such as his or her characters, or his or her question techniques that may impede proper communication of the questions. For example, the interviewer may have a high status compared with the participants.

In addition, a structured interview is directly influenced by the social interaction context – how interaction between the interviewer and interviewees can influence responses. In other words, the interviewer should be aware of unanticipated developments derived from interviewee differences. He or she should have interviewing skills that involve a high combination of observation, emphatic, sensitivity and intellectual judgement (Fontana & Frey, 2003).

Semi-structured interviews are determined partly by the interviewer in that the questions are defined in advance, and partly by the interviewee, in that the answers are left open. Unstructured interviews are often determined by the trend of the conversation. Some of the elements of unstructured interviews are: accessing the setting or context; understanding the language and culture of the interviewees; deciding on how to present oneself whether to be 'a nice person' or follow the format - this tactic includes maintaining the tone of a 'friendly' chat while trying to remain close to the questions; locating an informant; gaining trust; establishing rapport; and collecting empirical materials (Fontana & Frey, 2003). Individuals' answers to the questions are recorded through audio-tapes, transcribed or typed into a data file for analysis.

5.3.2 Reported Documents

There is a wide range of reported documents, often very large and lengthy that can be used to inform a research inquiry (Miles & Huberman, 1994). These reported documents are typically written texts which the researcher seeks to interpret in order to determine important meanings from the texts within a particular context (Denzin & Lincoln, 2003). At the same time, reported documents enter into a dialectic relationship between those contexts and the context of the analyst. According to Hodder (2003), this involves a hermeneutical method, in which the 'lived experience' surrounding the reported documents is translated into a different context of interpretation. In other words, reported documents require contextualized interpretation as many areas of experience are hidden by language (compared with say interviews), but they give alternative insights (Hodder, 2003). As the text is reread in different contexts, it is given new meanings; such meanings may appear contradictory and are always socially-embedded.

Due to the nature of such analysis, it is important that the researcher creates a document summary form. Miles and Huberman (1994) note that the summary form puts the document in context, explains its significance, and gives a brief summary and it can be used in the coding process.

5.3.3 Observation

Observation is defined as the process of gathering information about behavioural patterns of people in certain situations, in order to obtain information about the phenomenon of interest (Creswell, 2005; Johnson & Christensen, 2000). According to Johnson and Christensen (2000), observation involves observing all relevant phenomena, and taking extensive notes without specifying in advance exactly what is to be observed. Such observation is typically done in natural settings, and the type of role taken by the researcher during the conduct of an observation (or fieldwork) varies along a continuum of: participant-as-observer; complete participant; observer-as-participant; and complete observer (Creswell, 2005; Johnson & Christensen, 2000; Scott, 1997). The researcher may play all four roles at different times and in different situations during the conduct of a given qualitative research study. This is true especially when the researcher is in the field for an extended period of time.

Scott (1997) notes that the *participant-as-observer* role accepts the inevitable contamination of natural settings as a result of the researcher's presence, and that the researcher develops relationships with informants and makes no attempt to conceal his/her purposes. The researcher in say a classroom listens, watches, takes notes, walks around the class and talks to students about their work. According to Johnson and Christensen (2000), the participant-as-observer attempts to take on the role as an 'insider' (Creswell, 2005), similar to the complete participant. The researcher also spends a good deal of time in the field participating in activities, observing and recording information (Creswell, 2005; Johnson & Christensen, 2000). The researcher, however, explains to the participants in the group being studied that he or she is a researcher, and not a bonafide group member.

The *observer-as-participant* formalizes the participants' role, and sets limits to the amount and type of contact the researcher has with participants (Scott, 1997). Scott notes that in classroom observation of this type, the researcher makes little effort to interact with students or the teacher. The researcher takes on the role of observer much more than the role of participant (Johnson & Christensen, 2000). The participants are fully aware that they are part of a research study, but the researcher does not generally spend much time in the field. The researcher also may conduct several planned one-visit interviews with research participants. One disadvantage of this approach is that it is more difficult to obtain an insider's view. However, it is probably easier to maintain objectivity and neutrality.

Finally, the *complete observer* involves the researcher's interaction with the participants being limited to gaining and sustaining access (Scott, 1997). The complete observer fully takes on the role of an outsider who observes the phenomenon under study, watches, and records the activities (Creswell, 2005; Johnson & Christensen, 2000). He or she does not inform the people in the group being as studied or that they are being observed. The individuals being observed will thus not normally know that they are being observed. Creswell (2005) refers this type of observer as non-participant observer, where the researcher visits a site, and records notes without becoming involved in the activities of the participants. The complete observer thus conducts 'covert' or secret observations of participants and settings (Johnson & Christensen, 2000; Scott, 1997). This is in marked contrast to the complete participant who takes on the role of insider, essentially becoming a member of the group being studied and spending a great deal of time with the group (Johnson & Christensen, 2000).

In any type of observation research the researcher typically records observation in the form of field notes (notes taken during and after making observations). The notes taken are corrected and edited during an observation, or as soon as possible after they are taken, because that is when researcher recall is at its best. Videotaping is an additional method of 'taking notes' during observations. Some guidelines for observations are provided by Johnson and Christensen (2000), are shown in Table 5.3, and discussed in Section 5.5.2.

Table 5.3
Guidelines for conducting observations
(from Johnson and Christensen, 2000)

1. Who is in the group? How many people are there, and what are their kinds, identities and relevant characteristics? How is the membership in the group acquired?

2. What is happening here? What are the people in the group doing and saying to one another?

- What behaviours are repetitive, and which occur regularly? In what events, activities, or routines are participants engaged? What resources are used in these activities, and how are they allocated? How are activities organized, labelled, explained, and justified? What differing social contexts can be identified?
- How do the people in the group behave toward one another? What is the nature of this participation and interaction? Who makes what decisions for whom? How do the people organize themselves for interactions?
- What is the content of participants' conversations? What subjects are common, and which are rare? What stories, anecdotes, and homilies do they exchange? What verbal and non verbal languages do they used for communication? What beliefs do the content of their conversations demonstrate? What formats do the conversations follow? What processes do they reflect? Who talks and who listens?

3. Where is the group located? What physical settings and environments from their contexts? What natural resources are evident and what technologies are created or used? How does the group allocate and use space and physical objects? What is consumed, and what is produced? What sights, sounds, smell, tastes, and textures are found in the group uses?

4. When does the group meet and interact? How often are these meetings, and how lengthy are they? How does the group conceptualize, use, and distribute time? How do participants view the past, present, and future?

5. How are the identified elements connected or interrelated, either from the participants' point of view or from the researcher's perspective? How is stability maintained? How does change originate, and how is it managed? How are the identified elements organized? What rules, norms or more governs this social organization? How is power conceptualized and distributed? How is this group related to other group, organizations, or institutions?

6. Why does the group operate as it does? What meanings do participants attribute to what they do? What is the group's history? What goals are articulated in the group? What symbols, traditions, values, and world views can be found in the group?

5.3.4 Validity and Quality in Qualitative Research

As noted in the introduction to this chapter, it is important to describe steps taken to ensure the validity of the qualitative research approach. Johnson and Christensen (2000) identify three types of validity in qualitative research: *descriptive*, *interpretive*, and *theoretical*. The first two approaches are chosen, and are now discussed in turn.

Descriptive validity. Descriptive validity refers to the factual accuracy of an account as reported by the researcher. For example, in order to have descriptions covered in an intervention, the researcher asks the following key questions:

- Did what is reported as taking place in the intervention actually happen?
- Did the researcher accurately report what he/she sees and hears in the intervention?

The usual strategy used to enhance descriptive validity is to cross-check observations made by the researcher and say a teacher mentor who also was present in the classroom.

Interpretive validity. Interpretive validity means accurately portraying the meaning given by the individuals studied by the researcher. The researcher's interpretation of meaning includes aspects of individuals' viewpoints, thoughts, feelings, intentions, experiences, and involves internal validity and external validity. Internal validity means that the explanation of events or set of data can actually be sustained by the data, in the sense that the findings must be accurately described. Thus, attention is paid to a number of aspects of internal validity: plausibility and credibility; the types and amount of evidence required; and clarity on the types of claims made. On the other hand, external validity means the degree to which the results can be generalized to a wider population or situation. There are many categories of external validity reported in qualitative research (see, Cohen, Manion & Morrison, 2000; Creswell, 1998, 2002, 2005; Johnson & Christensen, 2000). Here the researcher considers three categories of external validity: researcher bias; characteristics of the participants; and the substantive content of the questions (Cohen et al., 2000; Johnson & Christensen, 2000). Biases include:

- The attitudes, opinions and expectations of the researcher
- A tendency for the researcher to see the participant in his or her own image
- Obtaining results consistent with what the researcher wants or expects to find
- Misperception on the part of the researcher about what the participant is saying, and
- Misunderstanding on the part of the participant about what is being asked.

For example, the researcher may tend to be selective in observation, be selective in the recording of information, uses his or her personal views and perspectives when doing data interpretation. To deal with such threats, two strategies, reflexivity and negative-case sampling, are used to reduce the effect of researcher bias (Cohen, Manion & Morrison, 2000; Johnson & Christensen, 2000).

Reflexivity. Reflexivity means the researcher actively engages in critical self-reflection about his or her potential biases, values, assumptions and predispositions (Creswell, 2005; Johnson & Christensen, 2000). This self-reflection may involve discussing personal experiences (see the 'personal dimension', Section 4.2), and the way the researcher collaborates with the participants during the phases of study. Such aspects of self-reflection may affect the research process, interpretations and conclusions. Creswell (1998) poses questions for the researcher to aid reflexivity:

- In the interview, will the researcher influence the contents of the participants' descriptions in such a way that the descriptions do not truly reflect the participants' actual experience?
- Is the transcription accurate, and does it convey the meaning of the oral presentation in the interview?
- In the analysis of the transcripts, were there conclusions other than those offered by the researcher that could have been derived? Has the researcher identified these alternatives?

- Is it possible to go from the general structural description to the transcriptions and to account for the specific contents and connections in the original examples of the experience?, and
- Is the structural description situation specific, or does it hold in general for the experience in other situations?

Negative-case sampling. This strategy involves the researcher carefully and purposely searching for examples or cases that *disconfirm* the researcher's expectations and tentative explanations. This strategy makes it more difficult for the researcher to ignore important information, and results in more credible and defensible findings. Aspects of validity quality in qualitative research are discussed in detail in Section 5.5.4.

5.3.5 Data Analysis in Phenomenology

This section presents a description of theoretical coding and content analysis of data for phenomenological approach derived from interviews, reported documents and observations. The analysis in terms of the coding draws upon the notion of grounded theory. The next paragraph discusses the theoretical coding and this is followed by a discussion of content analysis.

Coding. According to Johnson and Christensen (2000) and Creswell (2005), data analysis in grounded theory, and consists of three types, steps or stages: open coding, axial coding, and selective coding. The process of coding begins with sampling, identifying themes, building codebooks, marking and labelling text with symbols, constructing models (establishing relationships among codes), and testing these models against the data (Creswell, 2005; Johnson & Christensen, 2000; Ryan & Bernard, 2003). Here the researcher presents each of the processes as proposed by Ryan and Bernard (2003):

Sampling. Sampling begins with identifying a sample of text through reading transcripts line by line, naming (words or phrases), and categorizing these words or phrases into text segments either by random or purposive means, or extreme or deviant cases (cases can be typical examples of the phenomenon, represent variety for the phenomenon, or confirm or disconfirm a hypothesis) (Creswell, 2005;

Flick, 2006). Text segmenting involves identifying the basic units of analysis within the texts. Segmenting involves dividing data into meaningful analytical unit of text - a single sentence, several sentences, themes, a single theme, a paragraph, row, columns, pages or a complete document (Johnson & Christensen, 2000). A text segment is a group of sentences or paragraphs that relates to a single code, whereas code itself is the label used to describe a segment of text. In other words, a text segment can be coded line-by-line, sentence-by-sentence, or paragraph-by-paragraph, and a code can be linked to whole text segment (Flick, 2006). Flick (2006) suggests the following basic questions or strategies should be used to interrogate the text segment:

- What is the issue here? Which phenomenon is mentioned? (What?)
- Which individuals are involved? Which role do they play? How do they interact? (Who?)
- Which aspects of the phenomenon are mentioned or not mentioned? (How?)
- Time, course, and location. (When? How long? Where?)
- Aspects of intensity. (How much? How strong?)
- Which reasons are given or can be reconstructed? (Why?)
- With what intention, to which purpose? (What for?), and
- Means, tactics, and strategies to reach the goal (By which?)

Identifying themes. As themes are theoretical constructs, they may be identified before (e.g., from a literature review), during (from the researcher's own experience with those researched), and after (from the text itself) data collection. Themes are described as similar codes, aggregated to form a major idea. Here, a list of significant statements and meanings are constructed in order for the researcher to search for emergent themes. This also helps the researcher to understand individual and group differences. Themes have labels typically consisting of two to four words, and the following types (Creswell, 2005): *ordinary* – themes that the researcher might expect to find; *unexpected* – themes that are surprises and not expected to surface during a study; *hard-to-classify* –

themes that contain ideas that do not easily fit into one theme or that overlap with several themes; and *major and minor* – themes that represent the major ideas, or minor, secondary ideas or subthemes.

Building codebooks. In grounded theory, building codebooks is called axial coding. As codebooks are organized lists of codes, they should have a detailed description of each code, the meaning of the text segment or the meaning of each group of sentences, inclusion and exclusion criteria, and exemplars of real text for each theme. Then, an abstract theme is treated by providing examples of the theme's boundaries as well as some cases that are closely related but not included within the theme. Codes may address many different topics or categories of information or coding families. According to Creswell (2005) and Flick (2006) these consist of: setting and context codes (the specific conditions that influence the strategies); the causal conditions (categories of conditions or factors that influence the core category); perspectives held by participants or *in vivo* codes or the core category (the phenomenon central to the process); participants' ways of thinking about people and objects; process codes; activity codes; strategy code (the specific actions taken in response to the core phenomenon); and relationship and social structure codes; intervening condition (the general contextual conditions that influence strategies); and consequences - the outcomes from using the strategies. Examples of categories of codes are presented in Section 5.5.3.

Marking Texts. The act of coding involves 'tagging', placing or labelling a bracket around texts or sentences to mark off text for later retrieval, indexing or describing an idea (Creswell, 2005; Dey, 1993). Tagging can mark simple phrases or extend across multiple pages (i.e., tagging is not associated with any fixed units of texts). In other words, the researcher inspects the sentences seriously by taking apart and dissecting them, and uncovering, defining and analysing them (Patton, 1990). Patton proposes several steps for bracketing: locate within the personal experience, key phrases and statements that speak directly to the phenomenon in question; interpret the meanings of these phrases; obtain the subject's interpretations of these phrases; inspect these meanings for what they reveal about the essential, recurring features of the phenomenon; and offer a tentative statement, or definition, of the phenomenon in terms of the essential recurring features. In addition, the sentences are not interpreted in terms of the standard meanings given by the existing literature but are 'suspended' and put aside as well as the subject matter is confronted on its own terms. Other than tagging, the act of coding can also involve assigning values (nominal, ordinal or ratio scale) to a fixed unit of text (non-overlapping units of analysis). The non-overlapping units can be texts (paragraphs, pages, and documents), episodes, cases, or individuals. However in this study, part of marking texts is employed and most of data analysis involves content ananlysis, and is discussed next.

Content Analysis. Content analysis is the process of identifying, classifying or developing a general sense of the data (from the transcriptions of interviews, reported documents or observations), coding description and categorizing data (Carley, 1994; Creswell, 2005; Flick, 2006; Patton, 1990; Weber, 1990). The analysis not only focuses on the frequency, occurrence or categories of words or concepts in text or across text but also capturing the aspects of text (Carley, 1994; Silverman, 2003). Here the researcher seeks to establish a set of categories and then count the number of instances that fall into each category. In addition, the categories must be mutually exclusive and exhaustive. Dey (1993) defines mutually exclusive as meaning that no segment fits into more than one category, while exhaustive means that all data can be assigned into one category or another. To make categories exhaustive and mutually exclusive, new categories are added. Silverman (2003) suggests capturing the aspects of texts which depict 'reality', as discussed in Section 5.1. In other words, here the researcher's aim is to understand the individuals' categories and how these are used in a given task.

Carley (1994) proposes three types of content analysis: *conceptual analysis*, *procedural analysis*, and *relational analysis*. Conceptual analysis determines whether words, phrases, sentences or concepts are explicitly or implicitly present. Procedural analysis focuses on what procedural or actions are present in the text when the individuals are engaging in a task. In other words, this type of analysis focuses on processes such as domain, action sequences and decision sequences exhibited in the text. Relational analysis focuses not only on what concepts are present in the text but also on the relations between those concepts.

Creswell (1998), Johnson and Christensen (2000), and Patton (1990) provide general guidelines for analysis and representation of data from a phenomenological approach:

- The researcher begins with a full description of his own experience of the phenomenon. The researcher is aware of his or her bias, viewpoints or assumptions about the phenomenon being studied
- The experiences of 'others' are bracketed (see above)
- The researcher then finds statements or sentences (e.g., in interviews) about how individuals experience the phenomenon, lists out these significant statements or sentences ('horizonatalized' individual statement or sentence) and treats each statement or sentence as having equal worth or value. A list of repetitive, overlapping, irrelevant statements or sentences is eliminated
- These statements or sentences are grouped into 'meaningful unit or cluster', termed the delimitation process. The researcher lists these units or cluster, writes a description of the 'texture' of the experience – what happened – including verbatim examples. The texture is an abstraction of the experience that provides content and illustration but not yet essence. In other words, the texture of experience is a description of an experience that does not contain that experience.
- The researcher next reflects on his/her own description and identifies invariant themes in order to perform imaginative variation or structural description on each theme. In other words, the researcher seeks all possible meanings and divergent perspectives, varies the frames of reference about the phenomenon, constructs the phenomenon, and constructs a description of how the phenomenon was experienced by the individuals
- The researcher then constructs an overall description of the meaning and the essence of the experience, and
- This process is followed first for the researcher's account of the experience, and then for that of each individual. After this, a 'composite' description or the true meanings of the experience for the individuals is written.

Other than theoretical coding and content analysis, analysis from a phenomenological approach also can also employ categories proposed by Peshkin (1993) and Dey (1993): description; interpretation; and verification. Each of these categories is discussed in turn.

Description. Patton (1990) reminds researchers that descriptions must be carefully separated from interpretation. Here Patton say the 'description' needs to include the goals of the program, the primary activities of the program, the individual who is involved in the program, the program setting, happenings to people in the program, and the effects of the program to the participants. Miles and Huberman (1994) likewise note that description deals with both 'what is going on' and what is said by the individuals. It starts with a description of the setting after the initial reading and coding of the data from all sources to build a portrait of situations, places or events. In order to describe places or events, the researcher might ask, 'what is this place like?' or 'what occurred in this setting? In addition, a *thick description* or comprehensive descriptions and direct quotations should be included in data analysis. A thick description means, not only recording what an individual is doing, but also presents detail, context, emotion and the 'web of social relationships' among the individuals. Aspects of individuals such as considering the history of experiences, the significance of an experience or the sequence of events can then become the basis for an interpretation. Through a thick description the voices, feelings, actions and meanings of individuals are heard (Denzin, 1989).

Interpretation. Interpretation involves making sense of the data, and its meanings in context or analysing meanings through conceptualization: explaining the findings, answering the 'why' research questions, attaching significance to particular results, and putting patterns into an analytical framework (Dey, 1993; Miles & Huberman, 1994). In other words, the researcher is constantly moving back and forth: between the phenomenon and the researcher's abstraction, between the descriptions of what has occurred and the researcher's interpretation of those descriptions, between the complexity of reality and the researcher's simplification of those complexities, between the circularities and interdependencies of individual activity and the researcher's need for linear, statements of cause and effect. These form larger meanings about the phenomenon based on personal views and/or comparisons with past studies (Creswell, 2005). Patton (1990) comments that interpretation cannot be associated with causes, consequences and relationship - as these are related to the assumptions of quantitative analysis. The emphasis in interpreting explanation is thus instead on illumination, understanding and extrapolation rather than causal determination, prediction and generalization.

Interpretation has been discussed in this review of the literature in terms of comparing and contrasting with the researcher's positions, limitations of the study, and the personal dimension – all presented in Sections 1.5 and 4.3. Other aspects are discussed when addressing the research questions in Chapters 7 and 8, the researcher's personal reflection about the meaning of the data and suggestions for future research in Chapter 9.

Verification. Specifying verification steps helps to determine the accuracy of the account and its generalization. Participant-checking is typically used as a validity check. In this process, the participants review data interpretations and descriptions of their experiences, and provide feedback.

5.3.5.1 Analysing Interviews in Phenomenology

Analysing interviews begins either with case analysis or cross-case analysis (Patton, 1990). Case analysis means writing a case for each individual or each group interviewed, whereas cross-case analysis means grouping together answers or views from different individuals for the same questions or analysing different views or perspectives on central issues. In other words, answers from different individuals can be grouped by each question in the interview. However, Patton (1990) suggests researchers analyse interviews by individual case first, before engaging in cross-case analysis. If individuals are the primary focus of the study, this requires writing a case description for each individual. If the focus is on the program, then the analysis begins with a description of variations in answers to common questions.

The data obtained in phenomenology-based research are mostly collected through in-depth interviews (Flick, 2006; Johnson & Christensen, 2000). Creswell (1998) says that because phenomenology involves in-depth and extensive, and multiple interviews with participants, the researcher selects individuals who are easily accessible. As the interviews are in-depth in nature, the researcher needs to engage in a prior self-reflection, either for preparation or as the initial step in data analysis. Using interview data, statements or sentences are reduced to a common core or essence of the experience as described by the participants.

Transcription is the process of converting audiotape recording of interviews into texts (Creswell, 2005; Flick, 2006; Johnson & Christensen, 2000) usually called transcripts. The researcher himself transcribed the interviews. For example, researchers typically employ guidelines like those suggested by Creswell (2005) when transcribing interviews:

- Margins of two inches on each side of text are left empty for the researcher to jot down notes during data analysis
- On each page the space between the interviewer's comments and interviewee's comments is left empty for the researcher to distinguish between speakers during data analysis
- The researcher highlights or marks the questions in order to identify where one question ends and another question begins
- The researcher uses complete, detailed headers in the interview protocol, and
- The researcher transcribes all words, type the word [pause] to indicate when the interviewee takes a break or the interviewee cannot or will not respond to a question; type the word [laughter] to indicate the interviewee laughs, [telephone rings] to indicate a phone call that interrupts the interview or [inaudible] to mark the researcher cannot determines what is being said, and so on.

5.3.5.2 Analysing Observations and Reported Documents in Phenomenology

Initial analysis of observational data depends on how it may help to present the findings. Patton (1990) suggests the following process to organize the observational data: chronology; key events; various settings; people; processes; and issues. Some of these are shown in Table 5.3, page 155.

The interpretation of reported documents focuses on hermeneutical methods of context definition, including the construction of patterned similarities and differences (Hodder, 2003). In this thesis the researcher interprets different examples of reported documents and makes links between them. Thus, the researcher has to identify the context within which things have similar meanings. If the interpretation of context is comparable, then whether the interpretation of meaningful similarities and differences are mutually dependent.

5.4 QUANTITATIVE RESEARCH METHODS

This section discusses the methods for data collection and analysis that are associated with a non-experimental quantitative research methodology. Johnson and Christensen (2000) note that non-experimental quantitative research has three forms: *descriptive*, *predictive* and *explanatory*. Only descriptive research will be used here, as this work seeks to evaluate the pre-service physics teachers' conceptual understanding of science content. The descriptive information will seek to establish numerical evidence about how well the tests operate with different kinds of pre-service physics teachers under a variety of circumstances.

A survey is a procedure or method employed mostly in quantitative research and which seeks to describe a large group of persons, objects or institutions and their present situation (Jaeger, 1997). This population has at least one characteristic in common.

5.4.1 Survey Methods

In this research, it was decided that survey methods were to be used, and as Creswell (2005) says a survey involves a description of trends and the correlation of variables. Data in survey methods are gathered by means of standardised psychometric instruments and analysed via statistical procedures (Aiken, 1996; Creswell, 2005; Jaeger, 1997). This consists of gathering of limited data from a relatively large number of people at a particular time, and asking a large group of people questions about a particular topic. Creswell adds that a survey is not concerned with characteristics of individuals as individuals, but it is concerned with providing information about a population. Other authors describe a survey as the gathering of information concerning the opinions, practices, or possessions of a select group of individuals (see, e.g., Aiken, 1996). Among the aims of a survey are:

- to describe the characteristics of a population
- to obtain a description of situations and estimations of frequencies from the sample selected from the population
- whether to describe the nature of existing conditions; or to identify standards against which existing conditions can be compared
- to determine the relationships that exist between different variables, and
- to generalise the results obtained from the sample selected from the population to the larger population (Cohen, Manion & Morrison, 2000).

The following discusses one form of survey that is, questionnaires.

Questionnaires. The use of a questionnaire enables the researcher to question a sufficiently large sample of respondents in a short period of time. It may contain closed or open-ended questions. The following list is a combination of closed and open ended questions suggested by Gallup, (1947, cited in De Vaus, 1995). Survey questions are aimed at:

- seeing if the respondent has thought about or is aware of the issue (a closed question)
- getting general feelings on the matter (an open question)
- getting specific aspects of the issues (an open question)
- finding out respondents' reasons for their opinions (open questions), and
- finding out how strongly the opinion is held (a closed question).

In developing questionnaire items, four types of content question can be taken into account: behaviour, beliefs, attitudes and attributes (De Vaus, 1995). In terms of response categories, rating scales consisting of a number of pre-determined categories are used to represent varying degrees of attributes and properties (Aiken 1996; Wolf, 1994; Andrich, 1994). These types of content questions are discussed in more detail in Section 5.5.1.

Questionnaires often are used to measure an individual's attitude or perception about some issue or topic. Here the researcher develops scales and a given scale contains statements about which people can manifest some attitude, beliefs or perception (Dunn-Rankin, 1994). The validity of measurement of such attitudes and/or beliefs scales depends on both the frankness and the cooperation of the respondents, since attitudes and/or beliefs cannot be observed directly but are inferred or responses they make to a set of statements. According to Aiken (1996), an attitude and/or beliefs scale should consist of a series of statements expressing positive and negative feelings about a given institution, a group of people, or a concept. A respondent's score on an attitude and/or beliefs scale is then determined by the items with which he or she agrees or disagrees. Likert scales are the most common scales used to measure attitude and/or beliefs, and they consist of a series of statements, each statement followed by a number of scale response. Such statements are responded to differently by people who hold different points of view (Anderson, 1988; Dunn-Rankin, 1994). The statements endorsed positively are interpreted to mean that individual shows a favourable attitude and/or beliefs toward the object of interest. Likewise, statements that are endorsed negatively are taken to be evidence of an unfavourable attitude and/or beliefs toward the object of interest (Anderson, 1988). The use of Likert scales is discussed in more detail in Section 5.5.1.2.

5.5 RESEARCH METHODS USED IN THIS THESIS

As noted above, the literature suggests that the research methods chosen by researchers should follow directly from the questions asked (Patton, 1990). As this study involved an intervention of nearly six months' duration, an interpretive-based approach using a qualitative methodology was regarded as best means of data collection. The qualitative data were complemented with some quantitative data as described below. A detailed description of intervention in the 'physics teaching methods course' is given in Section 6.1. Thus, in this thesis, the researcher decided to integrate methods, linking paradigms to methods and combining research processes for all phases of the study.

To integrate methods, the researcher employed a combination or mixed-methodology approach (quantitative and qualitative), multiple methods of data collection and analysis - through 'within methods' (different types of data collection such as inspections of assignments of didaktik analysis and lesson plans, observations of microteaching and practicum, and interviews - words) and 'between methods' (quantitative and qualitative data collection procedures such as questionnaires, tests, final examinations, written reflection and interviews – numbers and words), and triangulation of data sources. Linking paradigms with method types enables the researcher to choose between method types. Combining methods help the researcher to cross-validate results on the same research question. As the researcher was resident in the natural setting for six months, the multiple methods employed here also attempted to reduce the influence of researcher-pre-service teacher hierarchal levels, and create a genuine partnership.

The key goal of using a mixed-methods or integrated-methods approach was to allow the strengths of one method to enhance the data from the other methods. In addition, qualitative methods serve not only to complement quantitative research, but it also as a follow-up to data gathered by quantitative methods. So the qualitative methods typically provide interpretive resources for understanding the results from the quantitative data. The benefits of this process were that validity of the results can be enhanced by this triangulation of findings from the various data sources (Creswell, 2005). According to Creswell (2002), triangulation is the process of corroborating evidence from different individuals, types of data, or methods of data collection – more discussion in Section 5.5.4. Creswell (2005) lists purposes for triangulation:

- Triangulation results in complementary methods, with the strengths of one method complementing the weakness of another
- Triangulation develops, in that data gathered from the first method may in sequence inform the data collection via the second method, and
- Triangulation adds scope and breadth to the study. Triangulation seeks convergence or confirmation of findings, however, triangulation also initiates contradictions and allows fresh perspectives to emerge.

Thus, discussion of each process in data collection, before and during the intervention are discussed in the following section, Sections 5.5.1 and 5.5.2, follow with data analysis of quantitative and qualitative data and measures taken to enhance the quality of the study are presented in Sections 5.5.3 and 5.5.4, respectively.

5.5.1 Quantitative Data Collection Methods

This section discusses the specifically quantitative data collection methods employed in the thesis: The Test of Understanding Graph in Kinematics (TUG-K) and The Force and Motion Conceptual Evaluation (FMCE) and a questionnaire survey administered to the pre-service physics teachers. The test of TUG-K was concerned with the topic of mechanics, which is seen as a basic and essential pre-requisite for much of physics learning. It was administered at the beginning of the course and thus served as a starting point to develop a general understanding of pre-service teachers' competency in physics. It was not used to test their achievement in physics as some of the particularly third year cohort group had taken physics course (in mechanics) previously but others had not (see Section 6.1 for a detailed discussion of this). The test was thus merely used as a strategy to understand and evaluate pre-service teachers' understanding and their knowledge of *specific physics concept*, and cross tab with the didaktik analysis. In addition, a survey questionnaire was employed to complement part of the tests. As the number of pre-service teachers enrolled in the physics teaching method course was reasonably large (113), the survey questionnaire was able to provide a general picture of their beliefs about and attitudes towards the teaching and learning of secondary school physics. It was also intended that these might serve to emotivate ideas, and then the capacity to provide anonymous responses might mean such responses would be more honest. Therefore, the next section presents a description of the criteria used in employing the test instruments and the approach used when developing the survey questionnaire for research question one.

5.5.1.1 The Test Instrument

There are a number of popular instruments that can be used to probe pre-service teachers' understanding of kinematics and dynamics (McDermott & Redish, 1999). For example, the Test of Understanding Graphs in Kinematics - TUG-K (Beichner, 1994), the Force Concept Inventory - FCI (Hestenes, Wells & Swackhamer, 1992), the Mechanics Baseline Test - MBT (Hestenes & Wells, 1992), and the Force and Motion Conceptual Evaluation - FMCE (Thornton & Sokoloff, 1998). Here the researcher employed two instruments, the TUG-K and FMCE, both deemed appropriate for pre-service teachers, and that can provide information about specific conceptual difficulties for individual pre-service teachers. The following are the reasons why the researcher employed these tests:

- Both tests are of relevance to the study as they have high construct validity and content validity, and the tests results can be used as a general indicator of pre-service teachers' understanding of graphical representations in kinematics and Newtonian concepts, and to determine whether the pre-service teachers had had similar physics learning experiences at secondary schools and at the University of Malaysia Sabah
- The pre-service teachers had taken physics courses at the University of Malaysia Sabah during their first year undergraduate study. The physics courses covered all questions in both tests and they thus appeared to be

suitable for pre-service teachers who enrolled in the physics teaching methods course, and

- The time required for the test is about an hour, which is suitable to administer in three contact hours per week for the physics teaching methods course.

Reliability and Validity of the Tests. There are aspects of place, the significance of tests, the Hawthorne effect (the presence of the researcher alters the situation as participants may wish to avoid, impress, direct, deny or influence the researcher), the time of day, the time of the university session, the temperature in the test room, the perceived importance of the tests, the amount of guessing answers, the way the test is administered, all that might affect the reliability of the tests (Cohen, Manion & Morrison, 2000). Other aspects that may affect reliability include: the range of the group that is being tested, the group's level of proficiency, and the length of the tests. Threats to reliability of tests include the following (Cohen et al., 2000): individuals – their motivation (those with low motivation might demonstrate less than their full abilities), concentration, forgetfulness, carelessness, guessing, the effects of practice; situational factors – the psychological and physical conditions for the tests (the context); and instrument variables – length of the tests, the difficulty level might be too low or too high, instructions might be unclear and ambiguous, language and readability (items either in first or second language).

With regard to validity, effective tests take into account the following factors (Cohen et al., 2000): content validity – this includes that the tests cover the relevant topics; the tests are relevant to particular programme; the programme covers the overall topics; criterion-related validity – this includes relevant, free from bias, precise and accurate, capable of being measured or achieved; construct validity – the tests items are related to constructs; concurrent validity – similar to predictive validity; predictive validity – results on the tests accurately predict subsequent performance; and consequential validity – the inferences made from the tests are sound.

5.5.1.2 The Development of the Questionnaire

The process of developing the instrument, the Belief About Physics Teaching (BAPT), as recommended by Aiken (1996) involved deductive, inductive, and empirical processes. In the deductive process, the researcher reviewed relevant literature about pre-service teachers' beliefs, knowledge, practices, teaching self-efficacy and their attitude towards teaching (see Section 4.1). The theoretical constructs or *scales* for items generated from these conceptions of pre-service teachers served as a starting point in the development of the BAPT instrument. Here, the term *scales* is used as a measure of theoretical constructs instead. In addition, the researcher modified some items from other instruments in the literature, for example, the Chemistry Attitudes and Experiences Questionnaire (CAEQ) (Dalgety, Coll & Jones, 2003), and the Elementary Science Teaching Efficacy Beliefs Instrument (STEBI-B) (Enochs & Riggs, 1990).

The Elementary Science Teaching Efficacy Beliefs Instrument (STEBI-B) was specifically developed for pre-service teachers and is used to evaluate personal science teaching efficacy (i.e., it evaluates pre-service teachers' perceptions of their ability as a classroom teacher); and science teaching outcome expectancy (i.e., it evaluates pre-service teacher's perceptions of their ability as to whether or not they can improve students' learning). Thus, in this study, some of the items of STEBI-B were used to investigate the influence of learning experiences on pre-service physics teachers. Ramey-Gassert, Shroyer, and Staver (1996) employed the STEBI-B instrument in their research and identified three factors that influence science teaching self-efficacy: antecedents, external factors, and internal factors. Among the factors used from this study were antecedents (science related experiences in school), and internal factors (attitude-toward science and interest in science). Another factor included in the questionnaire was the attitudes of pre-service physics teachers towards physics and learning. This factor was derived from the CAEQ instrument, in which the authors say learning experiences may influence participants' attitude towards teaching (Dalgety et al., 2003).

The second process is the inductive process, and this involved the use of factor analysis and reliability analysis to measure the internal consistency of the theoretical constructs or scales. Aiken (1996) notes that although researchers may have some initial ideas about what they intend to measure, the major purpose of this process is to let the data 'speak'. The internal consistency of a theoretical construct or scale was measured by calculating the item-total correlations. The development of the instrument involved the following:

Identifying Scales. A series of discussions relating to pre-service teachers' beliefs, knowledge, practices, teaching self-efficacy and their attitude towards teaching were held with a panel of experts, and this along with a review of relevant literature were used to develop the *scales* that formed the basis of the instrument (see, e.g., Dalgety, Coll & Jones, 2003; Osborne, Simon & Collins, 2003; Pajares, 2002; White et al., 1995). The researcher modified items based on comments from a panel of experts (supervisor, and colleagues where the intervention was conducted), and this resulted in a number of revisions. Feedback from written reflections during the first week of the physics teaching methods course were used to inform the scales used in the instrument. This process resulted in the following scales:

- *Physics learning experiences* consisted of two subscales at secondary school: *the classroom*; and *the laboratory*, and three subscales at the university: *lectures*; *tutorial classes*; and *laboratory classes*
- *Attitude-towards-physics* and *learning* consisted of three subscales: the *influence of physics teachers*, *physics lecturers*, and *feelings about physics learning* (positive or negative)
- *physics teaching self-efficacy* consisted of three subscales: *confidence to teach secondary school physics*, and *ability to teach secondary school physics*, and *confidence to teach specific secondary school physics topics*
- *Attitude towards, and beliefs about, physics teaching* consisted of two subscales: *interest to teach secondary school physics*, and *career interest in physics teaching*, and
- *Conceptual understanding* included a*bility to teach secondary physics topics*, *ability to teach general learning outcomes for the topic 'force and motion'*, and the *ability to teach specific learning outcomes of topic 'force and motion'*.

Scales Used in the Questionnaire. The scales and subscales were measured using a combination of ordinal and interval scales. Treating data as interval data means that tests such as correlation analysis (used to identify whether or not there is relationships between each item within the scale and between the scales) give results about statistical significance for any differences. Rennie (1998) recommends that in order to facilitate quantitative data interpretation, researchers should provide: correlation analysis, N values, means for scales, and standard deviations.

The pre-service physics teachers were asked to respond to items using a five point Likert scale: 1 – Strongly Disagree; 2 – Disagree; 4 – Agree; and 5 – Strongly Agree, all for statements that were presented in a random order in the instrument. As the measurement of attitudes of pre-service teachers is based on opposite or bipolar statements and adjectives, their response on a Likert scale is assumed to be the same (e.g., *strongly disagree* with *agree*). Thus, this is the reason why the ordinal scale in the instrument was treated as interval level data. Although these response options are nominal level, analysis of responses was summarised using interval-level statistics, such as the arithmetic mean, the standard deviation and standard score.

Some of the items on the attitude scale were positively worded and responses to positively worded items were scored 1 for strongly disagree, 2 for disagree, 4 for agree, and 5 for strongly agree. Responses to negatively worded items were scored 1 for strongly agree, 2 for agree, 4 disagree, and 5 for strongly disagree.

Validation of the scales. To develop a valid and reliable instrument is a complex process and an on-going process. The development of the instrument was repeatedly tested by piloting items, and analyzing responses or feedback from the panel of experts. The researcher sought to enhance construct validity of the instrument by asking the panel of experts to complete and comment on the instrument. This was followed by revision of the instrument, and piloting the instrument again. The researcher also was conscious that problems may arise as the questionnaire was administered in English. Some English words may mean different things to the pre-service teachers to that intended by the researcher, and this may result in different interpretation of the words (e.g., Malaysians may interpret some English words in different ways in a different context). The researcher slightly modified the wording to take account of the participants' English skills (based on the feedback from the researcher's colleagues at the institution involved in the study).

The researcher strived to enhance all aspects of validity when developing the instrument, with particular focus on content and construct validity. As noted above when identifying *scales*, the researcher verified the accuracy of the instrument by obtaining feedback and written reflections throughout the course, and also interviewed nine of the pre-service physics teachers who had completed the instrument. Convergent validity of the instrument is indicated by high inter-correlations with other measures or methods for the same *scale*. Discriminant validity is evidenced by low inter-correlations with measures or methods of measuring different *scales* (Aiken, 1996; Cohen, Manion & Morrison, 2000). If all of these are present, then the instrument can be said to have construct validity. Convergent and discriminant validity of the instrument were thus evaluated to determine whether items in each sub-scale were addressing the same scales. Convergent and discriminant validity can be evaluated using factor analysis and reliability analysis - a procedure for reducing a large number of variables to a smaller set. As Gardner (1995, 1996) notes the reliability of each sub-scale is a measure of convergent validity, but not of discriminant validity, whereas statistical discriminant validity is a measure of discriminant validity, but not of convergent validity.

Reliability of the Instrument. An item in an instrument is considered useful if there are consistent responses within a group of individuals who respond to the item. However, the reliability of the instrument generally and items specifically may be affected by several factors. According to Aiken (1996), important factors are: low motivation, distraction, an uncomfortable environment, and variance of the *scales*. For example, the pre-service teachers in this work are part of the Malaysian education system, and typically expect to follow instructions even if they do not wish to (e.g., participating in a research project like this). In other words, as the pre-service teachers enrolled for teaching methods course, inevitably they had to participate in research although it is possible they would rather not. Clearly if this were the case some item responses may be less than ideal.

Reliability for an instrument also can be enhanced by increasing score variance. This is done by adding more items for the same *scale*. Score variance also increases with the use of a heterogeneous group (e.g., sex, years of study, and learning experiences). The internal consistency reliability was calculated using the corrected item total correlation for each *scale*. The corrected item total correlation is the correlation between that item's score and the *scale* scores computed from other items in the instrument. If an individual item does not correlate with the total score of all the items, it can be inferred that the item measures a different *scale*.

The researcher thus conducted factor analysis, reliability analysis using Cronbach's alpha, and statistical discriminant validity, in accordance with the recommendations of Coll, Taylor and Fisher (2002). Gardner (1995) defines Cronbach's alpha as the ratio of the sum of the variances of the individual item scores to the variance of the *scale* score. Alpha is maximised when every item in a *scale* shares common variance with at least some other items in the *scale*. Statistical discriminant validity was evaluated using the average Pearson's correlation. Concurrent validity, convergent validity, criterion-related validity, predictive validity, internal or external validity also were taken into consideration.

However, the researcher did not consider that the reliability of the instrument necessarily meant that construct validity had been achieved (Aiken, 1996). The calculation of reliability of the instrument is shown in Section 6.2 and given that the sample was not uniform, and that there were a small number of attributes for each sub-scale, the researcher decided that the value of Cronbach's alpha may not give meaningful results. As the value of Cronbach's alpha depends on the number of attributes in each sub-scale, it was not calculated for each individual sub-scale. Additionally, the direction and strength of relationship between the two *scales* are indicated by the following coefficient suggested by Burns (2000), shown in Table 5.4.

Table 5.4
Correlation coefficient between two scales

Correlation coefficient	Strength	Relationship
0.90 – 1.00	Very high correlation	Very strong relationship
0.70 – 0.90	High correlation	Marked relationship
0.40 – 0.70	Moderate correlation	Substantial relationship
0.20 – 0.40	Low correlation	Weak relationship
Less than 0.20	Slight correlation	To be negligible

5.5.2 Qualitative Data Collection Methods

This section discusses specific qualitative data collection methods. Here the researcher followed the suggestions of Janesick (2003), and employed the notion of 'stretching exercise' in contrast with the notion of a 'pilot study' as typically used in quantitative research. The idea here is that a researcher needs to develop and solidify rapport with those involved directly and indirectly in the study. In this work this included the pre-service physics teachers who enrolled the physics teaching methods course, the Dean of the School of Education, the academic and non-academic staff at the School of Education. Additionally as a novice, the researcher required practice in methods such as interviewing, making observations, inspecting of written reports and refinement of research instruments. Prior to interviews with the pre-service teachers, the researcher tested the audio-tapes and held meetings with selected pre-service physics teachers. Expertise in purely technical things was required, and so the researcher spent time with a technician, an expert in video editing at the UMTP (Educational Technology and Multimedia Unit) university unit - and this helped the researcher to see how to get video clips transferred from a video camera to CD.

The intact weekly class of pre-service teachers enrolled in the physics teaching methods course TT4133 was briefed about the intervention. The synopsis of the course was modified slightly in terms of the content, as a result of the didaktik analysis. During the first seven weeks of the course, the researcher introduced the components of didaktik analysis to the pre-service physics teachers. At the end of the first week of the course, two assignments were required: didaktik analysis of specific physics content, and developing lesson plans. The researcher listed the specific physics content areas based on the Revised Form 4 Physics Curriculum Specification (Kementerian Pendidikan Malaysia, 2004), 'the official curriculum', for a group assignment on didaktik analysis (see Section 7.1). Each of pre-service physics teachers was free to choose their members for a group consisting of four or five students, and assigned a specific physics content area. They were provided with sources of information (e.g., science education journal articles or relevant websites) for their assignments, in didaktik analysis. The assignment of lesson plans was done individually, and these were prepared after the group assignment on didaktik analysis of specific physics content. Each pre-service physics teacher was then asked to plan and enact a teaching sequence for one of the three lessons during the microteaching. These assignments are part of the assessment requirement for the course. Both assignments in didaktik analysis and three lesson plans were analysed to address research questions two, three and four.

There were three sessions of focus group and/or individual interviews with the pre-service physics teachers: one at the beginning of data collection that is, a few days after completing tests of conceptual understanding – the TUG-K and FMCE, and written reports: One after the pre-service teachers completed the microteaching; and one after their practicum. Each approach employed upon request from the pre-service physics teachers. The first interviews were both one-on-one and/or focus group interviews and these focused on their views of the test on conceptual understanding of mechanics and their ideas about their prior experiences in teaching and learning of physics. The interviews helped the researcher to identify any conceptual difficulties the pre-service physics teachers held for mechanics topics. The second interview was conducted after the microteaching (discussed below). Here the pre-service physics teachers were asked about the topics and tasks given in the didaktik analysis, such as their confidence to teach the content, and their feelings about the process of teaching, their views of the physics methods course and its influence on their teaching, and their views of the assignments on didaktik analysis and their lesson plans.

For this study, a semi-structured interview was deemed most suitable as interviewees would have the freedom to answer in any manner they chose, English or Malay language. In addition, the interviewer is able to make comparison of responses between the interviewees. As this interview structure is formal in nature, some interviewees may feel uncomfortable speaking out, with each other or with the interviewer. The researcher employed a mixture of closed and open-ended questions when interviewing, and some data also were gathered in 'on-going meetings' via informal interviewing. In these latter interviews, the researcher was able to answer questions asked by the interviewees in a more relaxed fashion. Data from the closed question interviews were captured and a coded within pre-established categories. However, the data from open-ended questions in the 'on-going meeting' were different and the researcher attempted to understand a phenomenon without imposing any a priori categorization. These unstructured interviews retained a little structure in the sense that there is a setting, there are identified informants, and the interviewees are clearly discernible.

Observations of pre-service teachers were conducted during the microteaching at the university and during the practicum in the secondary schools. Observational data served to supplement interview data, and this in turn provided support for the interpretation of interview data. During the practicum, all of the 10 pre-service physics teachers selected were observed by the researcher on two occasions in their secondary schools (see Section 8.1). Each lesson was observed in terms of everything said by the pre-service teachers and his/her students, all recorded using a video-tape and transcribed verbatim. At the end of pre-service teacher's lesson, the researcher conducted interviews, first focus group interviews with three selected secondary school Form 4 physics students, followed by individual interviews with the pre-service teacher.

5.5.3 Analyses of Quantitative and Qualitative Data

This section discusses analyses of both quantitative and qualitative data. As the survey method was used in this thesis, appropriate statistical analyses were carried out. Item means and reliability for each *scale* were calculated: higher means taken to indicate favourable beliefs towards the *scale*, and high reliability suggesting those items measured the same *scale*. In addition to using Cronbach's Alpha, item-total correlations were also calculated. A comparison of means and standard deviations for each item was calculated to compare differences in responses between the two cohorts (namely third years and fourth years). An independent groups t-test was calculated to examine differences in responses (means scores) between the two cohorts. This was followed by calculating the effect size. The effect size evaluates the magnitude of any relationship among variables (Burns, 2000; Creswell, 2005). Burns (2000) suggests that an effect size around 0.20 is small, an effect size around 0.50 is moderate, and an effect size greater than 0.80 is large.

Correlation analysis is calculated to identify whether or not there are relationships between items within a *scale*, and between *scales*. If the correlations are significant (at the $p = 0.01$ for 1-tailed t-test level, or $p = 0.05$ 1-tailed level), any results are considered for further analysis. Analysis of the results of the instrument is presented in Section 6.2.1.

Two tests of conceptual understanding were used in this thesis. The TUG-K and the FMCE, and these focused on the pre-service teachers' understanding of kinematics and dynamics (force and motion) concepts. Both tests consist of 60 questions for Newtonian concepts across four conceptual dimensions: Kinematics graphs, Newton's First Law, Newton's Second Law, and Newton's Third Law. A score of 60% for each conceptual dimension was considered as a 'conceptual threshold'; and 80% score for each conceptual dimension was considered evidence of mastery. A score of less than 60% for each conceptual dimension was considered to indicate that the pre-service teacher's grasp of Newtonian concepts was limited (based on standards set by Thornton & Sokoloff, 1998).

Data collected through written reports about physics learning experiences in secondary school and university, together with the findings from the tests of conceptual understanding (TUG-K & FMCE), three focus group interviews with nine selected pre-service physics teachers, and the questionnaire survey were used to address the first research question. In other words, here the researcher sought to understand the pre-service teachers' beliefs about, and attitude-towards teaching and learning secondary school physics. The notion here was that their conceptual understanding and perceptions of their capability to teach physics may play a critical role in didaktik analysis.

Analysis of qualitative data involved evaluation of the pre-service teachers' assignments in didaktik analysis and inspection of their lesson plans (details of the analyses of these assignments are presented in Chapters 7 and 8). Aspects of didaktik analysis presented by the pre-service teachers in their assignments included a conceptual analysis of Form 4 physics content to be taught, as presented in the Malaysian secondary physics curriculum and textbooks, and analysis of literature on students' alternative conceptions. Textbook presentations and a synopsis of the history of scientific thinking about specific physics content, also were taken into account in this conceptual analysis. These processes sought to determine whether or not the pre-service teachers had an understanding of specific physics content, and whether or not they would be able to identify differences between scientific knowledge and school science. These aspects of didaktik analysis were coded to identify the relevant component of research questions two, three and four. The codes were based on the following categories, using data analysis in phenomenology (see Section 5.3.5):

- Setting and context codes (e.g., lecture or microteaching room, the researcher's office room, and classroom lecture)
- perspectives held by participants or *in vivo* codes (e.g., physics teaching is difficult)
- participants' ways of thinking about people and objects (e.g., problematic studying physics)
- process codes (e.g., locating students' alternative conceptions in journals during the assignments of didaktik analysis)

- activity codes (e.g., lack of coherence between the assignment on didaktik analysis, with lesson plans, the microteaching, and the practicum)
- strategy code (e.g., the researcher's assistance to the pre-service teachers), and
- Relationship and social structure codes (e.g., pre-service teachers doing group assignment, on-going meetings, and discussions with the researcher).

This coding was followed by an assignment involving the preparation of the three lesson plans derived from the didaktik analysis. Analysis of the lesson plans (intended curriculum) was based on components established by the researcher: learning outcomes, teaching sequence, assessment procedures, and reflection (ideas and beliefs) – see Sections 2.3.2 and 7.1.2. Here, the researcher sought to see how effective the teaching sequence (enacted curriculum) based on didaktik analysis was, and how well the written lesson plans were translated into learning in the microteaching. The designs of teaching sequences from the lesson plans also were coded to identify and address the relevant components for research questions two and three. The researcher described and interpreted information from the assignments of lesson plans, notes taken from observation of microteaching, and responses from the interviews. The pre-service teachers evaluation of the 'Physics Teaching Methods Course' also was used to complement data derived from assignments of didaktik analysis and lesson plans.

Other than the conceptual analysis and analysis of literature on students' alternative conceptions, the pre-service teachers' reports at the end of assignment of didaktik analysis provided insights into their beliefs, the difficulties they thought they might experience, the problems they encountered, and any difficulties in communication with the students they encountered during the practicum. Their written reports were described and interpreted by the researcher. Interpretations derived from the pre-service teachers' reports on their assignment of didaktik analysis were used to address the third research question. Some of the interpretations were supplemented by the on-going meetings with the researcher, the pre-service teachers' responses from the interviews conducted after observations of the microteaching as well as related questions from the final examination. Each coded aspect was grouped with others of similar nature, and the major themes were established. Finally, observations of practicum helped to derive conclusions for the entire set of research questions. Analysis of the results from these qualitative data are presented and discussed in Chapters 7 and 8.

5.5.4 Measures Taken to Enhance Qualitative and Quantitative Research Quality in This Thesis

The final feature of this description of the research methods used in this thesis concerns issues of confirmability (objectivity), subjectivity, credibility (internal validity), transferability (external validity or generalizability), dependability (reliability), trustworthiness and authenticity, data triangulation, and ethical considerations. These issues influencing the validity of the diverse data gathered in this thesis, were mentioned in Chapter 1 (see Section 1.5) and described briefly, but on qualitative research in Section 5.3.4. Here, the researcher discusses the issues mentioned above for both research methodologies. As this thesis involves qualitative and quantitative methods, and naturalistic research (see Section 5.1.3) it drew upon the suggestions of Lincoln and Guba (1985 & 2003), Janesick (2003), and Patton (1990).

At the heart of the dichotomy of quantitative and qualitative research is debate over the *quality of methods*, the *quality of the data*, and the *quality of the data analysis* (Patton, 1990; Silverman, 2004). As noted above, specifically, critics of qualitative research argue that such methods are inherently subjective and thus liable to researcher bias (see Section 5.3.4). For example, Silverman (2004) notes that qualitative methods such as interviews may suffer from two problems: The assumption of a stable reality or context (e.g., learning experiences) to which individuals respond; and the gap between beliefs and action, and between what individuals say and what they do.

In addition, during observations of microteaching or a practicum (a common qualitative method, and one used extensively in this thesis), the researcher may see and interpret what is happening according to his or her own viewpoint, and thereby ignore important things occurring because they are deemed unimportant or irrelevant. Thus quantitative researchers often say that they do ‘objective’ research whereas qualitative research is actually 'subjective' in nature (Creswell, 2002). Silverman (2004) notes that as a result of division of labour here between qualitative and quantitative methodologies, both seem to neglect a great deal about how individuals interact. In other words, both methodologies are concerned with the environment around the phenomenon, rather than the phenomenon itself.

With regard to quality of data, Patton (1990) and Silverman (2004) also suggest that the credibility and reliability of the data in qualitative methods need to be taken into account. For example, Patton (1990) notes that the credibility of the researcher is essential, as the researcher becomes the instrument of data collection, and as such becomes the centre of the data analysis process. In addition the quality of data analysis in terms of long (length of data) and well-transcribed (coding based on categories – see Section 5.5.3) contribute to the reliability and validity. This is done through the method of analytic induction which involves the constant comparative method, unlike case analysis which involves the use of data in relation to conclusions or explanations (Silverman, 2004). Thus, Silverman distinguishes between the quality of data analysis in qualitative methods, as comprehensive data treatment compared to quantitative methods in which data are seen to be significant and correlated with each other (statistical analysis). Other issues related to the quality of research as noted above, are further discussed next.

Objectivity and Credibility. Peräkylä, (2004) notes that the reliability and validity of qualitative research (e.g., in the analysis of text, or recording of interviews) is dependent on the objectivity and credibility of the process itself. Objectivity is a concept similar to confirmability, and refers to evidence for the relationship between the data and its interpretation. For example, to enhance the objectivity of recorded interviews, the researcher needs to ensure the accuracy and inclusiveness of recordings, as well as to test the truthfulness of the analytic claims that are being made about those recordings. Similarly in the analysis of texts, the researcher cannot control what was said in the text, but can select the range of texts that the respondents use. On the other hand, credibility is concerned with the constructed reality of participants in the research, and reflects the reconstruction's attributed to them (Guba & Lincoln, 1989). Overall, maximizing the credibility of the qualitative research requires the following (Lincoln & Guba, 1985): prolonged engagement in the field; persistent observation; triangulation (see Section 5.5 and the discussion below), and the researcher's supervisor checking of the data analysis.

Transferability. In naturalistic research, transferability is similar to the concepts of generalizability and comparability. In other words, transferability is concerned with the participant and settings, so that comparison between groups and translation of data (applicable to other situations) into different settings can be made (Cohen, Manion & Morrison, 2000; Lincoln & Guba, 1985). Cohen et al., (2000) suggest that transferability requires a clear, detailed and thick description of comparison.

Dependability. Silverman (2004) suggests that any instruments used in a study such as interviews, observation, texts and so on, need to be 'defended'. Inferences are considered dependable if comparisons made from instruments are drawn from similar methods. Dependability is a concept similar to reliability. Here, reliability is a necessary, but not sufficient, condition for validity; reliability is thus a necessary precondition of validity (Cohen et al., 2000). Janesick (2003) argues that validity deals with description and explanation, and whether or not the explanation fits the description. This is needed to make sure that the explanation is credible and defensible (Peräkylä, 2004; Silverman, 2004). In addition, Janesick (2003) reminds the researcher that there is more than one way of interpreting or inferring the intervention, and there is no one 'correct' interpretation.

Trustworthiness and Authenticity. Guba and Lincoln (1989) consider validity to be an empirical-positivist notion, and they propose the concept of *authenticity* in qualitative/naturalistic research. The characteristics of authenticity in naturalistic research include the following (Cohen, Manion & Morrison, 2000; Guba & Lincoln, 1989): Fairness – a complete and balanced representation of the multiple realities and constructions of a situations; ontological authenticity – make a fresh and more sophisticated understanding of a situation; educative authenticity – generate a new appreciation of these understandings; catalytic authenticity – give rise to specific courses of action; and tactical authenticity – beneficial to those involved in the study.

Triangulation. The trustworthiness of findings from qualitative research can be enhanced by cross-checking the validity of data using triangulation as mentioned above (Janesick, 2003; Patton, 1990) – see also Section 5.2. Through cross-checking, triangulation enhances the validity of data collected by drawing on a variety of data collection methods. Janesick (2003) and Patton (1990) identify four different types of triangulation: *Methods triangulation* checks the consistency of findings from a research question generated by different data collection methods; *triangulation of sources* checks the consistency of different data sources within the same method; *analyst or researcher triangulation* uses multiple analysts or researchers to review findings; and *theory triangulation* uses multiple theories or perspectives to interpret the data. As noted above (see Section 5.2) and Section 5.5, the first two types of triangulation are relevant, and were used in this thesis. For example, the second type of triangulation involved validating information obtained through interviews by checking with other written evidence such as the assignments of didaktik analysis, lesson plans, and written reports. As Patton (1990) notes, it is not necessary that this triangulation results in the convergence of research findings. What is important here is to study and understand when and why there are differences.

Ethical Considerations. The University of Waikato and the Centre for Science and Technology Education Research (CSTER) requires any researcher who undertakes educational research to gain ethical approval before gathering data. The University of Waikato has ethical guidelines to be followed in order the privacy of the participants protected. The main issues for the researcher here are the right of informed consent, the right to withdraw at any time during the research process, maintaining confidentiality, privacy, and anonymity of the participants after the data have been collected, and avoiding any disputes concerning the findings of the study. Therefore, the researcher had his research proposal approved by the CSTER Ethics Committee before the research began.

As a research was carried out at the University of Malaysia Sabah and Malaysian Secondary Schools, the researcher also needed permission both from the Dean of the School of Education, University of Malaysia Sabah, the Education Planning and Research Division (EPRD) in the Malaysian Ministry of Education, and the Economic Planning Unit (EPU) in the Prime Minister's Department. An official letter from the CSTER attached with research proposal was sent to the Dean of the School of Education after the Ethics Committee granted permission (see Appendix I). It is important to note that once approval was given from the Malaysian relevant authorities, then informed consent from the pre-service teachers does not arise and it is an obligation for them to participate as the study involved one semester of the physics teaching methods course.

A similar letter together with research proposal was also sent to the EPRD and EPU to gain approval (see Appendix II). Although the University of Malaysia Sabah has collaborative agreements with the Education Department to place the pre-service teachers in the secondary schools, the researcher was still required to present a research pass from the EPU, upon request to the school principals in which the research was conducted.

5.6 CHAPTER SUMMARY

This chapter presented the research methodology used in this thesis. It began with a discussion of three types of research paradigms: the empirical-positivist paradigm, the interpretive paradigm, and the critical theory paradigm. This was followed by a discussion of research methodology, and quantitative and qualitative research approaches. Next was a discussion of research methods available for data collection and data analysis associated with qualitative and quantitative research approaches. Following on these discussions, the specific research methods adopted for this study were described. A detailed description on the development of the questionnaire together with already available test instruments was presented. Finally, discussion of quantitative and qualitative data analysis together with specific issues of research approaches (such as objectivity, subjectivity, credibility transferability, dependability, trustworthiness and authenticity, triangulation and ethical considerations were presented.

CHAPTER 6

RESEARCH FINDINGS AND DISCUSSION: BELIEFS ABOUT PHYSICS TEACHING

CHAPTER OVERVIEW

This chapter presents the research findings for data collected in the School of Education at the University of Malaysia Sabah (UMS) during the second semester of 2005-2006. The chapter comprises five sections, and begins with Section 6.1 that describes the intervention, namely, a physics teaching methods course (TT4133), a continuous course of three credit hours offered every semester. This course included group assignments about didaktik analysis, the development of individual lesson plans, and teaching practice in microteaching sessions. This section is followed by a description of the background of the participants – being two groups of pre-service physics teachers. Section 6.2 elaborates on the administration of the *Beliefs About Physics Teaching* (BAPT) questionnaire, and includes detailed analyses of numerical data including examination of the reliability and validity of the BAPT questionnaire. Section 6.3 presents the findings for research question one by establishing pre-service teachers' beliefs about teaching and teaching physics prior to intervention, and the effect of the didaktik analysis have on their beliefs and practices in terms of their personal content knowledge and pedagogical content knowledge the after the intervention. An analysis of the scales used in the BAPT questionnaire: *Learning Experiences*, *Attitude-Toward-Physics and Learning*, *Physics Teaching Self-Efficacy*, and *Attitude Toward, and Beliefs About, Physics Teaching*. Section 6.4 which follows, focuses on the administration of *The Test of Understanding Graph in Kinematics* (TUG-K) and *The Force and Motion Conceptual Evaluation* (FMCE) tests, and includes findings from these tests and investigates the relationships between the participants' knowledge and beliefs about, and attitude toward, physics teaching.

6.1 INTERVENTION IN DIDAKTIK ANALYSIS OF PHYSICS

This section describes the setting in which the intervention was conducted from December 2005 until March 2006, and during the school practicum (May –July 2006). The setting description here includes details of the TT4133 course, the characteristics of participants and other aspects relevant to the intervention. This course was taught by the researcher after consent was gained from the Dean of the School of Education. The participants were informed that the Dean of the School of Education had agreed the researcher could conduct the course for the entire second semester.

During the intervention, a large data corpus was developed, including: participants' written reports describing their physics learning experiences at secondary school and university; tests of conceptual understanding – the TUG-K and FMCE; focus group interviews after administration of the tests; the BAPT questionnaire; written assignments about didaktik analysis; daily lesson plans; observations of participants' microteaching and practicum; minutes made by the researcher from meetings; participants' written reports at the end of the course; course evaluations; reports of reflections in the middle of the practicum; and individual interviews after classroom observations. Analysis of interview transcripts and examination of relevant questions from final examinations were used to further triangulate the above data. Some of these latter data are presented in Chapters 7 and 8.

At the beginning of the course, the participants were provided with a list of course topics for each week of the semester. They also were given an overview of the course prior to the intervention. In the first week of the TT4133 course the entire class was briefed about the 14 week course; the first seven weeks dealt with theoretical aspects of teaching methods, and the remainder dealt with the practicum. The researcher also briefed the participants about the assessment/ evaluation for the course: two pieces of course work on the didaktik analysis of physics; the development of three daily lesson plans; and a two hour final examination consisting of 60 multiple choice questions (conducted by the University's Academic Unit). The didaktik analysis task involved groups of four or five, and participants were free to choose their own group members. The researcher then assigned specific physics content for the work on didaktik analysis of physics.

The aims of the intervention were; to see what effect didaktik analysis might have on participants' beliefs and teaching practices in terms of their personal content knowledge and pedagogical content knowledge after the intervention; to help make participants see how to treat the problems of teaching and learning physics using didaktik analysis; and to investigate factors of assignments, microteaching, and practicum that might influence the effectiveness of didaktik analysis in improving the practice of teaching and learning for Malaysian pre-service physics teachers. The Dean initially indicated he would co-teach together with the researcher, but in fact did not due to administrative load. However, the researcher briefed the Dean from time to time about the intervention.

The lectures on didaktik analysis took place in the second and third weeks of the course, the same time the tests and written reports tasks were conducted. It took participants about 70 minutes to complete the 60 question tests on conceptual understanding – namely the TUG-K and FMCE (see Section 6.4). After completing the tests, the researcher asked the participants to write about their physics learning experiences at secondary school and at university (see Section 6.3.1). The first seven weeks of the course covered theoretical aspects of physics teaching methods, including didaktik analysis. Course topics included here were; didaktik analysis of physics, lesson plan development, the history, philosophy and nature of science, views of learning science, teaching and learning strategies, assessment of practical work in physics, and microteaching. The second seven weeks were spent on practical teaching in particular the microteaching sessions. During the microteaching sessions, a representative from each group attempted to transform the didaktik analysis and written lesson plans into staged teaching activities. The researcher observed these sessions, which also were video taped. This was followed by focus group interviews with a total of 10 participants.

6.1.1 Background of the Participants

There were 113 participants enrolled in the physics teaching methods course at the time of the study. Of these, 33 were males (29%) and 80 females (71%). There were two different cohorts: 35 participants (15 males and 20 females) in a three year programme called *special conversion for non-graduate teachers*; and 78 participants (18 males and 60 females) in a four year programme. The first cohort enrolled were those with some prior teaching experience involving several years in primary school, and the latter had no teaching experience. Both groups were in their final year of undergraduate studies in science education programme at the time of the study. As noted above, the participants enrol in physics as a minor, and mathematics as a major, both subjects taught outside the School of Education. The physics teaching methods course is intended to provide participants with teaching strategies, models of teaching science, theory of learning, microteaching, and assessment.

Participants from the third year programme. The participants in this cohort varied in terms of primary school teaching experience. Their training was funded by the Ministry of Education, and their entry into science education courses (mathematics and physics) was based on their science teaching experience. Their entry into science education courses (physics, mathematics, chemistry and biology) is thus based on their science teaching experience at the primary level. In fact a few third years did not actually teach science at primary schools, and had only a general science learning background at the secondary level. This entire group took physics as a minor and mathematics as a major, a condition imposed by the Ministry of Education. They had developed their beliefs about teaching in their years in the classroom, both as a teacher and as university student.

Participants from the fourth year programme. This group of participants had a different major to those from the three year programme: some took physics as a major and mathematics as a minor, and others vice versa. They could be considered as 'juniors' in terms of teaching and this group gained entry to teacher training based on their qualifications either through matriculation or STPM (Malaysian Higher School Certificate). They had learned physics at secondary school, mostly at the SPM (Malaysian School Certificate) level. However, some had not learned physics at the STPM level, but all who matriculated had experienced some physics learning. They had to complete physics and mathematics courses in the School Science and Technology before enrolling the physics teaching methods course at the School of Education.

6.2 ADMINISTRATION OF THE BAPT QUESTIONNAIRE

The BAPT questionnaire was administered during the seventh week of the methods course before the participants experienced the microteaching. The questionnaire was rigorously tested and this involved repeated pilots in which items responses were analysed and discussed with supervisors and colleagues from the CSTER and School of Education at the UMS, and feedback from participants' written reports of their physics learning experiences in secondary school and university conducted during the second week of the physics teaching methods course. The final version of the BAPT questionnaire contained the following scales: *Physics Learning Experiences* (Section 6.3.1, 12 items: 6 items in Tables 6.2 & 6.3, respectively), *Attitude-Toward-Physics and Learning* (Section 6.3.2, 11 items in Table 6.5), *Physics Teaching Self-Efficacy* (Section 6.3.3, 11 items: 6 items in Table 6.7; and 5 items in Table 6.9), and *Attitude Toward, and Beliefs About, Physics Teaching* (Section 6.3.4, 19 items: 11 items in Table 6.13; and 8 items in Table 6.15). These scales were developed to address research question one: *What effect does the incorporation of a unit of work on didaktik analysis have on pre-service teachers' beliefs about physics and teaching physics prior to the intervention, within the context of a Malaysian teacher education training programme?*

Next is a description in more detail about exposure to didaktik analysis experience on participants' beliefs gained through assignments which it was thought might influence microteaching, and practicum in secondary schools physics classroom. The purpose of the BAPT questionnaire was to identify participants' beliefs about and, attitude toward, physics teaching, prior to the intervention, and the effect didaktik analysis experience from assignments, microteaching and practicum have on their personal content knowledge and pedagogical content knowledge that might influence their beliefs about, and attitude toward, teaching practice in the didaktik approach after the intervention (together with other data).

Another part of the BAPT questionnaire related specifically to the confidence of participants to teach secondary physics topics (9 items, Table 6.10), their confidence in achieving 'general learning outcomes' for topics of force and motion (7 items, Table 6.11), and their confidence in achieving 'specific learning outcomes' for topics of force and motion (14 items, Table 6.12). The terms 'general learning outcomes' and 'specific learning outcomes' are used here because they are found in the Malaysian Form 4 Physics Curriculum Specifications. These items sought participants' view of the difficulty of specific topics of physics (topics of force and motion). All items in this part of the BAPT questionnaire were analysed, and conduct cross-tabulations were done for each item of each cohort. These latter data were analysed in combination with the findings from the tests - the TUG-K (Table 6.18, Appendix V, 21 questions) and the FMCE (Table 6.19, Appendix V, 39 questions) administered during the second week of the methods course. These findings are discussed in detail in Section 6.4.

6.2.1 Findings from the BAPT Questionnaire

All items on each scale contained a five-point Likert-type scale from 'strongly disagree' (scored 1) to 'strongly agree' (scored 5). Any negatively worded items were scored in the opposite way (i.e., 'strongly disagree' scored 5 points, 'disagree' 4 points, etc.). Scores for these items were then summed to produce a total score for the scales. Means and standard deviations were calculated, and the Cronbach alpha computed for each scale as a measure of construct validity of a scale (i.e., if the items were genuinely measuring the same scale, similar responses would be expected, see Section 6.2.2). Scores for an individual item for each of the scale were calculated to compare the differences of responses in terms of means and standard deviations between the two cohort groups. Item-total correlations were also used to see whether each item measured the same factor within the scale. The findings are discussed in detail in Sections 6.3.1, 6.3.2, 6.3.3, and 6.3.4.

At each level of analysis (whole scale and individual item) independent groups t-tests were used to examine differences in responses (the means of scores). Effect sizes analyses also were computed to examine if any possible effects on each scale as well as to examine statistical significance of differences. Correlation analysis was employed to examine relationships (for each item within the scale, and between the scales), and relationships summarised using a bivariate Pearson product-moment correlation. The correlations were checked for statistical significance either at p = 0.01(1-tailed) or p = 0.05(1-tailed) levels.

6.2.2 Reliability and Validity of the BAPT Questionnaire

The reliability and validity of the BAPT questionnaire is reported in Table 6.1. It can be seen that almost all of the scales have good reliability which suggests the items employed in the BAPT questionnaire are measuring the same scale. Reliability of each scale was calculated using Cronbach's alpha consistency coefficient. The low reliability of the *Physics Learning Experiences* scale for the third year cohort ($\alpha = 0.24$) points to a diverse range of experiences at secondary school and university. The smaller number of third year participants here compared with the fourth years means any variation would be exacerbated.

The high means for the scales suggest that overall the participants had good physics learning experiences, positive attitude-toward-physics and learning, high physics teaching self-efficacy, and overall are positive about teaching secondary school physics. The differences in means for the scales between the two cohorts are small except for the *Attitude Toward, and Beliefs About, Physics Teaching* scale (which varies from 54.4 to 58.4). The differences of means for the *Attitude Toward, and Beliefs About, Physics Teaching* scale were found to have statistically significant differences for some of the sub-scales (a detailed analysis of items with statistically significant differences for the two cohorts is presented in Section 6.3.4).

Table 6.1
Mean and reliability (Cronbach's alpha) for the scales of the BAPT questionnaire

Scales	No. of items (scores)	Third Year (n = 34)		Fourth Year (n = 65)	
		Mean	Alpha	Mean	Alpha
1. Learning Experiences	12 (12-60)	39.9	0.24	38.6	0.66
2. Attitude-Toward-Physics and Learning	11 (11-55)	32.6	0.79	34.3	0.79
3. Physics Teaching Self-Efficacy	11 (11-55)	37.5	0.83	36.7	0.59
4. Attitude Toward, and Belief About, Physics Teaching	19 (19-95)	54.4	0.84	58.4	0.80
Total	53 (53 - 265)	163.5	0.71	167.8	0.80
		Mean = 162.3 Alpha = 0.85			

The maximum and minimum possible scores for: *Physics Learning Experiences* are 60 and 12, respectively; for *Attitude-Toward-Physics and Learning*, and *Physics Teaching Self-Efficacy* (the higher the score, the higher the level of self-efficacy) maximum and minimum scores are 55 and 11; and *Attitude Toward, and Beliefs About, Physics Teaching* maximum and minimum scores are 95 and 19. The total maximum score of the BAPT questionnaire can range from 53 to 265. These findings are discussed in detail in Sections 6.3.1, 6.3.2, 6.3.3, and 6.3.4.

6.2.3 Research Question One Revisited

Research question one consists of establishing participants' beliefs prior to, and after the intervention, and investigating their practices and how these changed as a result of the intervention. The BAPT questionnaire was produced as a result of the particpants' reflections (written reports) to experiences of physics teaching and learning at school and at university, and TUG-K and FMCE tests. The BAPT questionnaire data were comparable to or triangulated to focus group interviews (Figure 6.2), and TUG-K and FMCE tests data were comparable to or triangulated to focus group interviews (Figures 6.6 & 6.7). The participants' beliefs prior to intervention, such as prior physics learning experiences, attitudes-toward-physics and learning, physics teaching self-efficacy beliefs, and conceptual understanding of specific physics content were derived from their written reports describing their physics learning experiences at secondary school and at university as well as tests of conceptual understanding, the TUG-K and FMCE. Both written reports and test were administered in the second week of the intervention, followed by focus group interviews. Initial planning was to have TUG-K and FMCE test administered at the first and seventh weeks, but due to unavoidable circumstances, the seven weeks tests could not be repeated. These reports were comparable or triangulated to focus group interviews (Figure 6.2).

Findings for the first research question were also derived from the participants' written reports about their physics learning at secondary school and university, the two tests - the TUG-K and FMCE, and the findings of the BAPT questionnaire. Data from the written reports of physics learning experiences and the focus group interviews were coded and collated into broad descriptors until general themes about learning experiences and their influence on attitude-toward-physics and learning, physics teaching self-efficacy, and attitude toward, and beliefs about, physics teaching emerged. Perceptions of learning at secondary and tertiary were compared to determine which experiences were influential on attitude-toward-physics and learning, physics teaching self-efficacy beliefs, attitude toward, and beliefs about, physics teaching and conceptual understanding (as measured by the tests - TUG-K and FMCE, see Sections 6.3.2, 6.3.3, 6.4.1 and, 6.4.2).

After the intervention, by the end of the semester didaktik analysis experiences gained through assignment of didaktik analysis and lesson plans, microteaching, and practicum. Participants' reactions to didaktik analysis experiences were tapped through their assignment of didaktik analysis (data were comparable to written reports, Table 7.4), followed by interviews (Table 7.6), evaluation (Table 7.7), final examinations (Figure 7.2), microteaching (observation data were comparable to interviews, Table 7.8), and during the practicum (observation data were comparable to written reports, Table 7.6), interviews (Table 7.6 & Figures 8.1 & 8.2).

6.3 PRESENTATION OF RESEARCH FINDINGS

Here begins presentation of the research findings for research question one. They continue (presented in this section) in the following section, Section 6.4. Examination of the diverse data sources provided insights into the participants' knowledge and beliefs about, and attitudes toward, physics teaching using a didaktik-based approach.

A summary of themes that emerged from the data is presented in Figure 6.1, and they were gathered from the interviews of nine participants (one participant was not able to be interviewed) and data from 89 written reports on physics learning experiences. Like responses of participants were grouped into emergent themes, and unlike responses were used to develop a deeper understanding of written reports and the interviews with the participants (7 from the third years, 2 from the fourth years). These emergent themes are discussed in detail in Sections 6.3.1, 6.3.2, 6.3.3 and 6.3.4 in turn. As noted in Section 6.2.3, the emergent themes from the interviews and the written reports of physics learning experiences in secondary school and university were combined with data from the BAPT questionnaire, and this is presented first.

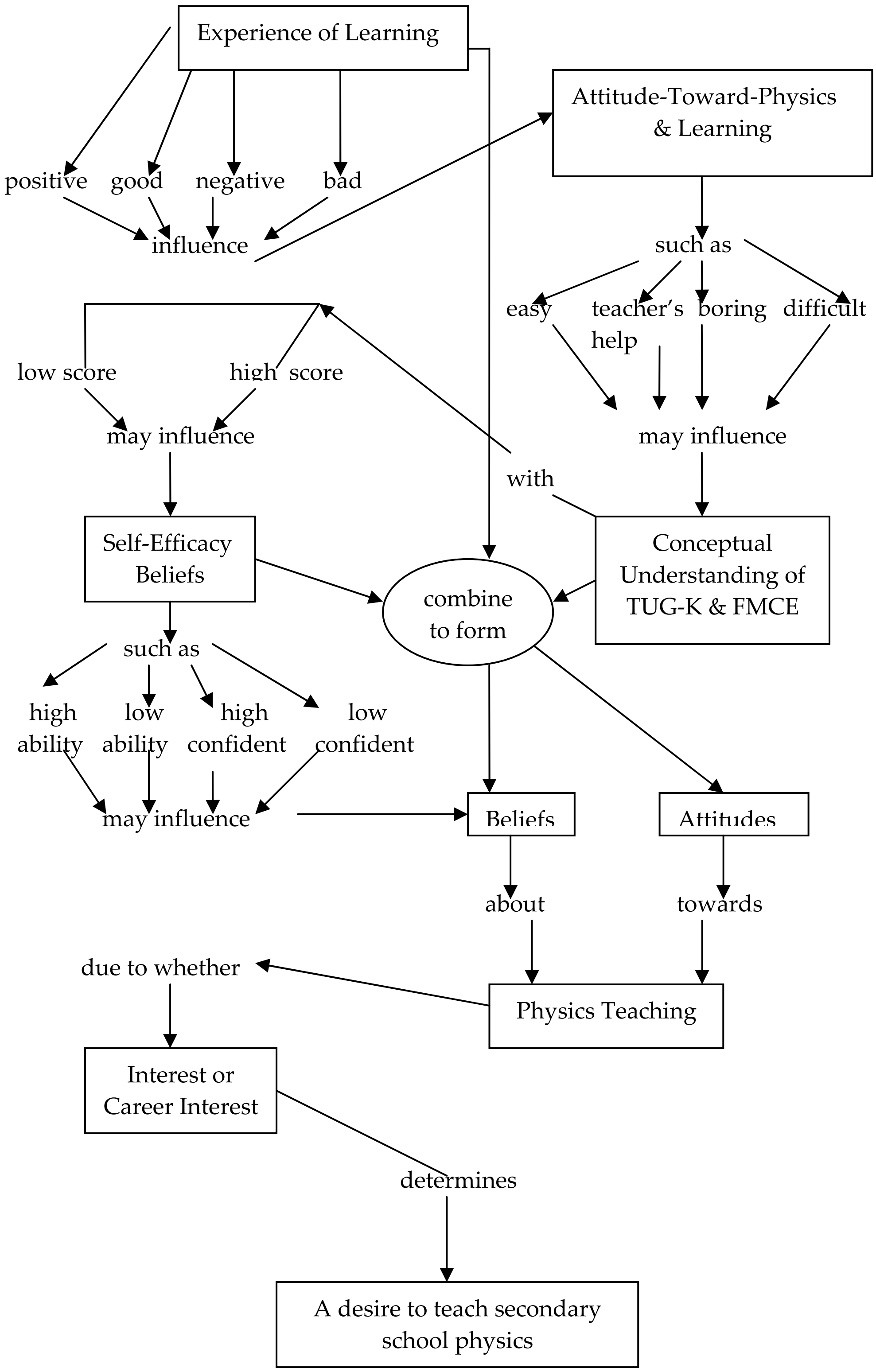


Figure 6.1
Concept map of themes arising from the scales of the BAPT questionnaire

6.3.1 Physics Learning Experiences

This section presents the findings of participants' responses for the BAPT questionnaire items about physics learning experiences at secondary school and university. Some 89 out of 113 participants who attended during the second week of the class also completed the written reports, 108 completed the TUG-K and FMCE tests, and nine participated in interviews after the tests. In addition, there were 99 participants who attended the seventh week of the class, and completed the BAPT questionnaire on the scales listed in Table 6.1. Examination of the data about reported physics learning experiences in both contexts and institutions resulted in two categories: *learning experiences in the classroom and/or lecture hall*, and *learning experiences in the laboratory*.

Like responses of physics learning experiences in the classroom and/or lecture hall, and laboratory from the written reports revealed the way participants said they experienced interactions with their teachers and lecturers, whereas the interviews revealed the participants' attitude toward, and beliefs about, learning and teaching physics. These responses or themes (as shown in Figures 6.1 & 6.3) then represent the influence of teachers and lecturers, on the participants' attitude toward, and beliefs about, learning and teaching physics. These interpretations of the influence of teachers and lecturers were categorized and compared with the scale until the categories and relationships among them were 'saturated'. This meant the researcher could be reasonably confident that the categories (*learning experiences in the classroom and/or lecture hall*, and *learning experiences in the laboratory*) represented the beliefs and attitudes of participants which might influence their intentions about teaching secondary school physics. Unlike themes were used to develop a deeper understanding of the positive and negative physics learning experiences, and are shown in Figure 6.3.

Next are the quantitative findings derived from the BAPT questionnaire. This is followed by qualitative findings from written reports and interviews.

Secondary School Physics Learning Experiences – Quantitative Findings (see Table 6.2): The quantitative data suggest that overall both cohorts of participants were positive about their secondary school physics learning experiences both in the classroom and in the laboratory (a mean greater than 3.00 is considered positive). Low standard deviations (equal to or less than one) suggest that the two cohorts had similar physics learning experiences in the classroom. Overall, for all of these items no statistically significant differences were found between the cohorts. However, differences in means between cohorts of participants vary for some items (items 1 to 4) suggesting a few participants had more negative physics learning experiences. The participants were more positive about their teachers explaining demonstrations before doing experiments (item 5). However, high standard deviations (equal to or exceeding one) suggest that some fourth years might have different prior experiences in physics learning in the laboratory. Likewise some fourth years were more negative about their physics learning experiences than the third years, as seen in item 6. Again, as item 6 has high standard deviations suggesting both cohorts of participants had diverse physics learning experiences in school laboratories.

Table 6.2
Mean and standard deviation for secondary physics learning experience from the BAPT questionnaire

Learning experiences (LE)	Third Year (n = 23)		Fourth Year (n =61)	
	Mean	SD	Mean	SD
1. The teacher discussed from textbook.	3.67	1.00	3.48	0.99
2. The teacher discussed from revision books.	3.63	0.87	3.43	0.96
3. The teacher discussed the outlines of crucial notes.	3.13	0.74	3.43	0.88
4. The teacher employed “drill and practice” method in his/her teaching.	3.17	0.70	3.48	0.89
5. The teacher explained the demonstration before the students carried out an experiment in a group.	3.88	0.85	3.72	1.07
6. The teacher did the experiment and the students noted down an observation, results, and conclusions by referring to the textbook.	3.21	1.21	2.85	1.24

Secondary School Physics Learning Experiences – Qualitative Findings: The protocol used in the written reports and interviews about secondary school physics learning experiences is presented in Figure 6.2, and a summary of the findings in Figure 6.3. Some 70 out of 85 participants provided comment on both positive and negative experiences in their physics learning at secondary school in their written reports.

Physics Learning Experiences - Secondary School Classrooms: Ten out of 70 participants make comments about positive and negative experiences about teaching methods: the most common complaint being that their teachers followed the textbook exactly - consistent with the agreement with item 1 from the BAPT questionnaire. Things the teacher used the textbook for were: to explain the lesson; to explain physics terms; to stress the factual and descriptive nature of physics; to focus on physics topics related to discussion and calculations; to relate topics to students' daily life experiences; to conduct group discussions; to ask the students do presentations; and to present a few question examples together with worked examples; and to solve mathematical equations in physics. Some comments were quite negative. For example, one participant noted that the reason the teacher followed the textbook was to make sure they covered the syllabus, whether or not the students understood the lesson:

"When we felt bored, we asked for five minutes rest, but the teacher gave us only 30 seconds" (R30, 4th, F) [*]. Other comments were similar, and another participant wrote: 'The teacher only talked by looking at the textbook' (R34, 4th). There were some positive experiences noted, with one participant commenting on an advantage of using textbooks together with a variety of teaching methods: "I remember that my physics teacher taught us all stuffs in the textbook and he used many interesting ways to teach us and let us understand more 'what is physics' " (R10, 4th F).

[*] Code for participant's number (R), year of programme (3rd or 4th years), and gender (M or F). Some stated their year of programme and gender, and some did not.

Written reports:

Think back to your experienced physics learning at secondary school and at the School of Science and Technology, University of Malaysia Sabah:

i. Do you recall your physics teachers and lecturers during his/her teaching?

ii. What do you remember about physics learning? What physics learning experiences are most vivid in your mind?

iii. How did they teach in the classroom and laboratory, and lecture hall and laboratory?

Interview:

i. Describe the most memorable, positive physics learning experience you had with your teachers and lecturers

ii. Describe the most memorable, negative physics learning experience that you had with your teachers and lecturers

Figure 6.2
Protocol for written reports and interviews about participants' physics learning experiences

Item 2 from the BAPT questionnaire concerned the teachers' use of revision books. This it seems was prevalent (Table 6.2), and the quantitative findings were supported by the written comments in the reports. Things mentioned here were that the teacher discussed the lesson from revision books and asked the students to jot down notes, and explained physics by using transparencies together with reference books. For example, one participant wrote that "We must copy back all the notes in the reference books [summary] to our exercise book" (R29, 4^{th}, M), but it seems this was not viewed negatively since he went on to comment that the teacher also "discussed the lesson using the revision books". Others noted that their teachers "jotted down notes" [either on board or transparency] more in terms of factual content, both with and without explanations.

Responses to item 3 from the BAPT questionnaire suggest that physics teachers commonly gave outlines of crucial notes. Examination of written reports suggest this was aimed at making it easier to memorise facts; that they gave notes and explained things by identifying essential parts of the notes to be memorized; and that the main teaching method was ‘chalk and talk’. The topics for which the teachers employed this method were basic physics concepts such as theories or laws, and teachers often used worked examples, or asked the students to apply the related formulae to solve physics problems. This is related to item 4 for which the data indicate that the teachers commonly employed the ‘drill and practice’ method (Table 6.2). Written reports indicated that this meant that teachers referred to workbooks, homework, exercises, calculations, using physics formulae to solve problems, asked about physics formulae, and asked the students to study on their own and understand them.

Physics Learning Experiences - Secondary School Laboratories: Responses to the BAPT questionnaire suggest that teachers commonly explained laboratory experiments using demonstrations before students did the actual experiments. A number of participants also mentioned this teaching method in their written reports. For example, one wrote: “We listened to the teacher’s explanation on demonstration and then did the experiment in a group” (R72). Other responses indicated that in some cases: “the teacher only performed the demonstration” (R29, 4th, M). In a similar manner it seems in group work the group leader did most of the work and that the activities were dominated by adherence to the syllabus: “I did not conduct experiment because a group leader did and the other members acted as assistant or observer … the experiment [was] conducted according to the syllabus” (R60, 3rd). But some reported actually doing the experiments themselves: “While we performed the experiment … the teacher went round, talked and observed in the laboratory” (R5, 4th, F). These comments support the findings of item 5 from the BAPT questionnaire which suggest that the participants had diverse learning experiences in secondary school physics laboratories.

The teacher in the classroom	The teacher in the laboratory
Used the textbook: *to explain the lesson, to explain physics terms, to stress the factual and descriptive nature of physics, to focus in physics topics related to discussion and calculations, to relate topics to students' daily life experiences, to conduct group discussions, to ask the students do the presentations, to present a few question examples together with worked examples, and solved mathematical equations in physics, to cover the syllabus, and prepare for examinations*. Used revision books, reference books, *workbook and exercise books*. Used *teaching aids* such as *OHP, transparency, PowerPoint presentations, and models and picture*.	Lectured and demonstrated before the experiment *so the students would know what to expect*. *Explained the scientific methods and showed experiment to allow student to visualize or verify a concept*. Focused experiment in the laboratory on *conceptual understanding and its applications*. *Imposed scientific findings from the textbook when the results did not come out the way it was supposed to.* *Emphasized the scientific methods as found in the textbook's experiment*.
Always asked students to study on their own, and understand physics on their own, prepare at home, do their homework. Encouraged students do exercises and revisions, discouraged students from taking notes in the classroom, encouraged students to summarise notes from reference books into exercise books, simplified physics concepts, encouraged students self-learning, encouraged students to search for more information in the library. Employed questions and answer sessions.	Chose *several important experiments*, and *did several experiments due to limited apparatus*. Directed group work in the laboratory.
Jotted down notes: more on factual content, and *with and without explanations*. Emphasized *theoretical aspects of physics*, essential notes, problem solving using the formulae, memorise physics formulae and rules	*Always taught physics in the laboratory*.
Employed *'chalk & talk'* teaching methods, *read the textbook*, always wrote on the blackboard and talked to himself, *talked through textbook*, and *taught the wrong concepts of physics*.	*Conducted physics experiment incorrectly*.
Seldom employed examples or connection physics with everyday life experiences, *seldom taught in the classroom*, rare or infrequent discussion, and *less exercises given*.	Seldom asked do the experiment.

Figure 6.3
Themes of secondary school physics learning experience (unlike themes are italicised) found in written reports and interviews

The last item in the BAPT questionnaire, more explicitly presented the notion that the teacher did the experiment and the students simply observed and took notes. In the written reports a large proportion of participants (some 70 out of 85) commented negatively about this type of teaching. In some cases it seems this was common teaching practice: “The teacher seldom asked the students to do experiment” (R6, 4^{th}, F), but in others it was related to things like lack of resources: “Not all of experiments were conducted - lack of activities” (R2, 4^{th}, F), because “the equipment was limited” (R77). These exercises seemed to be viewed quite negatively, and led to frustration with one participant commenting in an interview: “Less time allocated and sometimes some apparatus were not working very well for doing experiment in the laboratory. As a result, the students only noted down the answers which have been revealed earlier” (Bertha, 3^{rd}, F).

Although many of the participants reported not conducting experiments themselves, those who did were very positive about the benefits of doing practical work. So “physics learning through experiments [means] we can understand in more detail and effectively” (R27, 4^{th}, F), since “the teacher emphasis was on experiments [and] group work so that learning would be more easier [and] focused more on conceptual understanding and its applications” (R26, 4^{th}).

Quantitative Findings - Tertiary Physics Learning Experiences (see Table 6.3): Tertiary learning experiences occurred in lecture halls, tutorial classes, and these resulted in beliefs about learning and teaching physics. The data suggest that the third years were generally positive about their learning experiences with their lecturers in the lecture hall (items 2 & 3), tutorial classes (item 5) and about memorising physics formulae (item 6) (here, as above, a mean score greater than 3.00 is considered to be positive). The relatively low standard deviations (equal to or less than one) point to similar physics learning experiences at the tertiary level (items 1, 2, 4, 5 & 6). Participants’ responses for item 3 suggest that both cohorts had diverse learning experiences about physics lectures presented in English. Overall, the fourth years were relatively negative about these learning experiences (items 1 to 4) and they appear more likely to report negative experience about lectures in English than their third year counterparts. The learning experiences at the UMS seem similar for both cohorts and, for example, they indicated similar beliefs about their physics learning through memorisation and had positive learning experience memorizing physics formulae (item 6).

Table 6.3
Means and standard deviation for tertiary experienced physics learning from the BAPT questionnaire

Learning experiences (LE)	Third Year (n = 32)		Fourth Year (n = 64)	
	Mean	SD	Mean	SD
1. The physics lectures were presented in an interesting manner.	3.00	0.78	2.70	0.88
2. The physics lecture notes were clearly explained.	3.21	0.78	2.90	0.87
3. The physics lectures were presented in English.	3.25	1.19	2.80	1.12
4. The tutorial problems covered all parts of the course.	2.96	0.86	2.72	0.97
5. The tutorials help my understanding of physics lecture notes.	3.54	0.93	3.49	0.91
6. I learn through memorizing physics formulae.	3.25	0.94	3.57	0.83

Differences in means for the two cohorts were investigated for statistical significance and effect sizes. Independent groups t-tests for each learning experience item showed the differences between the means score for the third and fourth year participants were statistically different for two items (items 2 & 3, Tables 6.3 & 6.4): physics lectures notes clearly explained ($t = -2.276$, $df = 96$, $p < .025$), and physics lectures presented in English ($t = -2.657$, $df = 96$, $p < .009$). It seems the third year participants agreed the notes were clearly explained and presented in English.

Table 6.4
Items with statistically significant difference for two cohorts from the BAPT questionnaire

Item	Third Year Mean	Fourth Year Mean	Means difference (SD)	Effect Size	t	Significance (2-tailed)
1. LE2* (N_t =32; N_f = 64)	3.21	2.90	.31 (.84)	0.37	-2.276	.025
2. LE3* (N_t =32; N_f = 64)	3.25	2.80	.45 (1.14)	0.39	-2.657	.009

*Learning experience (LE) for items 2 and 3 from Table 6.3

N_t – third year; N_f – fourth year

As noted above, the reliability for the *Learning experiences* scale for the third years (α = 0.24) is relatively low, and this probably contributed (see Table 6.1) to the apparent difference in beliefs about learning experience. Reasons for the differences in beliefs were investigated in interviews and written reports, and are discussed next.

Qualitative Findings - Tertiary Physics Learning Experiences: Examination of responses to the questions in the written reports and interviews relating specifically to a positive and negative tertiary physics learning experience are shown in Figure 6.2, and the findings summarized in Figure 6.4. Several themes emerged and are now discussed in turn.

Physics Learning Experiences – Lectures: Findings from the BAPT questionnaire for item 1 (Table 6.3): *The physics lectures were presented in an interesting manner*, suggest that the participants of both cohorts were relatively negative about their lectures. This also was reflected in some comments from the written reports and interviews. A number commented negatively about their lectures: "'chalked and talked' [used] teaching methods such as PowerPoint presentations and used the transparency" (R1, 4th, F); "some lecturers were boring as teaching methods employed such as talked very fast were difficult to understand" (R31, 4th, F); "some lecturers seemed not able to teach well [and] physics was not as interesting as experienced during school days" (R54, 4th). However, the written reports also contained a number of positive comments such as "employed appropriate teaching methods [that] were quite interesting, exciting and fun" (R7, 4th, F).

Statistical analysis on item 2 - *The physics lecture notes were clearly explained* (see Tables 6.3 & 6.4) suggests that the third years were more positive than the fourth years. Again this was reflected in the qualitative data. For example, the following comment was made in the written reports: "notes and explanation …was good because he let us wrote down the notes slowly and explained step by step" (R63, 3rd). Again there were some contrasting views aired, with one participant commenting during interviews that "generally, during physics lecture if notes were not given, I think it would be difficult to understand physics" (Farah, 3rd, F). Likewise, some fourth year participants reported positive experiences with, for example, notes were that "quite good [and] simple and easy to understand compared with mathematics. The way the lecturer taught [was] easily understood" (R30, 4th, F). Negative experiences of physics learning with lecture notes, also were noted: "the lecturer did not teach so clearly [we] always studied on our own" (R10, 4th, F).

Findings from the BAPT questionnaire for item 6 (Table 6.3) suggest that both cohorts had similar learning experiences for: *memorisation of physics formulae*. A large number of participants also mentioned this in their written reports. Sample comments are: "we always memorising formulae [and] copied notes, memorizing the rules & facts" (R80) and "I did not know how to use the formulae" (R56, 4th); and "we had too many concepts [and] formula to remember" (R53, 4th, F).

A number of other themes about lecture learning experiences also emerged and these had to do with the way material was presented in lectures which consisted of students "Jotting down notes and formulae from PowerPoint presentations [and] listening all the times" (R40, 4th, F). So it seems the approach was mostly that "the lecturer explained and showed the solutions using the transparency and whiteboard" (R15, 4th, F), but some "lecturers taught the concepts, emphasized group work, conducted question and answer sessions, listed the formulae, conducted tests, helped how to learn physics as [we] passed all physics courses taken" (R21, 4th, F). Other positive comments from the participants about their lecture learning experience were that the "lecturers employed appropriate teaching methods by simplifying physics concepts, employed various assisted teaching aids, and assigned less problem solving" (R48, 4th, F), and that the students "studied concepts through textbooks, solved problem solving, discussed with friends on group assignment which increased cooperative values, physics learning more challenging but interesting as it involved presentation and working papers, and did the experiment" (R69, 3rd, M).

Tertiary Physics Learning Experiences - Laboratories: Unlike their secondary laboratory learning experiences responses about tertiary laboratory experiences did not attract much comment in the written reports. Only six participants reported on their tertiary physics learning laboratory experiences which were seen positively and "sometimes very funny and interesting [and] the experiments conducted were more systematic" (R35, 4th, M). However, some themes seen in school experiences also emerged such as "[we had] limited apparatus and cannot be used" (R44, 4th, M), "very bad laboratory experienced physics learning, the lecturers imposed experiment as found in the experiment's sheets [this participant had experienced conducting his own secondary school experiments]" (R49, 4th), meaning the students were "scared do the experiment but the lecturer helped a lot" (R63, 3rd).

The lecturer in the lecture's hall	Laboratory experienced physics learning
Used various assisted teaching aids such as OHP and PowerPoint presentation. Jotted down notes and listening, explained and showed the solutions using transparency and whiteboard. Taught the concepts and involved group work, less exercises given, listed the physics formulae. Emphasized theoretical aspects of physics, employed 'chalked & talked' teaching methods such as PowerPoint presentation and transparency.	Sometimes did the experiment, limited apparatus and cannot be used, make report and presented findings, Imposed experiment as found in the experiment's sheet.

Figure 6.4
Themes of tertiary experienced physics learning from written reports

Summary of Participants' Physics Learning Experiences: Examination of the findings from the BAPT questionnaire, the written reports and interviews suggest that the third and fourth year cohorts differed in their beliefs and experiences about learning and teaching physics. These differences in beliefs and experiences seem to be due to the influence of their teachers and lecturers, and the learning environments they experienced in their classrooms and laboratories. The data suggest that the third years placed high value on their lecturers' teaching, and on the teacher teaching in the classroom and in the laboratory. Positive learning experiences for the third years were their teachers' ability to explain things clearly, the fact that they provided examples, showed models and pictures, and their teachers' personality such as being strict. Negative issues were related to having limited physics learning experiences at secondary school.

The fourth years saw their teacher's teaching as strongly teacher-centred, and positive learning experiences were linked to teaching methods such as using appropriate teaching methods and using a variety of teaching methods for a variety of physics content; and teachers being enthusiastic, dedicated, setting a good example and being knowledgeable about their subject. Negative learning experiences were that some teachers were weak or had little physics content knowledge and were overly strict.

Physics laboratory learning experiences also appeared to influence participants' interest in physics, particularly if the teacher let the students carry out experiments in the laboratory – which they seemed to enjoy. Other positive learning experiences included showing models related to physics, and generally learning in the laboratory rather than the classroom. However, in some cases this type of learning experience was negative, for example, if their teacher demonstrated the experiment, or if there was a lack of apparatus meaning the experiment could not be carried out. Overall, some participants had positive or good learning experiences, while others had negative or bad learning experiences. These learning experiences seem to influence participants' attitude-toward-physics and learning, and are discussed next.

6.3.2 Influence of Learning Experiences on Attitude-Toward-Physics and Learning

This section presents findings about the influence of participants' learning experiences on their attitude-toward-physics and learning, and is based on the findings of the BAPT questionnaire and responses to interviews. The rationale here is that learning experiences not only serve as the basis for identifying participants' attitude-toward-physics and learning, but also might influence their intention to teach secondary school physics. The findings from the BAPT questionnaire are presented first, followed by the findings from the written reports and interviews.

Influence of Learning Experiences on Attitude-Toward-Physics and Learning – Quantitative Findings (Table 6.5): Views as to the participants' attitude-toward-physics and learning were developed from investigation of physics lecturers' influence (items 1 to 8) and physics teachers' influence (items 9 to 11). Physics lecturers' influence varies with means responses ranging between 2.42 and 3.96 for both cohort groups. Responses related to physics lectures and lecturers point to positive responses for items 2, 4, 5 and 7 for both cohorts (a mean response of greater than 3.00 is considered positive) and in contrast responses for items 1, 3 and 8 for fourth years and items 3, 6 and 8 for third years were negative (i.e., means less than 3.00). However, standard deviations for items 6 and 8 indicated that *enjoyment of physics learning*, and *easier to understand physics courses* varied for the third years. In other words, the third years for a range of reasons, did not enjoy physics learning, and some physics courses seemed difficult to understand (more detailed findings are reported in Table 6.5 with the qualitative data). The mean response for item 8 suggests that the third years seem more likely to have difficulty in understanding physics courses than the fourth years, and indicates a less positive attitude toward physics. It is important to note that third years less attitude-toward-physics and learning in item 8 was derived from physics lecturers' influence, whereas item 9 was derived from the physics teachers' influence.

Table 6.5
Mean and standard deviation for attitude-toward-physics and learning from the BAPT questionnaire

Attitude-Toward-Physics and Learning (ATPL)	Third Year (n = 29)		Fourth Year (n = 63)	
	Mean	SD	Mean	SD
1. I get a thorough understanding of the lecture notes	3.08	0.69	2.72	0.72
2. I get to know how to solve problems in physics	3.12	0.71	3.02	0.72
3. I gain conceptual understanding of physics lecture notes	3.00	0.80	3.00	0.61
4. I learn physics concepts through books	3.58	0.90	3.73	0.74
5. I discuss physics problems with other students	3.96	0.72	3.72	0.97
6. I gain enjoyment of physics learning	3.00	1.02	3.36	0.95
7. I gain greater confidence as a student of physics	3.12	0.91	3.03	0.91
8. Physics courses are easy to understand	2.42	1.07	2.64	0.98
9. I loved physics because the teacher had motivated me	2.88	1.24	3.06	1.22
10. Learning physics was difficult to understand	2.15	0.88	2.83	1.02
11. Learning physics was boring because the teacher was in ineffective in his/her teaching	2.31	0.88	3.14	1.32

Responses to items 9, 10 and 11 for the third years suggest that they had a negative attitude about a number of aspects of physics, consistent with item 8 which points to a negative attitude toward physics learning overall. As these items were derived from the physics teachers' influence, the third years' prior secondary physics learning seems to influence their learning at the university. For the fourth years similar trends were seen, although they were a little more positive overall. For example, the fourth years held a positive attitude due to their teachers' influences: motivation and teaching methods. In addition, the particular nature of physics itself contributes to this influence (item 10). Although diffculty is not the same as negative attitude, but as a result of a number of influences such as teacher's trait or personality, the particular nature of physics, and teacher's teaching methods, point to negative attitude especially the difficulties in learning the particular nature of physics.

Differences in means for the third and fourth years were investigated for statistical significance using an independent group t-test for each item. Statistically significant differences ($p < .005$) were found for four items (6, 8, 10, & 11, Table, 6.5): *gain enjoyment of physics learning* ($t = 2.325$, $df = 96$, $p < .022$) - the fourth years gained more enjoyment of physics learning than the third years; *physics courses are easy to understand* ($t = 2.037$, $df = 96$, $p < .045$) - the third years had more difficulty in understanding different physics courses at university than the fourth years; *learning physics was difficult to understand* ($t = 2.959$, $df = 96$, $p <.004$) - the fourth years appeared to have understood different topics of secondary school physics more easily more than the third years; and *learning physics was boring because the teacher was ineffective in his/her teaching* ($t =2.955$, $df = 96$, $p < .004$) - the fourth years seemed to see physics learning as boring if the teacher was deemed ineffective in his/her teaching than the third years. Mean differences less than zero were considered a less positive response, and effect sizes were moderate, greater than 0.5. Moderate effect sizes from cohorts' comparison indicate the practical significance of the mean differences.

Table 6.6 shows individual items for which statistically significant differences were found for the two cohorts. Thus, the terms less or more are employed here for comparison purposes between the two cohorts. Overall these data suggest that the fourth years were more positive about physics learning than the third years. By far the biggest difference in means was for item 11 which related to *physics learning being boring if the teacher was ineffective in his/her teaching*. A factor here may be that the fourth years were the last cohort to follow old physics curriculum which was specifically designed for physics majors (i.e., being a physicist). On the other hand, the third years were the first cohort to follow the new physics curriculum, specifically designed for physics teachers.

Table 6.6
Items with statistically significant difference for two cohorts from the BAPT questionnaire

Item	Third Year Mean	Fourth Year Mean	Means difference (SD)	Effect Size	t	Significance (2-tailed)
1. ATPL6* (N_t =29; N_f = 63)	3.00	3.36	-.36 (.97)	-0.37	2.325	.022
2. ATPL8* (N_t =29; N_f = 63)	2.42	2.64	-.22 (1.01)	-0.22	2.037	.045
3. ATPL10* (N_t =29; N_f = 63)	2.15	2.83	-.68 (.98)	-0.69	2.959	.004
4. ATPL11* (N_t =29; N_f = 63)	2.31	3.14	-.83 (1.20)	-0.69	2.955	.004

* Attitude-toward-physics and learning (ATPL) for items 6, 8, 10 and 11 from Table 6.5

N_t – third year; N_f – fourth year

Influence of Learning Experiences on Attitude-Toward-Physics and Learning – Qualitative Findings: The questions from written reports and the interview protocol relating specifically to *attitude-toward-physics and learning* are shown in Figure 6.2, and participants' responses to these questions were used to triangulate the BAPT questionnaire data for the participants' *attitude-toward-physics and learning*, with a particular focus on the influence of physics teachers and lecturers.

The Influence of Physics Teachers: The interview data suggest that the teacher shapes the participants' attitude-toward-physics and learning. For example, in the interviews beliefs about physics and learning appeared to be influenced by the teacher, as seen in a comment: "my teacher this time was very good in physics ... She can teach very well ... I can concentrate to study because she again, gave the short notes, I think, that one was good for us to sit for SPM - Malaysian School Certificate" (Bertha, 3rd, F). In another example, a participant commented in his written reports that he loved physics because the influence of his teacher: "My teacher said physics is based on observation and relate the concepts to one another and to the daily activities. I also had to find all the answers by myself" (R29, 4^{th}, M).

An interesting example was noted by one fourth year about how her teacher's approach influenced her attitude-toward-physics and learning:

> When I learned physics in the classroom and in the laboratory, my teacher always asked questions, before and after class. If we cannot answer the question, he asked us to run to the next floor and lift the chair. They taught us about understanding the concept and using it in the question given. We were always asked about the formulae (R9, 4^{th}, F).

Another female participant commented on the way she received support from her teacher, saying that

> Although physics was very interesting but it was quite difficult to understand. For me, I passed physics at the SPM (Malaysian School Certificate) level because my physics teacher paid more attention to me. She taught all about physics, and knew me so well. She will ensure that all the school works related to physics finished on the same day before I was allowed to go home (Alice, 4^{th}, F).

Good or positive physics classroom learning experiences appeared to be influential on the participants' attitude toward, and beliefs about, learning and teaching physics. Among good classroom learning experiences elicited from the interviews were understanding physics better if teachers gave good explanations and provided examples. For example, one female third year commented that "it was good to have a teacher gives short notes for preparing in the national examinations [SPM- Malaysian School Certificate]" (Bertha, 3^{rd}, F). The participants' attitude toward learning also seemed to be influenced by their ideas about the nature of physics – that it was difficult to understand. For example, a third year female commented that "I think one needs to have the skills in understanding physics" (Geetha, 3^{rd}, F). Other comments on experienced physics learning include, rote learning, memorisation formulae, and doing exercises and revisions. For example, "the teacher taught physics only based on reference books, and students were asked to write notes into the exercise book" (R29, 4th, M). These beliefs of participants seem to have been shaped by their prior experiences, specifically learning with their teacher.

Good or positive physics laboratory learning experiences also seemed influential on participants' attitude toward, and beliefs about, learning and teaching physics. Among the positive experiences noted was that: "The teacher can show the model of studies that related to physics topic [and] it was interesting because [of the] methods of conducting experiments the teacher used [and] the laboratory apparatus" (R84). It seems "working in a laboratory [was] much more fun [and] based on a scientific approach [but] the experiments' results should be accepted although the results were faulty [i.e., the results did not come out the way it was supposed to]" (R39, 4th M).

On the other hand, bad or negative physics laboratory experiences led participants to see physics laboratory learning as uninteresting. Sample comments include: "Some experiments we did in a laboratory were not really interesting" (R18, 4th, F), and "the physics lesson was not very interesting in laboratory" (R22, 4th, F). This, it seems might be related to perceptions of teacher incompetence in the laboratory: "My physics teacher also didn't know how to conduct physics experiment correctly" (R53, 4th, F).

Influence of Physics Lecturers: The influence of lecturers, particularly their lecturing style, appeared to shape participants' attitude-toward-physics and learning, and physics teaching. For example, one female third year commented that little teaching actually occurred, saying that "lecturers taught physics based on notes, I truly learned physics from my own efforts" (Helen, 3rd, F).

Findings from the BAPT questionnaire for item 8 (see Table 6.5) suggest that some physics courses seemed difficult to the participants. Written reports and interview data suggest this was mostly because of a lack of secondary physics learning experiences. For example, one commented that "I did not have experience in physics learning as I was not a science stream student. I had only the experience of learning general science" (R73, 3rd); and another said that "I never learned physics before entering the university… I had difficulty in learning physics because I was forced to study at the university" (R65, 3rd, F).

Despite having no secondary physics learning experience, the influence of lecturers' approach in instruction also sometimes helped physics learning. For example, a third year commented that "I started learning physics in June 2003 and the lecturer helped us a lot" (R61, 3rd). The interviews also pointed to the influence of class-mates who could help make physics courses easier to understand, as seen in the following comments: "Luckily I have bachelor type course-mates and I learned from them and I try my best to pass in the exams because for me it was very hard [but] I have my friends to help and give me extra tuitions" (Camela, 3rd, F).

Some fourth years also reported difficulty in understanding the physics courses. One reason cited was a lack of experience in advanced secondary school physics learning. For example, a fourth year female noted: "It was quite hard for me because I didn't take physics during Form 6 [i.e., Year 12, 18 years old]" (R12, 4th, F). Other difficulties in understanding physics course included not knowing how to solve problems because of "lack of practice … less exercises given" (R48, 4th, F); and overload of topics: "Too many concepts [and] formula to remember" (R53, 4th, F).

Findings from the BAPT questionnaire for item 6 (see Table 6.5) suggests that fourth year participants enjoyed physics learning more than the third years. In some cases, unenjoyable physics learning for the third years seemed to be due to the behaviour of a particular lecturer in quite mundane ways which were deemed off-putting: "The lecturer was always late to the physics class or lecture" (R71, 3rd). The enjoyment of physics learning among fourth year participants seemed to be related to lectures being presented in an interesting manner (item 1, Table 6.3): "Some were really good [and this] resulted in more interest in physics" (R2, 4th, F). Enjoyment of physics learning also was linked to lecturers' personality, for example, a lecturer with a good personality was seen to be someone who was "serious and responsible … concerned about their teaching" (R35, 4th, M). However, some fourth year participants who commented on unenjoyable physics lectures commenting that "the lectures were boring because it was difficult to understand" (R5, 4th, F) indicative of content problems, but probably related to lecturing style since "we just listened to lectures presented in the lecture hall" (R59).

Views about the value of lecture notes in developing conceptual understanding of physics (items 1 & 3, Table 6.5) were influenced by lectures being presented in an interesting manner. For example, "some lecturers were good in teaching, gained A grade in electronics and quantum physics in the second year of study" (R2, 4th, F). The quantitative data suggest that the fourth years found it easier to understand different physics courses than the third years (item 8, Table 6.5). This was borne out in the written reports as seen in comments by a fourth year female:

> As I was very interested in physics, I really appreciated the capability of my lecturers who had made great efforts to teach physics courses …I had … learned physics courses such as electric and magnetism, quantum physics, electromagnet, basic and advanced electronics, thermodynamics, mechanics statistics, measurement and experiment in physics, optical physics, digital electronics and communication, and solid state physics (R20, 4th, F).

Although the fourth years reported finding it easier to understand different physics courses than the third years, the use of lecture notes in developing conceptual understanding for the third years seemed to be much influenced by how the lecturer actually used the notes. For example, if the notes were accompanied by clear explanations this was seen favourably: "The lecturer was good because he let us wrote down the notes slowly and explained them step by step" (R63, 3rd). However, interviews revealed that if the notes were not explained, this was seen negatively: "The lecturer was merely relying on notes I had to put my effort to understand physics concepts [the] notes were not enough, more examples should be given in the lectures" (Helen, 3rd, F).

Summary of Participants' Attitude-Toward-Physics and Learning: Findings from the BAPT questionnaire, written reports and interviews suggest third and fourth year cohorts differed in their attitude-toward-physics and learning. These differences in attitude seem to be influenced by their learning experiences and teaching styles of their lecturers and teachers in terms of teaching methods and personality, and the learning environment in the classroom and laboratory. The third years placed considerable importance on teaching style, and on teaching in the classroom and laboratory. These differences are supported from statitistical significant using an independent group t-test, and findings from qualitative found that there were many different opininons within each cohort as well as between cohorts because they come from diverse physics learning experiences.

Successful teaching methods that the teacher or lecturer tried to make physics learning interesting included; was simple, related the physics concepts to everyday life, employed cooperative learning, used teaching aids, gave crucial notes, and used formulae to solve physics problems. On the other hand, teaching methods that make physics learning difficult and boring were: over use of the textbook; talking by just looking at the textbook, requiring students to just copy notes from the transparency without explaining them, just writing on the blackboard and the teacher talking to him or herself, and having limited or no physics learning experience at secondary school.

Personality traits of teachers, such as dedication, being strict or lenient made some participants sees physics learning as difficult and boring. Teachers that made students work hard could help students understand physics, while lenient teacher could mean that students found it difficult to understand physics. So a strict teacher was not necessarily a bad thing if he or she also made the subject interesting and helped the students come to enjoy physics. Boring teaching was when it was highly teacher-dominated such as when a lecturer used ‘talk and chalk’. Such teaching made physics seem difficult to understand, and physics learning also was seen as boring when it involved learning a lot of formulae, and the teacher or lecturer imparted too abstract physics knowledge, did not attract students’ attention. The students felt tired listening and disengaged when the teacher did not know how to manipulate formulae, taught the wrong concepts of physics, seldom asked the students anything, or asked the students study on their own. As a result of these learning environments which were deemed boring, the students became stressed, afraid of physics, hated physics, were forced to study, just to pass the examinations, and overall did not favour physics as a subject.

Negative attitudes which were mentioned include teaching being boring, stressful, the content being hard or difficult to understand, and when the teacher taught the wrong concepts of physics to the students. Positive experiences include physics being interesting, fun, exciting, understanding physics easily through experiments, passing exams with good achievement and being easier to understand. In other words, the participants’ good or positive experiences in the classroom and laboratory physics were related to specific teaching methods, teacher's personality and learning environment.

6.3.3 Physics Teaching Self-Efficacy Beliefs

This section presents the findings of participants' self-efficacy beliefs about physics teaching in general, and secondary school physics topics in particular. The scale scores have been discussed in Section 6.2.2. As the scores for the scale of physics teaching self-efficacy beliefs for both cohorts are nearly similar or the differences in means between the two cohorts are small (which varies from 37.5 to 36.7), then the researcher decided to discuss each item in this Section for this scale using mean differences. A mean score (equal to or exceeding three) is considered to be confident, and standard deviation (equal to or exceeding one) indicates participants had different physics teaching self-efficacy beliefs. The scale of physics teaching self-efficacy beliefs from the BAPT questionnaire consisted of: *confidence to teach secondary school physics* (6 items – Table 6.7); *ability to teach secondary school physics* (5 items – Table 6.9); and *confidence to teach secondary physics topics* (9 items – Table 6.10). These findings are presented first, and were triangulated with interview data and the TUG-K and FMCE tests, followed by the descriptions of the findings from the interviews.

Participants' Self-Efficacy Beliefs, Confidence to Teach Physics – Quantitative Findings: Data from Table 6.7 suggest that the third years were somewhat under confident about teaching physics compared with their fourth year counterparts (item 1, strong agreement means participants were not confident for a given item, since the items are in effect negatively worded). This is supported by differences in confidence between the third and fourth years for item 2. Rules imposed by the Ministry of Education mean the third years had no choice but to teach physics (item 3), and as a consequence they also had to enrol in physics courses, as part of their training (item 2). Responses to item 2 also indicates some participants for both cohorts saw that they had no choice except to enrol physics courses as this course is coupled with mathematics courses (as either a major or minor). Responses to item 4 suggest that the participants think teaching secondary school physics would be stressful. However, responses to items 5 and 6 suggest that the fourth years seem to believe that good teaching is related to the adequacy (or otherwise) of learners' background in physics and their achievements. Hence, feelings about teaching self-efficacy may be moderated by factors beyond participants' control – like the background of the learners, learners' capability, and rules imposed by the Ministry of Education.

Table 6.7
Mean and standard deviation for self-efficacy beliefs – confident from the BAPT questionnaire

Physics Teaching Self-Efficacy (PTSE)	Third Year (n = 28)		Fourth Year (n = 64)	
	Mean	SD	Mean	SD
1. I would not teach physics if it was not required by the Education Ministry	3.95	1.19	3.13	1.26
2. I was required to enrol physics courses by the Ministry of Education	3.40	1.23	2.90	1.01
3. There is very little I can do to avoid teaching physics	3.30	0.80	3.24	0.89
4. My physics teaching will result me having more stress	3.60	1.09	3.14	1.18
5. Inadequacy in a student's physics learning background can be overcome by good teaching	3.75	0.85	3.87	0.75
6. Students' achievement is directly related to their teacher's effectiveness in physics teaching	3.95	0.95	4.10	0.73

Differences in mean responses for third and fourth years were investigated using independent groups t-test for each item, and statistically significant differences ($p < .005$) were found for two items; (items 1 & 2, Table 6.8): *I would not teach physics if it was not required by the Education Ministry* ($t = 3.015$, $df = 96$, $p < .004$); and *I was required to enrol physics courses by the Ministry of Education* ($t =-2.359$, $df = 96$, $p < .021$). The first item suggests that the third years have less desire to teach physics than the fourth years. Consistent with this, the latter suggests that the third years felt they were more limited in their choice to enrol in physics courses than the fourth years. The statistical tests indicate that the third years were likely to have low physics teaching self-efficacy beliefs. Thus, the third years were under-confident or had low 'outcome expectancy', and felt incapable, whereas the fourth years were more confident had high 'outcome expectancy', and felt more confident about their ability to teach physics successfully.

Table 6.8
Items with statistically significant difference for two cohorts from the BAPT questionnaire

Item	Third Year Mean	Fourth Year Mean	Means difference (SD)	Effect Size	t	Significance (2-tailed)
1. PTSE1* (N_t =28; N_f = 64)	3.95	3.13	.82 (1.24)	0.66	3.015	.004
2. PTSE2* (N_t =28 N_f = 64)	3.40	2.90	.50 (1.08)	0.46	-2.359	.021

* Physics teaching self-efficacy (PTSE) for items 1 and 2 from Table 6.7

N_t – third year; N_f – fourth year

Participants' Self-Efficacy Beliefs, Ability to Teach Physics – Quantitative Findings (Table 6.9): It is important to note that this Table is the subscale of physics teaching self-efficacy beliefs, resulted from a review of relevant literature, discussion with panel of experts (supervisor and colleagues), and feedback from the participants. Findings for the responses to item 1 suggest that the third years learned physics at the university mostly to pass their examinations. The data also suggest they felt they gained little learning in the laboratory at university (item 2), learned by memorisation at secondary school (item 5), and this meant they felt their perceived lack of conceptual understanding of basic physics making them feel they would struggle to teach physics (item 4). Due to perceptions of a lack of learning experiences in the laboratory at university and in memorisation at secondary school - together with lack of conceptual understanding of basic physics (items 2, 3, 4 & 5) - the third years seemed to believe that they would not be able to teach secondary school physics. However, the standard deviations for items 1 and 2 point to a variety of views, meaning things other than physics learning just to pass the examinations, and that some may have had more experience in the laboratory. These findings indicate the third years with low ability or low 'personal self-efficacy beliefs are hesitant to teach physics, whereas the fourth years with high ability are more motivated to teach physics.

Table 6.9
Mean and standard deviation for self-efficacy beliefs – ability from the BAPT questionnaire

Physics Teaching Self-Efficacy (PTSE)	Third Year (n =30)		Fourth Year (n= 64)	
	Mean	SD	Mean	SD
1. I learn just to pass physics exams	2.90	1.12	3.02	1.35
2. I gain very little experience in the laboratory	2.15	1.14	2.71	1.31
3. Problems I may encounter in my teaching are due to my lack of conceptual understanding of basic physics	3.60	0.99	3.63	0.77
4. My own lack of conceptual understanding may prevent me from teaching physics better	3.50	0.76	3.37	0.90
5. I learned physics through memorizing	3.35	0.81	3.54	0.88

Participants' Self-Efficacy Beliefs, Confidence to Teach Physics, and Ability to Teach Physics – Qualitative Findings: Findings from interviews and written reports relating specifically to physics teaching self-efficacy beliefs, again are based on the protocol shown in Figure 6.2. These data were used to triangulate the BAPT questionnaire data from the scale of self-efficacy beliefs – *confidence, and ability to teach physics* scale. Again, the findings from this scale were triangulated with the findings from the influence of other scales: *physics learning experiences with teachers and lecturers*, and *attitude-toward-physics and learning* that have on physics teaching self-efficacy beliefs.

Findings from interviews support the quantitative findings, with a fourth year female commenting there were "rules imposed to take physics as a minor" and that "the physics courses conducted by the School of Science and Technology were not related to secondary school level" (Alice, 4th, F). These learning experiences at university were one reason cited for reluctance about physics teaching. Some of the participants in the third years commented that they only learned physics at their SPM (Malaysian School Certificate) level, and then joined the teachers' college before entering the university to take physics as a minor – a condition set for the third years. As might be expected, the impact of participants' views about their own physics knowledge seemed to be influential on their confidence to teach physics. For example, one commented that "due to the nature of physics, one needs to have skills in understanding it" (Helen, 3rd, F), before teaching, and another commented that he "only learned physics in teachers' college", meaning "the subject was quite difficult" for him to teach. To counter this he "learned physics at the training college directly from the lecturer as well as from his colleagues". In fact, some of his "colleagues discouraged me from taking this course", but his "determination to become a physics teacher" made him "persevere studying the subject" (Issac, 3rd, M).

Other comments point to the influence of secondary school physics learning experiences as a reason for their perceptions of their ability to teach physics. For example, one third year female commented that "although teachers' explanations were good, but less cognitive ability on my part made physics learning difficult" (Farah, 3rd F). Another female also commented on her ability "I think physics is related to daily life, but it is difficult to be learned" *(*Geetha, 3rd, F). What this implies was that they often felt that they "had to learn this subject and spend more time" (Diana, 3rd, F). This self-efficacy belief related to the amount of effort and interest put into learning how to teach physics. Lack of ability has resulted in decrease of self-efficacy to teach physics.

Self-Efficacy Beliefs about Teaching Secondary School Physics: The participants' self-efficacy beliefs about teaching secondary school physics consisted of three scales: *confidence to teach secondary physics topics* (9 items) – Table 6.10; *confidence in achieving 'general learning outcomes' for topics of force and motion* (7 items) – Table 6.11; and *confidence in achieving 'specific learning outcomes' for topics of force and motion* (14 items) – Table 6.12. The second and last scales sought participants' ratings of difficulties for specific topics in physics. The findings are presented in the form of percentages for each item selection. These findings were analysed together with the findings in Section 6.4 on the Tests of TUG-K and FMCE.

Table 6.10
Confidence to teach secondary physics topics from the BAPT questionnaire

Confidence to teach secondary physics topics	3rd Year (n =34)		4th Year (n =65)	
	% AG	% DA	% AG	% DA
1. Introduction to Physics	41	15	71	5
2. Force and motion	41	9	39	8
3. Force and Pressure	29	32	34	14
4. Heat	35	15	39	15
5. Light	38	12	51	15
6. Wave	24	21	40	19
7. Electricity and Electromagnetism	12	45	39	25
8. Electronics	9	44	41	20
9. Radioactivity	12	47	25	28
Average Mean Score	29		42	

AG – Agree; DA - Disagree

The *confidence to teach secondary physics topics* mean scores (average mean score) was 29% for the third years and 42% for the fourth years. These findings from Table 6.10 suggest that the fourth years were more confident about teaching secondary physics topics than the third years. The level of confidence, however, varied depending on topic and, for example, radioactivity and electronics were topics for which third years felt particularly less confident to teach. In particular, the *Confidence to Teach 'Force and Motion' Topics* (Table 6.10), it can be seen that about 40 % of both cohort groups were confident to teach 'force and motion' topics. However, around 30% of the third years were confident about achieving all of the 'general learning outcomes' for 'force and motion' (the concept of linear momentum being an exception, Table 6.11). In general, participants were confident about achieving all of the 'general learning outcomes' for 'force and motion' with means score of 27% for the third years and 46% for the fourth years.

These data suggest in each case the fourth years were more confident in achieving 'general learning outcomes' compared with their third year counterparts. This varied a little, but overall about twice the proportion of fourth years indicated that they felt confident about achieving general learning outcomes for force and motion topics.

Table 6.11
Confidence in achieving general learning outcome of 'Force and Motion' from the BAPT questionnaire

Confidence to achieve 'general learning outcome' of force and motion	3rd Year (n= 34)		4th Year (n= 65)	
	% AG	% DA	% AG	% DA
1. Linear Motion	26	9	55	5
2. Inertia Concept	32	21	51	6
3. The Concept of Linear Momentum	18	27	46	5
4. The Effect of Force	32	23	43	12
5. The Force of Gravity	29	27	43	6
6. The Balanced Force	26	21	39	15
7. Work, Power, Potential Energy & Kinetic Energy	29	23	55	9
Average mean score	27		46	

AG – Agree; DA - Disagree

Confidence to Teach Specific 'Force and Motion' Topics: Around 40% of the third years felt confident about achieving 'specific learning outcome's (Table 6.12) when teaching acceleration and deceleration, equations of motions, Newton's First Law, Newton's Second Law, Weight, and Newton's Third Law. Least confidence was for the topics of equilibrium and impulse and impulsive force, and collisions and explosions.

In general, participants were confident about achieving all of the 'specific learning outcomes' for 'force and motion', means scores of 33% for the third years and 47% for the fourth years. Again the fourth years were more confident than their third year counterparts, except for Newton's Third Law which was about the same. These three findings from Tables 6.10, 6.11 and 6.12 suggest that the third years overall were less confidence about teaching physics than the fourth years.

Table 6.12
Confidence to teach "force and motion" topics from the BAPT questionnaire

Confidence to achieve 'specific learning outcome' of force and motion	3rd Year (n =34)		4th Year (n= 65)	
	% AG	% DA	% AG	% DA
1. Distant and Displacement	26	15	57	9
2. Speed and Velocity	35	12	60	5
3. Acceleration and Deceleration	38	9	54	5
4. Graphs of Linear Motion	35	15	51	11
5. Equations of Motion	38	9	51	11
6. Newton's First Law	44	9	51	15
7. Conservation of Momentum	21	18	34	14
8. Collisions and Explosions	18	15	35	19
9. Newton's Second Law	41	12	45	15
10. Impulse and Impulsive Force	23	27	40	11
11. Free Fall	32	18	45	11
12. Weight	41	12	55	6
13. Equilibrium	23	15	41	11
14. Newton's Third Law	38	9	38	17
Average mean score	33		47	

AG – Agree; DA - Disagree

Summary - Physics Teaching Self-Efficacy Beliefs: The findings suggest that in the case of self-efficacy beliefs about physics teaching in general, and secondary school physics topics in particular, the thirds years had relatively low physics teaching self-efficacy beliefs compared with their fourth year counterparts. This difference is particularly significant for items 1 and 2 (see Table 6.8), and overall it seems the third years were reluctant to teach physics, because they were forced to enrol in physics courses. As a consequence, they believed that physics teaching would be difficult, as evidenced by their agreement that they expected stress if asked to teach secondary school physics. They enrolled in physics courses purely for the sake of passing the examinations, and their lack of laboratory learning experiences, the fact that they learned by rote memorisation and feelings of lack of conceptual understanding of basic physics, made this cohort group quite under confident about teaching secondary school physics. They believed that they would not be able to teach secondary school physics. On the other hand, the fourth years seemed to be more confident about becoming secondary school physics teachers. In conclusion, participants with low ability or low 'personal self-efficacy beliefs' were found to be under-confident with a low 'outcome expectancy' to teach physics. The findings of this section, physics teaching self-efficacy beliefs, are compared with Section 6.4.3 the actual conceptual understanding on the TUG-K and FMCE tests.

6.3.4 Attitude Toward, and Beliefs About, Physics Teaching

This section presents the findings about the participants' attitude toward, and beliefs about, physics teaching from the BAPT questionnaire. This scale consisted of two sub-scales: *interest to teach secondary school physics* (11 items) – Table 6.13, and *career interest in physics teaching* (8 items) – Table 6.15. The findings from this scale were triangulated with the findings from the influence of other scales: *physics learning experiences*, *attitude-toward-physics and learning*, and *physics teaching self-efficacy* that have on participants' attitude toward, and beliefs about, physics teaching. Finally, the findings were triangulated with data from written reports.

Attitude Toward, and Beliefs About, Physics Teaching – Interest (Table 6.13)*:* Participants' responses for the BAPT questionnaire for the scale to the *attitude toward, and beliefs about, physics teaching* suggest that the third years were less positive or had low physics teaching interest (a mean greater than 3.00 is considered to be positive), suggesting they might not actually want be a physics teacher, or think that physics teaching would not be enjoyable (items 1 & 2). Both results are consistent with the statistical tests from Table 6.8 (items 1 & 2) which suggest that the third years have less tendency to want to teach physics than the fourth years (i.e., the third years were likely to have low physics teaching confident). From Table 6.9 (items 2, 3, 4 & 5), it also seen this group believes they would not be able to teach secondary school physics (low ability). This might in part be due to having not good secondary school learning experiences (item 3, Table 6.13), and their perceptions as to how capable they were at physics in the national examinations (items 4 & 5, Table 6.13). Although most of the third years had some primary science teaching experience (item 6, Table 6.13), *few* thought physics teaching would be easy (item 8, Table 6.13), or felt that the physics courses they had done did not give them enough knowledge to teach physics (item 7, Table 6.13).

Nonetheless, high standard deviations (equal to or exceeding one) for item 8 suggest that although both cohorts believed physics teaching would be difficult, some of them may think physics teaching also would not be difficult. Item 8 reflects the findings for items 1 and 2 (i.e., some might want to be a physics teacher and think physics teaching would be enjoyable), item 3 (i.e., some might have had good secondary school learning experiences), item 4 (i.e., some third years perceived they were capable at physics in the national examinations, SPM - Malaysian School Certificate), and item 6 (some felt they had some primary science teaching experience). Interestingly, responses to item 5 indicate that the fourth years believed physics teaching would be easy because they were capable at physics in the national examinations, STPM - Malaysian Higher School Certificate. They linked student learning to an individual's competency (item 9) rather than good teaching (item 10). On the other hand, the fourth years whilst having more interest in physics teaching than the third years, were still relatively less positive about physics teaching (means less than 3.00). Overall they still did seem to want to become a physics teacher (item 1), and some linked both student learning to an individual's competency and good teaching (items 9 & 10). Finally, the fourth years also had more interest in using apparatus in the laboratory than the third years.

Table 6.13
Mean and standard deviation for attitude toward, and beliefs about, physics teaching from the BAPT questionnaire

Attitude-Toward-Physics Teaching (ATPT)	Third Year (n=30)		Fourth Year (n=64)	
	Mean	SD	Mean	SD
1. I want to be a physics teacher.	2.85	1.31	3.17	1.10
2. I enjoy teaching physics.	2.65	1.09	3.00	1.11
3. My previous secondary physics learning experiences were good.	2.45	1.19	2.97	1.14
4. I was good at physics in SPM.	2.20	1.15	2.54	0.99
5. I was good at physics in matriculation/STPM	1.70	0.92	2.61	1.05
6. I taught science in primary school before.	2.85	1.14	2.31	1.20
7. Physics courses I have taken gave me enough knowledge for me to teach physics	2.45	0.95	2.68	0.97
8. Teaching physics is easy	1.85	1.09	2.20	1.00
9. A good student does well in his/her classes even if the physics teacher exerts little effort	2.85	1.04	3.39	1.10
10. If students are under-achieving, it is likely due to ineffective physics teaching	2.95	0.83	3.56	0.93
11. Using physics apparatus in the laboratory is easier	3.00	0.92	3.19	0.88

Differences in means for the two cohorts were examined for statistically significant differences using an independent group t-test for each item (Table 6.14). Statistically significant differences ($p < .005$) were found for four items (3, 4, 5 & 10): *My previous secondary physics learning experiences were good* ($t = 3.046$, $df = 96$, $p < .003$); *I was good at physics in SPM* ($t = 2.521$, $df = 96$, $p < .013$); *I was good at physics in matriculation/STPM* ($t = 4.861$, $df = 96$, $p < .000$); and, *If students are under-achieving, it is likely due to ineffective physics teaching* ($t = 2.403$, $df = 96$, $p < .019$). Overall it seems that the fourth years had better learning experiences at secondary school than the third years. The fourth years also felt they performed better in the national examinations - SPM (Malaysian School Certificate) and STPM (Malaysian Higher School Certificate) than the third years. Mean differences less than zero were considered less positive response, and effect sizes were found to be moderate and large. Although large effect sizes indicate the practical significance of the mean differences, larger effect sizes also means less statistical significance (considered not significant) compared to the items with lower effect sizes. Finally, the fourth years seem more likely to believe that student learning was linked to good teaching than the third years, thus supporting findings from the attitude-toward-physics and learning (Section 6.3.2) data showing physics teaching interest becoming less for the third year participants.

Table 6.14
Items with statistically significant difference for two cohorts from the BAPT questionnaire

Item	Third Year Mean	Fourth Year Mean	Means difference (SD)	Effect Size	t	Significance (2-tailed)
2.ATPT3* (N_t =30 N_f = 64)	2.45	2.97	-.52 (1.16)	-0.45	3.046	.003
3.ATPT4* (N_t =30; N_f = 64)	2.20	2.54	-.34 (1.04)	-0.33	2.521	.013
4. ATPT5*(N_t =30; N_f = 64)	1.70	2.61	-.91 (1.01)	-0.90	4.861	.000
5.ATPT10*(N_t=30; N_f = 64)	2.95	3.56	-.61 (.90)	-0.68	2.403	.019

* Attitude toward, and beliefs about, physics teaching (ATPT) for items 3, 4, 5 and 10 from Table 6.13

N_t – third year; N_f – fourth year

Attitude Toward, and Beliefs About, Physics Teaching: Career Interest - Quantitative Findings (Table 6.15): The findings suggest that both cohorts of participants held a positive attitude toward physics teaching, and saw teaching as their career of choice (item 1) - but this was not so for some of fourth year cohort group. Most saw physics as necessary for their degree (item 2), and felt that physics teaching in English would be difficult (item 3). For some it was not only due to language but also the content. However, the difficulties or challenges might result in better physics learning (item 4). Hence, physics teaching might be stressful, but it would make them better prepared for teaching (item 5). Additionally, items 4 and 5 indicate the fourth years seemed to have a more positive attitude towards physics teaching than the third years. Although the participants knew the Ministry wanted them to teach physics (item 6), for the fourth years their career in physics teaching seems to be influenced either by their physics teachers or their physics lecturers. Items 8 is consistent with the findings for items 6 and 7, suggesting that the third years attitude-toward-physics teaching was not much influenced by social attitudes by a significant other such as their principal, family, relatives or colleagues. Thus overall, it seems they were influenced more by career interest rather than perceptions of difficulty by peers and other influential people.

Table 6.15
Mean and standard deviation for attitude toward, and beliefs about, physics teaching from the BAPT questionnaire

Attitude-Toward-Physics Teaching (ATPT)	Third Year (n= 29)		Fourth Year (n=61)	
	Mean	SD	Mean	SD
1. Teaching is the first choice of my career	4.40	0.75	3.73	1.27
2. I require physics for the degree	3.10	1.33	3.37	1.14
3. Teaching physics in English is difficult	3.45	1.57	3.93	1.22
4. Although teaching in English is difficult, it is likely physics knowledge can be improved	3.60	0.94	3.73	0.83
5. Although it is likely that physics teaching may cause me stress, the stress also will make me more prepared	3.65	0.81	3.71	0.87
6. The Education Ministry thinks I should teach physics	3.15	1.18	2.97	1.03
7. Most people who know me think I should teach physics	2.90	1.17	2.93	1.03
8. I want to teach physics because most people who are important to me think I should teach physics	2.35	1.27	2.44	0.93

Statistically significant differences ($p < .005$) were found for just one item (item 1, Table 6.16): *Teaching is the first choice of my career* ($t = -2.079$, $df = 96$, $p < .040$). Here it seems that the third years were more positive about teaching as a career of choice than the fourth years. From these findings, the data again indicates that teaching as a career of choice is due to experiences in teaching at primary school and enrolment in science courses merely for the sake of gaining higher qualifications, whereas the fourth years have had no experience teaching.

Table 6.16
Items with statistically significant difference for two cohorts from the BAPT questionnaire

Item	Third Year Mean	Fourth Year Mean	Means difference (SD)	Effect Size	t	Significance (2-tailed)
1. ATPT1* (N_t =29 N_f = 61)	4.40	3.73	.67 (1.13)	0.59	-2.079	.040

* Attitude toward, and beliefs about, physics teaching (ATPT) for item 1 from Table 6.15

N_t – third year; N_f – fourth year

Attitude Toward, and Beliefs About, Physics Teaching: Career Interest - Qualitative Findings: Quantitative data about participants' attitude toward, and beliefs about, physics teaching with respect to career interest were triangulated with data from written reports. Several of the participants said that they loved physics learning at secondary school because of good teachers. For example, one female participant commented in her written report that,

> I loved this subject very much when I was in secondary school because it needed me to carry out a lot of interesting experiments. The physics teacher also had a vast experience and in-depth knowledge. These factors made my teacher impart knowledge to us easily (R19, 4th, F).

This participant's attitude was different for secondary and tertiary experiences (going from interested to not interested). At secondary school she said:

> I only learned physics during my SPM level, and did not take at STPM level. While I was in Forms 4 and 5, I was taught by the same physics teacher. He was responsible and very well versed in physics. I still remember him because he was concerned about my low achievement in

> physics … he wrote notes on the white board without using any transparency. He managed to use white board very well and the limit of his notes was very accurate with the size of the white board. We copied down his notes. Once finished, he explained his notes together with appropriate teaching aids. We often went to the laboratory to do the experiment ... He normally did the experiment, while the students watched. If the experiment set was enough, the students can do the experiment in a group.

However, at university this changed:

> However, when I enrolled at the School of Science and Technology, physics became my minor. I became to dislike physics. I think the reason was that I did not learn physics at the STPM level. I did not like physics in the university because all of the lecturers only used the transparency and 'talked'. In addition, most of the lecturers were reluctant to impart more information about the topics taught. The basic of each topic was not taught because the lecturer thought all of the students were brilliant. Finally, I lost in my physics learning (R1, 4^{th}, F).

The influence of attitude-toward-physics and learning on beliefs about physics teaching was reflected in written comments by another fourth year female participant who noted that her physics teacher helped her become interested in physics teaching:

> Physics learning in the classroom was interesting because of the experienced teacher and concerned about students who were either low or high achievers … The teacher's instruction in secondary school was quite effective because the instruction was quite enthusiastic, and the teacher always concerned about students' achievement. The teacher also conducted physics learning in the afternoon after class session ended.

> Students who had questions can ask the teacher and discussed individually (R16, 4th, F).

The importance of the teacher's influence on participants' attitude-toward-physics and learning was evident in comments of a female participant. Again there were differences between school and tertiary experiences. She commented that at secondary school:

> I loved physics subject since I was in Form 4. It started with my physics teacher who enhanced and foster the interest in my physics learning. When I was in Form 4, he was an excellent physics teacher and also head of mathematics and science. The physics experiment I remembered the most was during conducting experiment of how to measure velocity and acceleration using the ticker tape and trolley. When I was in Form 5, I had other physics teacher who was also taught additional mathematics. I was strongly satisfied with his/her lesson and s/he also had an expertise and excellence in the subject. S/he was able to describe of how a phenomenon happens by relating it to physics.

This participant also noted that physics lecturers at the university by mentioning those who influenced her physics learning:

> As I was very interested in physics, I really appreciated the capability of my lecturers who had made great efforts to teach the subject. I had the opportunity to learn physics topics such as electric and magnetism, quantum physics, electromagnet, basic and advanced electronics, thermodynamics, mechanics statistics, measurement and experiment in physics, optical physics, digital electronics and communication, and solid state physics (R20, 4th, F).

The impact of physics learning on attitude toward teaching also seemed related to teaching methods. For example, a comment from fourth year was that:

> I always remember the time getting scolded by the physics teacher and the mood down as I got poor result in the exams. The teacher always did chatting and talking, and burdened the students with lot of exercises. In the laboratory, I seldom did the experiment, just noted down the observations, results and conclusions by referring to the textbooks. Doing experiments was boring and stressful. The things I always did in the classroom and physics laboratory were to compare between the theory and experiments. At university, learning physics was very difficult to understand what they have talked and what kind of thinking they had. I learned physics through memorizing, focused on examinations and laboratory report. I had always to memorize physics concepts or formulae by heart even though I didn't understand at all. The lecturers used chalk and talk and sometimes asked the students to present the assignment which was related to the course. The first two years we had tutorials and laboratory. I did experiment but not quite often. One of the final exams of physics was conducted in open book. I honestly disliked physics (R4, 4^{th}, F).

In contrast, another fourth year participant initially hated learning physics at secondary school because of emphasis on formulae, theory, calculations and lack of experience in conducting experiments. However, this experience was different at university:

> I find out that there was so much different than the one in my olden days. I feel that I am attracted to and stick to it. Everyday was physics! The assignments given by the lecturers were much harder and challenging but I love the way they taught apart from that, the experiments were much more advanced. Although formulae, theories and calculations STILL burdened me, but I was starting to cope with it! (R50, 4^{th})

A number of themes also emerged from examination of participants' written reports in both the third and fourth years, and these are presented in Figure 6.5.

Pre-service teachers' attitude toward, and beliefs about, secondary physics learning	Pre-service teachers' attitude toward, and beliefs about, tertiary physics learning
Rote learning and memorisation. Gained knowledge through own initiative including search for answers	Rote learning, study concepts through textbooks, and memorisation of formulae.
Questions and answers session as a way of evaluating and helping in understanding the lesson. Focused on achievement	Employed appropriate teaching methods was quite interesting, sometimes the lectures were boring as it was difficult to understand, some seemed not able to teach well and stress.
Teacher's personality such as high calibre, enthusiastic, interest, workaholic, concerned, dedication, explained personally and strict; lost temper when students did not know the answers, lenient.	Lecturer's personality such as high calibre, enthusiastic, interest, workaholic, concerned, and dedication.

Figure 6.5
Themes about attitude toward, and beliefs about, physics teaching based on participants' written reports

Attitude Toward, and Beliefs About, Physics Teaching - Summary: The findings presented here suggest that the third year participants did not enjoy physics learning at university and only enrolled in physics courses because they considered teaching as their career interest and needed to pass these courses. Their decision to take up teaching as a career was influenced by their teaching experiences at primary school, and a perceived need to gain higher qualifications, meaning they were forced to enrol in physics courses as a compulsory condition set by the Ministry of Education. However, some believed that physics teaching at secondary school would be difficult, not only because of the content, but also because the medium of instruction was to be English. Hence, the physics courses provided by the university were deemed inadequate. They also believed that physics teaching might not be enjoyable because they had not had good secondary physics learning experiences, and had not performed well in national examinations. The participants' who did not enjoy physics learning, and believed they would have difficulty teaching physics, were likely to have negative attitude-toward-physics teaching. In addition, the third year participants who had more career interest in physics teaching were likely to have negative attitudes towards physics teaching than those who had high physics teaching interest.

The findings also suggest that although physics teaching is seen as difficult in terms of content and because of the language used in instruction, some participants were still positive about teaching physics, feeling they would end up being better prepared and trying to improve their physics knowledge. Hence, some of the third years could still see value in doing physics courses as a compulsory condition for doing physics teaching. In such cases, their decisions were not much influenced by their physics learning experiences at secondary schools.

Finally, in order to understand the influences of learning experience on attitude toward, and beliefs about, physics teaching, three correlation analyses were concluded: (a) relationship between learning experience (LE) and attitude-toward-physics and learning (ATPL); (b) relationship between learning (LE) experience and physics teaching self-efficacy (PTSE); and (c) relationship between learning experience (LE) and attitude toward, and beliefs about, physics teaching (ATPT).

Table 6.17
Correlation analysis of the BAPT scales

Scales	Third Year (n =16)				Fourth Year (n = 56)			
	LE	ATPL	PTSE	ATPT	LE	ATPL	PTSE	ATPT
1. LE	1				1			
2. ATPL	.017	1			.455**	1		
3. PTSE	.261	.019	1		.220	.252*	1	
4. ATPT	.430*	.553*	.323	1	.335**	.720**	.208	1

** correlation significant 0.01 level (1-tailed)

* correlation significant p = 0.05 level (1-tailed)

In general there was a moderately strong correlation between *learning experiences* and *attitude-toward-physics and learning* scales for the fourth years (r = .455), and it seems that fourth years who had good learning experiences tended to have a positive attitude toward physics. However, there was no correlation between *learning experiences* and *attitude-toward-physics and learning* scales for the third years, or between *learning experiences* and *physics teaching self-efficacy* (r =.261, .220) for either cohort. There was a moderately strong correlation (r =.430) for third years and weak correlation (r = .335) for fourth years between *learning experiences* and *attitude toward, and beliefs about, physics teaching*. These correlations support the findings from the BAPT questionnaire for *attitude toward, and beliefs about, physics teaching* suggesting that the third years who had experienced teaching in primary school were likely to have been influenced in terms of teaching (other than physics) as a career interest, while fourth years who had experienced good physics teaching from their teachers and good achievements in physics were likely to have been influenced in terms of their interest in physics teaching.

Although there were no statistically significant correlations found between *attitude-toward-physics and learning* and other scales for the third years, there was a correlation between *attitude-toward-physics and learning*, and *attitude toward, and beliefs about, physics teaching* scales for both cohorts (r = .553, moderate correlation for third years, and r =.720, strong correlation for fourth years). These correlations are consistent with the findings from the BAPT questionnaire on *attitude toward, and beliefs about, physics teaching* which suggests that the third years who had low ability and who did not have good secondary school learning experiences or considered themselves incapable in physics in the national examinations, were likely to have less interest in physics teaching. In contrast, some fourth years believed physics teaching would be easy as they were capable at physics in the national examinations and linked student learning to individual's competencies, were likely to have influenced them in physics teaching interest. Again, there also was no correlation between physics teaching self-efficacy, and attitude toward, and beliefs about, physics teaching for either cohort.

6.4 ADMINISTRATION OF TUG-K AND FMCE TESTS

The tests TUG-K and FMCE (see Appendix V) were administered during the second lecture of the Physics Teaching Methods course. These tests:

- aimed to identify pre-existing participants' conceptual understanding of kinematics graphs and Newton's Laws of motion, and used as a diagnostic tool or as a strategy to evaluate their conceptual understanding and knowledge
- provided information about learning difficulties in kinematics graphs and Newton's Laws of motion that participants might have, and
- were used to determine whether or not learning experience of participants at secondary school and the university influenced their beliefs about, and attitudes toward, physics teaching practice in the 'didaktik approach'.

There were 60 multiple choice questions across the two tests: the first 21 questions in the TUG-K concerned conceptual understanding of kinematics and graphs, while the remaining 39 questions from the FMCE were concerned with Newton's Laws of motion: Newton's First Law (7 questions), Newton's Second Law (22 questions) and Newton's Third Law (10 questions). In total 108 participants (76 out of 78 fourth years, and 32 out of 35 third years) completed the tests. A score of 60% for each conceptual dimension was considered evidence of sound conceptual understanding; a score of 80% for each was regarded as a mastery level, and a score of less than 60% as limited understanding. The results of the tests are presented in four sections.

Section 6.4.1 presents findings about participants' conceptual understanding based on the TUG-K, followed by the findings for conceptual understanding based on the FMCE in Section 6.4.2. Section 6.4.3 discusses the findings for both tests, and compares participants' conceptual understanding from the tests with their self-efficacy beliefs. Section 6.4.4 compares participants' conceptual understanding from the tests with their attitude toward, and beliefs about, physics teaching.

After completing the tests in the second week, the participants were given the BAPT questionnaire in the seventh week which represented self-reported confidence about a list of Form 4 secondary school physics topics (see section 6.3.3, Tables 6.10, 6.11 & 6.12). These items were used to gain some indication of the participants' attitude toward secondary school physics. In addition to these tests and the BAPT questionnaire, interviews with nine participants (one was not able to be interviewed) were conducted to evaluate their understanding of secondary school physics topics, and help determine which specific topics of physics they deemed difficult, and what might influence their confidence about, and ability to, teach secondary school physics. The next Section 6.4.1 presents responses to the TUG-K test.

6.4.1 Research Findings - Conceptual Understanding from the TUG-K

The TUG-K test was employed to examine participants' understanding of graphs and kinematics as it related to secondary school physics. Beichner (1994) identified seven areas of conceptual understanding for these topics (Table 6.18). The research findings indicate that generally both cohorts had difficulty understanding kinematics graphs for things such as position, velocity and acceleration. However, the third years were classified as achieving mastery (i.e., above 80%), and the fourth years conceptual understanding (i.e., above 60%) for determining displacement given a velocity-time graph.

Table 6.18
Third and fourth year participants' conceptual understanding of kinematics graphs concepts as measured by the TUG-K test (n=108)

The Test of Understanding Graph - Kinematics [1]		3rd Year (n=32)	4th Year (n=76)
Given	Conceptual Understanding	% correct	% correct
1. Position-Time Graph	Determine velocity	52	54
2. Velocity-Time Graph	Determine acceleration	40	47
3. Velocity-Time Graph	Determine displacement	85	66
4. Acceleration-Time Graph	Determine change in velocity	27	23
5. A Kinematics Graph	Select another corresponding graph	47	34
6. A Kinematics Graph	Select textual description	49	35
7. Textual Motion Description	Select corresponding graph	43	33

[1] Based on Beichner (1994)

Conceptual Understanding of Kinematics as Measured by the TUG-K - Qualitative Findings: The questions from written reports of tertiary physics learning experiences and the interview protocol relating specifically to difficulties in understanding kinematics graphs are shown in Figure 6.6. Several themes emerged and are now discussed.

i. Generally, did you think questions on kinematics were easy?
Please indicate your rating using the following scale:
Easy _1_ _2_ _3_ _4_ _5_ Difficult

ii. Which question/s of kinematics, do you think were easier? Please indicate those item/s.

iii. Which question/s of kinematics, do you think were difficult? Please indicate those item/s.

Figure 6.6
Interview protocol for participants' views about the TUG-K

Perhaps not surprisingly, only one fourth year felt that the questions from the TUG-K were easy. Three third years said that they thought the questions were difficult, and one fourth and four third years did not know, or were uncertain. This is consistent with all nine participants' performance in the TUG-K test, for which their proportion of correct responses varied between 19 and 71%.

To illustrate further, one third year participant scored 19% correct and subsequently rated the TUG-K test as difficult. Although she rated some questions as easy, examination of her responses to the TUG-K showed she got none correct. Another two third years scored 48% and 43% correct answers respectively, for the TUG-K test, and also rated it as difficult. Based on examination of their test responses, they were considered to have very limited conceptual understanding of graphs and kinematics. On the other hand, one fourth year participant who scored 71% correct answers from the TUG-K test, said she thought it was easy, and she did seem to have a sound conceptual understanding of graphs and kinematics. Likewise the two third years who indicated that they did not know or were uncertain about how hard the TUG-K test was, were found to have limited conceptual understanding of graphs and kinematics, scoring 57% and 50% correct, respectively. Similarly, two participants were considered to have a sound conceptual understanding of graphs and kinematics as they scored 62% and 67% correct, respectively. Finally, one fourth year seemed to have sound conceptual understanding of graphs and kinematics as she scored 62% correct.

Discussion: The mean score for the tests was about 49% for the third years, and 42% for the fourth years (Table 6.18). This is quite low for both cohorts, suggesting that the participants' grasp of kinematics graphs is rather limited. The slightly higher mean for the third years is probably due to the fact that they had done courses in kinematics during the first year at the university, and so their exposure to the topic was more recent. On the other hand, the syllabus for the fourth years was different from the third years, and did not include kinematics. Some of fourth year cohort group applied their understanding of kinematics graphs when they studied physics in secondary school. But overall the participants' understanding of kinematics as measured via the TUG-K is considered limited.

6.4.2 Research Findings - Conceptual Understanding of Newton's Laws from the FMCE

Similar to the TUG-K test, the FMCE test was employed to evaluate participants' conceptual understanding of Newton's laws of motion. The findings are presented in Table 6.19. These data suggest that the participants had difficulty understanding Newtonian laws of motion. Both cohorts had studied these topics before: the third years had taken mechanics in their first year university courses, and the fourth years in secondary school. The fact that their physics learning experiences either at university or secondary school had little effect on participants' understanding about Newtonian concepts is of concern, especially given that it is intended they become physics teachers. The findings from the FMCE are consistent with the TUG-K test. This may be because conceptual understanding of kinematics graphs influences conceptual understanding of Newtonian concepts.

Table 6.19
Third and fourth year participants' conceptual understanding of Newtonian concepts as measured by the FMCE test (n=108)

Newtonian Concepts of Motion (Questions)	3rd Year (n=32) % correct	4th Year (n=76) % correct
First Law of Motion (23, 26, 35, 36, 38, 45, 47)	33	27
Second Law of Motion (22, 24, 25, 27 to 34, 37, 39 to 44, 46, 48 - 50)	22	21
Third Law of Motion (51- 60)	17	17

Conceptual Understanding of Newtonian Concepts as Measured by the FMCE - Qualitative Findings: The questions from written reports about tertiary physics learning and interview protocol relating specifically to difficulties in understanding Newtonian physics are shown in Figure 6.7. Several themes emerged and are now discussed.

i. Generally, did you think questions on Force and Motion easy? Please indicate your ratings on the 1 – 5 scales.
Easy _1_2_3_4_5_ Difficult

ii. Which question/s of Force and Motion, do you think were easier? Please indicate those item/s.

iii. Which question/s of Force and Motion, do you think were difficult? Please indicate those item/s.

iv. What is your physics background?

v. What do you understand by “understanding physics”?

Figure 6.7
Interview protocol for participants’ views about the FMCE

The nine participants all scored relatively poorly in the FMCE, with correct answers ranging between 18% and 31%. This low percentage of correct answers seen seems to indicate they had very limited knowledge of Newtonian concepts. The findings from interviews are consistent with their performance in the test, and in the interviews they stated that they found the questions on the FMCE test generally difficult. As for the FMCE test although participants rated a number of FMCE questions as easy, they could not answer the same questions correctly. One of the participants who did not specifically state which questions were easier or difficult - commented “the questions were difficult, I don’t have basic physics, so I feel confused with the questions. I think most of the questions were difficult” (Diana, 3rd, F).

When asked about their physics background (question IV), five participants said they only learned physics at the SPM (Malaysian School Certificate) level and one commented “as most of us mentioned physics is difficult and very interesting subject because this is very near to our line [profession] at University of Malaysia Sabah” (Bertha, 3rd, F). Two said they only learned physics at university, one commenting that:

> My physics background was not so good because from primary to secondary schools, I did not study physics. None of my family members studied physics. Nobody tell me about physics. My parents just worked in a village. They were no education at higher level. First, just now I said I see physics subject in the Gaya's Teacher College. I come to this university to study physics. That physics is difficult. I learned first physics from the University of Malaysia Sabah (Issac, 3rd, M).

The remaining commented they did not have much physics background. Comments from participants' interviews about their physics background who answered both the difficulties of TUG-K and FMCE influence their attitude toward, and beliefs about, physics teaching. Finally, when asked further what they meant by 'understanding physics' (question V), some seven participants listed their responses in the following categories: "Understanding the actual physics concepts" (Farah, 3rd, F); "Understanding the correct concepts of physics which are related to daily life" (Helen, 3rd, F); "Physics is one of the subjects related to anything happens in a daily life" (Issac, 3rd, M); "Physics is universal, it involves everything in everyday life" (Bertha, 3rd, F); "Physics related to everyday life, it involves many formulae" (Camela, 3rd, F).

Discussion: The mean test score of 24% for the third years, and 22% for the fourth years are considered low (see Table 6.19), indicating that participants' conceptual understanding of Newton's laws of motion is limited. These findings support the findings from the BAPT questionnaire. The findings of the BAPT questionnaire also point to the value of the TUG-K and FMCE tests as probes for evaluating participants' attitudes whether they have the confidence about their ability to teach secondary school physics. The findings from the TUG-K and FMCE tests, interviews and the BAPT questionnaire are consistent, and overall point to a lack of ability and lack of confidence as affecting participants' attitudes towards teaching specific physics topics at the secondary level.

6.4.3 Conceptual Understanding and Self-Efficacy Beliefs

The TUG-K and FMCE tests suggests that the physics learning experiences of these pre-service teacher participants for both cohort groups, either at secondary school or university, did not result in them understanding kinematics graphs or Newton's Laws of motion. This is revealed in the participants' weak performance in the TUG-K and FMCE tests. These results were subsequently compared with their self-efficacy beliefs about their confidence and ability to teach secondary school physics (Tables 6.10, 6.11 & 6.12).

About 10 % for both cohort groups strongly disagreed with the statement that they *had the confidence to teach the topic of 'force and motion* (item 2, Table 6.10). This points to very low self-efficacy beliefs, and is likely related to their limited understanding of the topic of 'force and motion'. It also seems that because of their weak conceptual understanding, the participants may view teaching as a last resort, particularly in the case of the third year cohort, who strongly agreed with such statements (items 1 & 2, Table 6.7): *I would not teach physics if it was not required by the Education Ministry*; *I was required to enrol physics courses by the Ministry of Education;* and *physics teaching is their first choice of career* (item 1, Table 6.15). These findings indicate that participants have low physics teaching self-efficacy beliefs, and performed poorly in the TUG-K and FMCE tests, but they had more tendencies towards wanting to teach (but not physics teaching).

The third years also seemed to believe that physics teaching would be difficult (item 8, Table 6.13). This attitude-toward-physics teaching tends to reflect participants' feelings of their ability to create a positive impact on their students when teaching, and is consistent with their beliefs about experiencing stress if asked to teach secondary physics (item 5, Table 6.15). Thus, it seems they felt had no choice except to teach this subject. They were reluctant to teach physics, but were forced to enrol in such courses just for the sake of passing examinations (item 1, Table 6.9). Together their lack of laboratory learning experiences at the university and learning experiences at secondary school (that consisted of rote memorisation), resulted in perceptions of a lack of conceptual understanding of basic physics (items 2, 3 & 5, Table 6.9), meaning this cohort seemed to believe that they were not capable of teaching secondary school physics. Finally, from examination of the findings on participants' about their confidence to teach secondary physics topics and confidence to teach force and motion topics, it seems clear that the third years were less inclined to teach physics than the fourth years as a result of their low scores in the TUG-K and FMCE tests. Hence, it seems that a lack of conceptual understanding, means the third years had low self-efficacy beliefs about their ability to teach secondary school physics. The third years with low level self-efficacy beliefs were more reluctant to teach than the fourth years.

6.4.4 Comparison of Conceptual Understanding with Attitude Toward, and Beliefs About, Physics Teaching

The low actual conceptual understanding of participants as evidenced by their performance on the TUG-K and FMCE tests is consistent with their attitudes toward, and beliefs about, physics teaching either due to their interest or their career interest (Tables 6.13 & 6.15). So, for example, some third years who found physics difficult, might not have the intention to be a physics teacher, and thus believed that physics teaching might not be enjoyable (item 2, Table 6.13). Although most of the third years had the primary science teaching experience, most did not have good secondary physics learning experience or achieve well in the national physics examinations (items 3, 4, 5 & 6, Table 6.13).

Both fourth and third years considered that the physics courses they took at the university did not equip them to teach secondary school physics (item 7, Table 6.13). Although both cohorts overall thought that physics teaching would be difficult, some thought physics teaching would be easy (item 8, Table 6.13). The reasons physics teaching might be easy include; being a physics teacher, enjoying teaching physics, previous secondary physics learning experiences were good, being good at physics in SPM (Malaysian School Certificate), and had having taught science in primary school (items 1, 2, 3, 4 & 6, Table 6.13). However, interestingly some of the fourth years believed physics teaching would be easy because they achieved well in the matriculation/ SPTM (Malaysian Higher School Certificate) and national physics examinations (item 5, Table 6.13). This suggests that at least some of the fourth years had better learning experiences than their third year counterparts. An additional factor here is that some participants from both cohorts believed that a good student could still do well in his/her classes even if their physics teacher exerted little effort (item 9, Table 6.13). However, the fourth years seemed to believe ineffective teaching could be a factor in student under-achievement (item 10, Table 6.13). Finally, experience in using physics apparatus in the laboratory did not appear to influence the participants' attitude toward, and beliefs about, physics teaching for either group (item 11, Table 6.13). Looking at participants' attitude toward, and beliefs about, physics teaching, suggests the third years did not have intentions of becoming physics teachers. In other words, they did not have any great interest in physics teaching as a profession. This conclusion is consistent with their low performance in the TUG-K and FMCE tests about understanding of kinematics graphs and Newton's Laws of motion.

The findings reported in Table 6.15 suggest that the third years chose *teaching* as their career (not physics teaching) but that the fourth years do not necessarily consider teaching as their first choice of career (item 1). However, both cohorts seem to have enrolled in physics courses for more than just meeting the requirements of their degree (item 2). Some in both groups believed that physics teaching in English was not difficult (item 3), but the fourth years appeared to have a more positive attitude towards physics teaching than the third years, despite perceptions of difficulty in English language, and the likelihood of experiencing stress when teaching secondary school physics (items 4 & 5). In addition, participants from both cohorts believe the Ministry of Education and people who knew them were the factors contributing to their career in physics teaching (items 6 & 7). However, some third years wanted to be physics teacher whether or not other people thought they should teach physics (item 8).

Overall the findings here suggest that these participants' attitude toward, and beliefs about, physics teaching were due to career interest as a teacher and not intrinsic interest in physics or physics teaching as a profession. It also seems that weak conceptual understanding exerts considerable influence on participants' beliefs about, and attitude toward, physics teaching.

6.5 SUMMARY

This chapter presented the findings for data collected from written reports of physics learning experiences at secondary school and at university, the TUG-K and FMCE tests, focus group interviews with selected participants, and the BAPT questionnaire – all of which were used to address the first research question. The findings suggest that participants from both cohorts varied in terms of their attitude toward, and beliefs about, physics teaching.

The findings also provide indicators of factors from didaktik analysis assignmnents, microteaching, and practicum that might influence the implementation of secondary physics teaching practice using a didaktik approach. These indicators suggest that factors might be; participants' prior physics learning experiences, their attitude-toward-physics and learning, their physics teaching self-efficacy beliefs, and their conceptual understanding of specific physics content. The following chapter, Chapter 7, presents research findings for research questions two and three, and focuses on identifying the actual beliefs from assignments, microteaching, and practicum that influenced the effectiveness of using didaktik analysis in terms of improving the practice of teaching and learning, and their self-efficacy beliefs through reflection on their microteaching and practicum experiences.

CHAPTER 7

RESEARCH FINDINGS AND DISCUSSION ON DIDAKTIK ANALYSIS AND REFLECTIONS

CHAPTER OVERVIEW

This chapter presents the research findings for research questions 2 and 3, namely:

- What factors from assignments, microteaching, and practicum influence the effectiveness of didaktik analysis in terms of improving the practice of teaching for Malaysian pre-service physics teachers?
- To what extent does didaktik analysis help pre-service physics teachers engage in reflection on teaching and learning? To what extent do pre-service physics teachers undertake reflection onteaching and learning associated with didaktik analysis experience?

The research findings from Chapter 6 suggested that participants' beliefs about, and attitude-toward physics teaching are influenced by their prior physics learning experiences. Overall it seems participants' beliefs, teaching experience and competency, and physics knowledge all combine to form self-efficacy beliefs about physics teaching. In particular, the findings from Chapter 6 point to the influence of participants' physics content knowledge on their physics teaching self-efficacy. Here the researcher explores this in greater detail, seeking to identify *the extent* to which exposure to assignments on didaktik analysis of specific physics content influences participants' teaching practices – as evidenced in their microteaching and during the practicum, and their feelings of self-efficacy. These assignments sought to address issues of content knowledge and applying didaktik analysis to specific physics content.

The chapter is in three sections. Section 7.1 which follows describes the didaktik-based physics teaching methods course which involved group assignments, preparation of lesson plans and a teaching sequence, and microteaching done as part of the course. This is followed by Section 7.2 which presents findings for research questions 2 and 3. The chapter ends with a summary of the findings for the research questions in Section 7.3.

7.1 DESCRIPTION OF THE DIDAKTIK-BASED PHYSICS TEACHING METHODS COURSE

This section presents a description of the didaktik-based physics teaching methods course that was based on group assignments of didaktik analysis, development of individual lesson plans from group assignments, and teaching sequence that occurred in the microteaching.

7.1.1 Group Assignment of Didaktik Analysis

This section describes the group assignment of didaktik analysis done by participants during their coursework. All enrolled participants contributed in developing a component of didaktik analysis relating to a specific physics content area specified by the researcher in advance. Such development involved searching for specific physics content derived from the science education literature and websites, and analysis of Malaysian Form 4 physics textbooks and the Form 4 Physics Curriculum Specifications. Each member of the group took on responsibility for investigating a given component of didaktik analysis, and reporting their findings to the group. Once each group completed compiling and analysing this material, the completed group assignment was subsequently used by each participant to develop an individual lesson plan. Upon completion of their lesson plans, each group of participants was required to hand in an assignment on didaktik analysis to the researcher. However, the submission of lesson plans occurred at a later stage - once a representative of each group completed the teaching practice in the microteaching.

The whole cohort of participants was divided into 29 groups, and each group was required to do an assignment on didaktik analysis during the methods course. Some groups dealt with the same topic 'general learning outcome' (see Table 7.1), as presented in the Revised Form 4 Physics Curriculum Specifications (Kementerian Pendidikan Malaysia, 2004) and physics textbooks. This occurred because there are only 21 general learning outcomes, but there were 29 groups. The assignment task involved investigating the impact of using didaktik analysis in the microteaching. There were four specific Form 4 physics content areas: Force and Motion; Force and Pressure; Heat; and Light. The content area of Force and Motion consists of eight 'general learning outcomes'. Overall, 11 groups of participants were involved in the assignment of the didaktik analysis of Force and Motion; consisting of eight third years, and 36 fourth years.

Table 7.1
General learning outcomes of 'force and motion' from the revised Form 4 physics curriculum specifications

Learning Outcome	Number of Groups	Number of Participants	
		3rd Year	4th Year
Linear motion	2	-	8
The concept of inertia	2	4	4
The concept of linear momentum	1	-	4
The force of gravity*	2	1	7
Work, power, and energy	1	-	4
The force in equilibrium*	1	3	2
The effect of force	1	-	3
The elasticity of materials	1	-	4
Total	11	8	36

* one group contained both third and fourth years

Here the researcher presents the findings for the didaktik analysis of Force and Motion from one group, to show in detail the process of didaktik-based physics teaching that occurred in the methods course – the force in equilibrium (see Table

7.1). The assignment for this group was related to the specific topics evaluated in the TUG-K and FMCE tests (Chapter 6). The group in the study consisted of five female participants: three third years and two fourth years. The other 10 groups did an assignment on didaktik analysis on other general learning outcomes, but discussion of this is not included here.

7.1.2 Individual Lesson Plans

This section describes the individual lesson plans produced from the group assignment on didaktik analysis. After completing group assignments of didaktik analysis and receiving feedback from the researcher (either as an individual or as a group), each participant prepared his or her lesson plan - following the format given during the lecture, and drawing on content from the group assignment of didaktik analysis. Some participants followed the format established by the researcher; others did not. Analysis of lesson plans was based on a framework developed by the researcher (see Figure 2.2, Chapter 2), and this consisted of examination of; content, learning outcomes, pre-requisites, a teaching sequence, teaching aids or media, assessment procedures, follow-up activities, and reflection (ideas and beliefs). Here, again it is important to note that developing a lesson plan itself consists of thinking about planning (the first three components of didaktik analysis), developing and implementing a teaching sequence (see Sections 2.3.3 and 3.3), and *reflections* - *before*, *during* and *after* planning the lesson (Section 4.1.4). The lesson plan was subsequently transformed into a teaching sequence, and implemented as classroom activities in the microteaching by the participants. An example of a daily lesson plan from one participant is shown in Figure 7.1.

Daily Lesson Plan

Date: 28.02.2006 Time: 0810 – 0845 (40 minutes)

Form: 4S1 No. of Students: 35

Learning Area: Force and Motion

Learning Objectives: Analysing forces in equilibrium

a. resolve a force into the effective component forces
b. solve problems involving resolution force

Learning Outcome: At the end of this lesson, students will be able to

a. resolve a force into the effective component forces
b. solve problems involving resolution forces

Teaching Aids: laptop, LCD, manila card, glue tape, worksheet, whiteboard

CCTS : inferring and observing

Moral value : cooperative, dare to try, hard working, confident

Method: cooperative learning, constructivism learning and contextual learning

Learning pre-requisite: students should know what are vectors, forces, resultant, mass, weight, the units of measurements used in each quantity. They should also have a basic understanding of algebra, geometry and trigonometry. Students' alternative conceptions: students have more complicated between resultant force and resolution of force. For example, resolution of force means that a force can be resolved into two components which are perpendicular to each other while the resultant force is two forces which act on an object can be combined into a single force.

Figure 7.1
Example of a daily lesson plan for didaktik teaching assignment

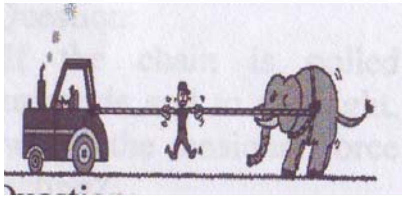
Learning outcomes	Activity	Questions/Discussion/Examples
Induction Set (5 minutes) Recall previous lesson where forces are in equilibrium. Slide 1:  • Look at the slide, what can you notice from there? • What happen to the boy if the force of the car engine is greater than the force from the elephant? • What happen to the boy if the force from the elephant is greater than the force from the car engine? • How can make sure the boy stay in the same position? • List some activities related to this concept in our daily life.	Teacher shows the slide about force in equilibrium. Teacher asks students a few questions based on the situation in the slide. Teacher guides students to relate previous lesson with today's lesson. Teacher encourages students in whatever situations we get along in our daily life must remain equilibrium.	Students observe the slide and answer the question asked by the teacher
Step 1 (10 minutes) Resolve force into component forces Example 1: if the chain is pulled upwards and to the right, where the tensional force acting? 	Teacher shows example that how to resolve a single force into the two component forces. Teacher asks students based on the questions given. Teacher gives explanations to students about the topic of resolution of force to let them know better.	Students observe the slide and answer the questions asked and try to sketch out the tensional force in their notebook. Students follow instruction and calculate the component forces using trigonometry. Expected answer; i. Acting upward and rightward upon the dog ii. $F_{vertical}$ = 38.6 N; $F_{horizontal}$ = 45.9 N

Figure 7.1
Example of a daily lesson plan – *continued*

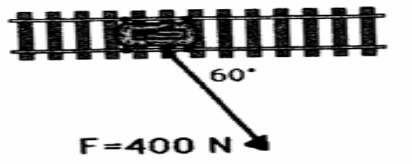
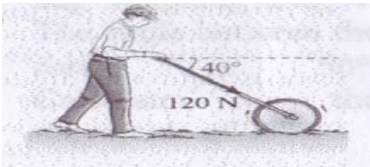
Learning outcomes	Activity	Questions/Discussion/Examples
Example 2: using the picture in Example 1, assume that the chain is exerting a 60 N force upon the dog at an angle 40^{o} above the horizontal. Determine the vertical component of force and the horizontal component of force. Step 2 (5 minutes) Explaining with examples about resolution of force  A 400 N force is exerted at a 60 degree angle to move a railroad car along a railroad track. Determine the magnitudes of the components of force acting upon a railroad car.	Teacher guides the students calculate the component forces using trigonometry Teacher asks questions to guide students to solve the problem.	Students answer the questions asked. Expected answer: $F_{vertical}$ = 346 N $F_{horizontal}$ = 200 N
Step 3 (15 minutes) Assess the lesson concerning resolve forces into two components.  i. The figure shows a groundsman pushing a concrete roller along a field with a force of 120 N. Calculate the horizontal and vertical components of the force. What is the function of each component?	Teacher gives group work to each group and walk around to make sure they do their group work with honestly and cooperation. Teacher and students discuss the answer for the group work together.	Students discuss the answer among their group members. After finish the group work, students stick the answer on the white board. Expected answer: The horizontal component of 91.9 N pushes the roller forward while the vertical component of 77.1 N helps to press the roller onto the ground.

Figure 7.1
Example of a daily lesson plan – ***continued***

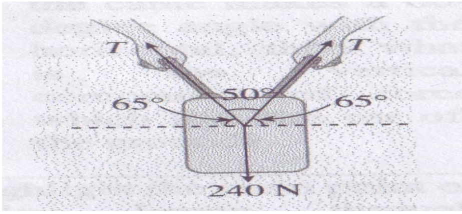
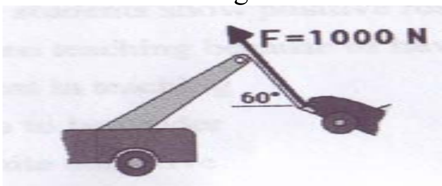
Learning outcomes	Activity	Questions/Discussion/Examples
		
ii. Two friends going on a trip help each other carry a heavy bag as shown in the figure. They each exert a force T to carry the bag weighing 240 N. The angle between the forces is 50 ^{o}. Calculate the magnitude of T.		T = 132.1 N
		
iii. Consider the tow truck as shown. If the tensional force in the cable is 1000 N and if the cable makes a 60 degree angle with the horizontal, then what is the vertical component of force which lifts the car off the ground?		$F_{vertical}$ = 866 N
Conclusion (5 minutes)		
Highlight the main point of today's lesson through questioning.	Teacher gives the homework to students and inform them to hand in tomorrow Teacher concludes the lesson and asks students answer the question orally.	Homework and Reflections:

Figure 7.1
Example of a daily lesson plan - *continued*

7.1.3 Description of Teaching Practice in the Microteaching

During the seven weeks of the physics teaching methods course, the participants were asked to plan and carry out a teaching sequence for three lessons. Participants were then required to practise teaching (peer teaching) based on the lesson plans they developed. They were observed once (one representative of the participant for each group) as part of their university course, and this allowed assessment of how well the written lesson plan was translated into the planned teaching sequence. Analysis of written lesson plans, lesson observations, interview transcripts, written reflections and evaluations all were used to evaluate the impact of employing the didaktik analysis on the participants' beliefs and their actual practicum in the classroom.

As noted above, a representative from each group was required to teach his or her lesson in a microteaching session that lasted about 10 to 15 minutes. The researcher observed the participants, and they were video-recorded in each session. Observation recording followed a sheet prepared in advance. Here, the researcher sought to see how effective the teaching sequence was, and how well the written lesson plans were translated into teaching during microteaching. The design of the teaching sequence in the lesson plans also was coded to identify the relevant components used to address research questions two and three. The researcher examined and interpreted information from an assignment for this lesson plan, read the notes taken during observations of microteaching, and analysed responses from interviews. Individual interviews were conducted with participants, and these involved discourse about their lesson plans, and aimed to see whether or not participants understood the didaktik analysis of specific content area, and what was considered salient in their teaching practice. The usual evaluation of the physics teaching methods course also was used to complement data derived from assignments of didaktik analysis and lesson plans. Section 7.2 now presents the findings for research questions two and three, which form the basis of this chapter.

7.2 PRESENTATION OF FINDINGS FOR RESEARCH QUESTIONS 2 AND 3

Research question two concerned identifying the *actual* beliefs and experiences of participants from didaktik analysis assignments that influenced their teaching practice in the microteaching, and during the teaching practicum. The researcher examined the participants' group assignments for the specific content areas from the Form 4 secondary physics: conceptual analysis of content; analysis of textbook; and analysis of literature on students' alternative conceptions. The researcher then analysed the participants' written reports about what they perceived to the successful, unsuccessful, or problematic components of didaktik analysis – that is things that might impact upon their beliefs about teaching practice during the microteaching. The findings from the written reports were cross-checked with participants' views on the group assignment and methods course through interviews (in the middle of the semester) with 10 participants after the microteaching was completed. Again, these views about the group assignments and the methods course from interviews were cross-checked through selected participants' evaluations of the entire physics teaching methods course (at the end of the semester), and one question in the final examination (see Figure 7.2). Some questions from the interviews were also addressed in 'written reflections' and individual interviews during the practicum.

An analysis of the individual lesson plans based on an assignment of didaktik analysis was used to evaluate the impact of implementing didaktik analysis-based teaching practice in the microteaching. The lesson plan was cross-checked with the focus group interview held after the microteaching, and the observations of microteaching with one representative of the group. The following section explores this for one group; the example used here is the group assignment on 'the force in equilibrium', that formed part of the didaktik analysis.

7.2.1 Research Findings from the Group Assignment on Didaktik Analysis

This section presents findings for didaktik analysis of Force and Motion from one group of participants for the learning outcome, 'the force in equilibrium'. The group participants consisted of three third years and two fourth years; all five of whom were females. The participants started their assignment on didaktik analysis of 'the force in equilibrium' by stating the objectives of the Malaysian physics curriculum. The following are findings developed from an examination of their conceptual analysis of 'the force in equilibrium', in which they conducted an analysis of the physics textbook for the 'force in equilibrium' concept, and then analysis of literature on students' alternative conceptions of 'the force in equilibrium'

Conceptual analysis of 'the force in equilibrium'. In their analysis, the group commented that "although Form 4 Physics Curriculum Specifications mentioned Newton's third law, there is nowhere in the present textbook where this Newtonian concept is related to 'the force in equilibrium'". The group participants noted that the curriculum specifications ask physics teachers "to relate the 'force in equilibrium' concept to daily life", and the group listed the terms (necessary for understanding 'the force in equilibrium') [together with their explanations of 'the force in equilibrium'] as being: "Equilibrium, resultant force, force, interact, action-reaction, resolution of force, acceleration, friction, normal force, exert, velocity, mass, pushing, and acting".

Analysis of textbook for 'the force in equilibrium'. The group observed that the physics textbooks were based on curriculum specifications set by the Curriculum Development Centre of the Malaysian Ministry of Education. However, the group felt that there was insufficient material in the present textbook, arguing that instruction based on the textbook content alone would result in school students having difficulty understanding 'the force in equilibrium' concept. The topic 'force in equilibrium' in the textbook analysed by the group consisted of four pages with statements of; "'learning outcomes', activity, explanations of force as a vector quantity, and problem solving".

The group also compared the material from the school textbook with other 'established' physics textbooks, and reported the Form 4 Physics textbook as being "less attractive and boring", with "less examples to explain the concepts, and laws and principles as it may result in students' difficulties to understand the concepts of force and motion". The group provided an example for this topic as found in the textbook as consisting of: "one photograph, a few diagrams or figures which are not clear to represent the principle of force in equilibrium", and noted that "Newton's third law is not mentioned as it is related [Newton's third law] to equilibrium", and that there were "few examples on explanation of the resolution of forces". As a result of this, the group felt "teachers [would] have to search for more information or initiate their own activities as a preparation for their classroom teaching". In summary, the group suggested that the content of 'the force in equilibrium' should be presented in a more interesting way, should have more colourful pictures, and provide more questions and suggestions for student activities.

Examination of research on students' alternative conceptions for 'the force in equilibrium'. This component of didaktik analysis involved the group examining research findings about students' alternative conceptions for 'the force in equilibrium' from websites and science education journals. Their search for research about students' alternative conceptions from the literature on students' alternative conceptions for 'the force equilibrium' resulted in the material presented in Table 7.2. The group also listed some characteristics of the resultant and resolution forces with regard to 'the force in equilibrium' and this is shown in Table 7.3.

Table 7.2
Participants' analysis of related literature on students' alternative conceptions about 'the force in equilibrium'

Newtonian	Students' alternative conceptions for "the force in equilibrium"
Newton's third law is concerned with forces and considers how a force is produced	Forces as being things in themselves, as events, and as properties of objects
Whenever two objects interact, the object exerted force on one object equal in size and opposite in direction to the force exerted on the other object	Forces are thought of as a dominance principles Forces are thought of involving living things, but not on inanimate and inert objects
A force is an interaction between objects, never occurs single but always in pairs as a result of the action between two objects that: - are arbitrary assigned the names action and reaction; - are of the same type (normal-normal, tension-tension, friction-friction etc); - have the same magnitude (why? because!); - act on different objects (object pairs); - act in opposite directions (obvious, hopefully), and - may have different effects (since acceleration is inversely proportional to mass)	Forces are thought of as innate or a acquired property which is linked with the pre-Galilean notion of impetus which implies that forces are not seen as arising from an interaction between objects Forces concepts are understood as context dependent, for example Newton's third law which involves velocity, mass, pushing, and acceleration Newton's third law is thought hold in a static situation, but not in a dynamic situation (in cases of acceleration and uniform velocity)
A simple rule for identifying action and reaction forces. Which is action: Object A exerts a force on Object B, reaction: Object B exerts a force on Object A	Newton's third law popular with the phrase: to every action, there is an equal and opposite reaction. Action and reaction are opposite forces, acts on different objects, but understood as 'action' is a 'cause' and 'reaction' is a 'response'.
Newton's third law states that a body will remain at rest or move with constant velocity when a net force of zero acts on it. When the net force is zero, the force are said to be balanced or in equilibrium; and when a body is in equilibrium, the resultant force on it is zero.	The concept of force introduced at the very beginning of teaching as a measure of the strength of interaction The terms everyday views and scientific views.

Table 7.3
Participants' analysis of related literature on resultant and resolution forces for 'the force in equilibrium'

Characteristics of	
Resultant force	Resolution force
Two forces which act on an object can be combined into a single force called the resultant force	A force can be resolved into components which are perpendicular to each other
When an object is in equilibrium, the resultant of the horizontal components of the forces acting on it is zero	The resolution of vectors into two components is the inverse of finding the resultant of the two vectors, and
If several forces are applied to an object and the object remains stationary or If the object continues to move with uniform velocity, the forces are said to be in equilibrium	The principle of the resolution of vectors is very important in solving problems which involve several forces which act in different directions
The resultant of the vertical component is also zero, and the resultant or net force acting on a body experiencing a number of forces acting simultaneously is given by the vector sum of all the individual forces acting	
Forces in equilibrium add to produce a resultant of zero. If several forces, not in equilibrium, act on a body, the force which is required to produce equilibrium is called the equilibrant	

The data for the group assignment of 'the force in equilibrium' presented above was from one group. These findings from the examination of the didaktik analysis assignments, were cross-checked with participants' written reports (reflections) to see what participants perceived to be the successful, unsuccessful, or problematic components of their didaktik analysis experiences (which were conceptual analysis of content, analysis of textbook, and analysis of literature on students' alternative conceptions). The following analysis presents the findings for participants' experiences on didaktik analysis assignments – things that might influence their beliefs about teaching practice in the microteaching.

Group Assignment of Didaktik Analysis Experiences. The protocol used in the written reports about the assignment of didaktik analysis experiences is presented in Table 7.4.

Table 7.4
Written reports used to identify the actual beliefs and experiences about group assignment of didaktik analysis

i.	Think back to your group assignment, generally which components of didaktik analysis were successful and which were unsuccessful? Was the explanation of didaktik analysis clear? Were the resources accessible?
ii.	Think back to your experience on assignment before, during and after, the conceptual analysis of physics content. Did the conceptual analysis of physics content help to improve your teaching practice? What difficulties did you encounter?
iii.	Did analysis of textbook presentations help to improve your physics content?
iv.	Did identifying and addressing students' alternative conceptions help improve your teaching practice? What constraints did you encounter in gathering research findings of students' alternative conceptions?
v.	What experiences based on didaktik analysis would you want to add?

Fifty nine out of 105 participants provided written reports at the end of the semester: Some 47 participants commented on what they saw as the successful and unsuccessful components of didaktik analysis in their assignments; 40 participants commented on how clear the explanation of didaktik analysis was, with 31 and 9 participants respectively saying the explanations were clear and not clear. Likewise, 40 participants commented on the accessibility of the resources, with 22 and 18 participants respectively saying the resources were accessible and inaccessible. Some 40 participants thought that conceptual analysis of physics content would help them improve teaching practice. Only one was unsure as to whether or not conceptual analysis would improve his teaching practice because he felt preferred teaching methods are based on what individuals find convenient (based on experienced with his or her teachers' teaching). A further 33 participants commented on the Form Four physics textbook, with 25 of them noting that the analysis helped to improve their understanding of physics content, and 30 participants commented on the importance of identifying and addressing students' alternative conceptions. In response to question (v), 44 out of 59 participants reflected specifically on the assignment of didaktik analysis in their physics teaching methods course – some findings related to research question two, others to research question three are shown in Table 7.9. Some findings from Table 7.4 related to research question three, and are presented in Section 7.2.4. A summary of findings from written reports about didaktik analysis assignment for questions 1 to 4 is shown in Table 7.5.

Table 7.5
A summary of beliefs and experiences from group assignment of didaktik analysis

	N=59
Comments related to components of didaktik analysis	47
Clarity of didaktik analysis	40
Accessibility of information for a given specific physics content	40
Conceptual analysis of content	40
Difficulty to obtain information on conceptual analysis of specific content	28
Analysis of textbook presentation	33
Difficulty to obtain information on analysis of textbook presentation	1
Gathering research findings of students' alternative conceptions	30
Difficulty to gather information on research findings of students' alternative conceptions	14
Difficulty to differentiate everyday language and physics langauge	3

Comments related to components of didaktik analysis: The content analysis in participants' written reports pointed to two components of didaktik analysis perceived to be *useful*: conceptual analysis of physics content, and analysis of the textbook. The value of conceptual analysis of physics content was thought to be that "we have to write all about conceptions that relate to a given specific physics content" (R4, 4th, F), which "gives the opportunity for the teacher to study in detail the related Form 4 physics content" (R31, 4th, M). The latter resulted in participants finding about the conceptions of specific physics content in detail, but they disliked them: "This methods course was quite helpful but it takes time to analyse specific physics content" (R31, 4th, M).

Participants felt that they benefited from looking for content in different textbooks which provided "a lot of resources" (R44), which was useful in terms of helping "identify the strengths and weaknesses of textbooks", and being able to choose a good textbook meant "physics teachers should use other physics textbooks such as GCSE [General Cambridge Senior Education] " (R31, 4th, M). The strengths of the "good textbooks" included that they "contain the illustrations that can be taken from Form 4 physics textbook and the practical book" (R33, 4th, F), and weaknesses include that they were "brief, did not contain many activities or problem-solving examples", and a general lack of material prescribed in the curriculum: "lack of explanation in curriculum specifications and the language used in explanation is quite poor" (R14).

On the other hand, two components of didaktik analysis perceived to be *difficult*, were analysis of textbooks which were deemed by some as "confusing" (R53), and gathering research findings about students' alternative conceptions "because it was hard to find students' alternative conceptions" (R11). The former was probably associated with difficulty in understanding what was required in the analysis of a textbook, whereas the latter may be as a result of having difficulty in understanding the term 'alternative conceptions'. Other problems in the assignment of didaktik analysis were difficulty in distinguishing "everyday language and scientific language" (R27), and "identifying the difference between everyday knowledge and scientific knowledge" (R29). Difficulties not specific to components of didaktik analysis, were that "this course was quite difficult because

I did not understand what the lecture was about" (R5), and that "there were not enough resources" (R13) for the specific physics content.

Clarity of didaktik analysis: The content analysis about the presentation of clear explanations point to a positive experience for this aspect of the didaktik analysis assignment. These participants commented that they gained physics knowledge for certain topics "after this didaktik analysis assignment, I gained physics knowledge on certain topics" (R2), meaning they found the topics not as hard as they imagined "the assignment was not really hard" (R4) because the lecturer "showed many ways to be a good teacher" (R35). They also noted that "if more references were given, then the explanation[s] will be more clear" (R18). If the explanation was deemed clear, then participants said this meant they were "able to know the difference of the textbook and reference books [as a result of conceptual analysis]" (R23), especially "for the part of 'definitions' " (R28), with the exception that "some terms used were too difficult to understand" (R30). They felt they learned more about students' alternative conceptions "I have learned more about students' alternative conceptions" (R9), and the conceptual analysis of physics content meant they "could improve conceptual analysis of physics content" (R43), which in turn meant they were able "to develop good lesson plans and engage in good teaching practice" (R43). They also learned to write and understand Form 4 physics and also improved in their English: "I have learned to write and understand about Form 4 physics and also English language" (R45). Although 31 participants noted that they understood the assignment of didaktik analysis, some of their comments suggested otherwise especially in the "questioning and explaining techniques" (R2).

Nine participants indicated they did not get a clear explanation of didaktik analysis from the researcher saying they did not know what the course was all about and thus became confused, meaning it was hard to do the assignment: "Too hard to understand, I did not know what was the course all about [and] became more confused" (R8). Some commented that they understood "only certain components" (R1), but in fact appeared to understand the assignment. Some noted they did come to understand "scientific terms, nature of science, everyday language and scientific language, and everyday knowledge" (R27) including "the components of 'definitions' " (i.e., terms used in didaktik analysis) (R28) as a result of the didaktik analysis assignment.

The accessibility of the resources: The content analysis of participant's written reports suggested participants felt they found "the resources from journals and websites accessible" (R45), but this "depends on the physics content" (R37). Interestingly, resources deemed accessible were for "preparing the lesson plan and teaching" (R22). Although some participants said the resources were accessible, they had difficulty in gathering information on specific students' alternative conceptions: "It is hard to find the journals that related to students' alternative conceptions" (R30). Other inaccessible resources mentioned were "especially textbooks and journals" (R1), and "electronic journals" (R2). Some of these resources were accessible generally, but it was "hard to find journals about force and motion" (R29), that is, specific physics content.

Conceptual Analysis of Form Four Physics Content: The content analysis from 10 participants' comments, revealed five factors about how the conceptual analysis of Form 4 physics might improve teaching practice, by the enrichment of the existing physics curriculum "making a comparison between Malaysian physics curriculum and international physics curricula [which] is linked with enrichment or improvement of the existing Form Four physics curriculum" (R1). This it was felt, would result in "better understanding about physics content and clarifying some misconceptions held by pre-service teachers" (R27), and make the "teaching and learning process more organised" (R7, 4^{th} F). This would involve using a variety of teaching methods and "many strategies and information [that were] learned from this assignment" (R43), which might mean participants would increase in confidence to teach as a result of "mastering physics content" and becoming "more confident in teaching" (R14).

Some 28 out of 40 participants experienced difficulties with the conceptual analysis of specific physics content including finding "resources inaccessible" (R1), these resources being things such as "electronics journals, journals, reference books not according to specific physics content" being "very hard to access in the University's library" (R2), as well as "few journals related to the topic" (R13). Such problems resulted in a "lack of knowledge on this topic" (R4), together with English language barrier since some felt that they "cannot speak

English very well" (R29), meaning they were "sometimes confused about how to explain" (R6), and to "apply physics content in plain English" (R12). Overall then it was felt participants "needed more resources in order to understand physics concepts" (R11) together with cooperation amongst group members and advice on "how to get group members to cooperate" (R40), otherwise "it was impossible to do analysis on all about specific physics content, if cooperation between participants was required" (R58). Participants felt they needed to know how to transform specific physics content into different teaching sequences, for example, "how to conduct activities or experiments, and to make students understand physics" (R37), and "how to find activities which are more fun and involve all students" (R39). Fear of not being able to cover the syllabus as the result of other contents surfaced along with a perceived "need to follow the sequence of physics teaching from the curriculum specifications", meaning that "if some other content were added which thought to be very important, then we will be facing problem in completing the syllabus" (R42). However, gathering information on alternative conceptions meant they needed to know "how to find misconceptions in physics content" (R40), and as a result of the conceptual analysis some came to believe that "some concepts are very difficult to understand" (R30).

Analysis of Form Four Physics Textbook: Some 11 out of 33 participants commented on why analysis of Form Four physics might improve their physics content knowledge.

The data analysis about this didaktik analysis component suggests that it would improve participants' physics content knowledge in terms of providing deeper study of specific physics content as a result of comparing material from a variety of textbooks or journals: "I needed to study deeper of physics contents [so] I can compare the variety sources content of physics" (R1), because "the textbook is the main method of teaching in the classroom" (R6), and that it serves as "a reference for the basic physics" (R24).

On the other hand, eight participants thought analysis of the Form 4 textbook would not improve their physics content knowledge, suggesting that some did not understand or were confused about how this component of didaktik analysis could help their teaching. These participants felt that the Form 4 physics textbook did not explain in the content enough detail: "It is not enough to depend only on the textbook, but also to refer to other sources such as reference books, articles and websites" (R3), and that the "textbook does not explain in detail about the content" (R11), noting that "some content may not be updated" (R12), meaning that it "cannot fulfil the needs of the students"(R16).

The Importance of Identifying and Addressing Students' Alternative Conceptions: Some 17 participants noted that analysis of literature on students' alternative conceptions helped them to improve teaching practice because a lesson developed in advance could take into account students' alternative conceptions: "I can design a lesson [to] avoid misconceptions of students" (R1). Information on students' alternative conceptions also was felt could provide guidance for the teachers in planning a teaching sequence which might "guide the skills or activity to be carried out during the teaching and learning process" (R6). Hence, this component of didaktik analysis might help teacher correct alternative conceptions held by students and help them in teaching practice: "It can correct the wrong concepts held by the students and [the] students remember their alternative conceptions and they do not repeat them" (R7, 4^{th} F). This it was thought, might be useful because "it helps to differentiate between scientists' conceptions and students' alternative conceptions" (R13).

Some 14 of 30 participants experienced difficulties gathering research findings on students' alternative conceptions. Perhaps these difficulties related to such negative experiences as: Seven participants described their struggles with searching for "resources, especially electronics journals, journals, and reference books" (R1). Four participants said resources they found were not related to the specific physics content they needed: "The information from the journals is not according to the assigned specific physics content" (R4), or that it was not suitable for the secondary school level: "There is not much research findings about students' alternative conceptions in secondary school level" (R33). Another four participants were confused about how to deal with students' alternative conceptions: "[It] is hard for me to understand the way students think and try to explain to them by the physicist point of view" (R9).

The findings from the written reports were cross-checked with participants' views on the group assignment and methods course through interviews (in the middle of the semester) with 10 participants after microteaching was completed, and are presented next. The following interview findings include data from a group who dealt with 'the force in equilibrium', and additional groups whose assignments were on the 'reflection of light' and 'refraction of light (to ensure data from these additional groups did not influence the former). Again this presentation considers how the actual beliefs and experiences of didaktik analysis influenced their teaching practice in the microteaching.

The Influence of Didaktik Analysis on Microteaching: After the microteaching, focus group or individual interviews were conducted with 10 participants concerning their assignments of didaktik analysis and the methods course. The questions in the interview protocol generally related to participants' views on the methods course, and specifically their views on the assignment of didaktik analysis and its influence on their physics teaching. Participants' responses to their interviews about the assignments on 'the force in equilibrium', 'reflection of light' and 'refraction of light' associated with the physics teaching methods course and didaktik analysis, also are analysed and presented next.

Table 7.6
Interview protocol about didaktik analysis experiences

i. What is your view on the assignments of didaktik analysis and their influence in your physics teaching? helpful _1_ 2_ 3_ 4_ 5_ not helpful
ii. Did the assignment of didaktik analysis have any influence in your physics teaching? What are the influences?
iii. What is your view on the physics teaching methods course? helpful _1_ 2_ 3_ 4_ 5_ not helpful
iv. What have you learned from the physics teaching methods course that will be significant to your teaching practice? Are those items mentioned what you expected to learn?

Interviews after the microteaching were conducted with 10 participants. Of these one third year said she was not sure, or was uncertain, as to whether or not the assignment of didaktik analysis was helpful in the microteaching. The remainder considered that the didaktik analysis assignment was useful (question i, Table 7.6). The participants' agreement seemed to be associated with positive learning experiences in the physics teaching methods course, meaning they subsequently felt more confident about their teaching physics during their upcoming school placement: "That is why didaktik analysis is very good and very useful for us [the] an assignment of didaktik analysis makes me more confident to teach physics and ready to go for teaching practice" (Diana, 3^{rd}, F). This positive learning experience also seemed to influence participants' attitude-toward physics teaching: "The introduction of didaktik analysis has attracted my interest more in physics teaching" (Camela, 3^{rd}, F).

One third year reported that he found the methods course not helpful, and three were not sure or uncertain as to whether or not the physics teaching methods course was helpful in the microteaching. The remainder believed the methods course was useful (question iii, Table 7.6). The participants valued the physics teaching methods course because they thought physics itself is a difficult subject: "This course is very useful because physics was hard [and] as a teacher before I [had] never taught physics: (Camela, 3^{rd}, F). The participants also found the course useful because it introduced them to a variety of teaching methods, and guided them as to how to develop lesson plans: "In terms of teaching methods and the strategies of writing the lesson plans" (Geetha, 3^{rd}, F). In addition, it assisted in learning physics concepts and "provides the concepts and teaching practice in the microteaching" (Farah, 3^{rd}, F).

Several themes emerged from the interviews about the assignment on didaktik analysis (question ii, Table 7.6). First, participants noted specifically that didaktik analysis helped identify potential alternative conceptions: "the assignment of didaktik analysis at least helped us to identify students' alternative conceptions in specific physics areas. This subsequently helps students in their physics learning" (Helen, 3^{rd}, F). This was seen as a way of gathering students' alternative conceptions on specific content area, which helped participants to understand difficulties encountered by physics students during learning: "I was able to learn how to gather students' alternative conceptions on specific content area [and] it helped me to understand difficulties encountered by physics students" (John, 3rd, M). As a consequence, teachers might see how this "can be applied in our daily physics teaching" (Kathy, 3rd, F).

The importance of identifying alternative conceptions was, not only a help when teaching secondary students, but also alerted the participants to the prospect of their own alternative conceptions: "This is the first time I learned the components of didaktik analysis [and] preparing didaktik analysis is useful [because] I think this is the starting point in teaching methods that alternative conceptions can be found not only for secondary students but also among pre-service physics teachers" (Bertha, 3rd). This part of didaktik analyses then enabled them – by analyses of specific physics content particularly in the websites presentations – to understand the content themselves. As in the websites there were "many examples given" (Alice, 4th, F) that were related to specific physics topics. Solutions and problem-solving exercises, and good explanations for the topics also were provided: "I think explanations given in the websites are quite useful compared with the textbooks, for example, the concepts of force in terms of its explanation and solutions on problem-solving. I was confused about resultant force before, but after studying from the websites then I understand the concepts of force" (Esther, 4th, F).

The reason this was deemed helpful was that it then meant these participants felt more confident: "As we have already gathered students' alternative conceptions for the assignment on didaktik analyses, we have become more confident to teach secondary school physics" (Farah, 3rd, F). Didaktik analysis thus seemed to help improve participants' physics content knowledge, helped them think about the views of students, and as a consequence helped participants develop a more positive attitude-toward-physics and teaching when preparing both lessons and teaching aids, and conducting the microteaching. Subsequently they considered these things would help during the practicum. As a result of microteaching and practicum, being a good physics teacher would make teaching physics more interesting:

> After you taught me about didaktik analysis, it helped me [know] what I should prepared for not only deals with content knowledge but also [to] think the views of students. [Now] I think microteaching is an important aspect to build the confidence. After a few months attended this course [means] at least I have the confidence to teach physics during school placement. I will practice myself what I have learned during my school placement. I hope after completing my teaching practice [that] being a physics teacher will be more interesting (Bertha, 3rd, F).

Several themes emerged from the interviews on aspects learned and expectations hoped to gain, from the physics teaching methods course (question iv, Table 7.6). The participants considered that it was essential to have physics content knowledge when preparing a daily lesson plan: "After I went through the course and did the assignment, I realised the importance of physics content knowledge in didaktik analysis in preparing a daily lesson plan" (Diana, 3rd, F). This made developing a daily lesson plan more interesting, as teaching might become more active: "I found that developed a daily lesson plan was interesting [and] previously, I thought it was just for teaching but I found the lesson become more active" (Camela, 3rd, F). This occurred despite initially confronting this task producing some personal tension: "Preparing lesson plans created quite a bit of tension before I started in the microteaching" (Esther, 4th, F), and the fact that the microteaching of colleagues looked like their teaching was sometimes boring: "As students in microteaching are our colleagues, some got the feeling that their activity was so boring" (Bertha, 3rd, F). Finally, the participants felt that microteaching might help to rectify teaching weaknesses: "Now I realised that teaching practice in the microteaching helped me to correct any weaknesses" (Esther, 4th, F).

The initial expectation was that the participants from this course hoped "to learn physics concepts [and] I just wanted to learn the physics concepts " (Farah, 3rd, F), as well as "to learn more about teaching approaches" (Camela, 3rd, F), and how to develop lesson plans, techniques of asking questions, and how to be a good physics teacher so they were "able to write a daily lesson plan" and develop "technique of asking questions in order to get good response from the students in the classroom and I really would like to become a good physics teacher" (Helen, 3rd, F).

After the methods course, participants changed such views and their attitude-toward-physics and teaching: "Prior to this course, I did not like physics. [But] after this course I would have more confidence to teach physics "(Camela, 3rd, F), because " I thought initially content in curriculum specifications is enough, but not so after doing an assignment of didaktik analysis" (Diana, 3rd, F). As well as seeing how they might improve practice in terms of preparing for a lesson, some felt they learned about teaching aids and approaches: "I know [that] preparing for teaching aids [means] a lot of approaches need to be applied in teaching the content of physics" (Alice, 4th, F), and some found out more about research on teaching: "I would really like if the course focused research more on how to teach physics in the classroom effectively" (John, 3rd, M).

These views on group assignment and methods course from the interviews were cross-checked through participants' evaluations of the teaching methods course (Table 7.7). Ninety five out of 105 participants who attended the last lecture completed the evaluations of the physics teaching methods course. It was found that all items scored more than 60%, with the exception of item (i). This evaluation indicates that some participants may have experienced difficulties in their assignment in terms of limited course references in the library, as well as understanding some of the content of the methods course. These difficulties may be linked to the substantial challenges associated with combining physics content knowledge with the methods course content. Some of these items from the evaluations also point to a number of more practical applications of assignment of didaktik analysis associated with physics teaching methods course. Participants apparently see the researcher as providing useful feedback on the assignment, monitoring their understanding, and they valued his expertise in didaktik analysis.

In addition, these participants' responses about the influences of the assignment of didaktik analysis on their physics teaching were cross-checked with a question from the final examination (see Figure 7.2). This suggested that conceptual analysis of curriculum specifications (4%) was considered the most difficult component of didaktik analysis, whereas lesson plans and teaching sequence in the microteaching (64%) were the most successful aspect of the assignment for the participants. In other words, analysis of the reflective questions on didaktik analysis of specific physics content, suggests the lesson plans and teaching sequence in microteaching were the preferred experiences, whereas conceptual analysis of curriculum specifications, was the least preferred.

Table 7.7
Part of the 25 items on course evaluation of the physics teaching methods course (TT4133) relating to assignment of didaktik analysis

Items	1	2	3	4
i. Course references in the library	13* (13.7)	42 (44.2)	30 (31.6)	10 (10.5)
ii. Course content fidelity to syllabus and course objectives	3 (3.2)	7 (7.4)	65 (68.4)	20 (21.0)
iii. The lecturer monitored students' understanding	5 (5.3)	14 (14.7)	59 (62.1)	17 (17.9)
iv. Intellectual challenge in assignments		5 (5.3)	52 (54.7)	38 (40.0)
v. Students' understanding in instruction	7 (7.4)	30 (31.6)	50 (52.6)	8 (8.4)
vi. Lecturer's feedback on assignments		8 (8.4)	48 (50.5)	39 (41.1)
vii. Course objectives achieved		11 (11.6)	62 (65.3)	22 (23.1)
viii. Lecturer's expertise appropriate with the course	2 (2.1)	3 (3.2)	58 (61.0)	32 (33.7)
x. Fieldwork suitable for the course objectives	4 (4.2)	11 (11.6)	61 (64.2)	19 (20.0)

1 – not satisfactorily 2 – less satisfactorily 3 – satisfactorily 4 – very satisfactorily

* – number of participants ( ) - percentages

i. Which of the following experience is the most preferred?

A Conceptual analysis of curriculum specification – 5 (4 %)

B Analysis of Form 4 physics textbook presentations – 7 (6 %)

C Studies of students' alternative conceptions – 29 (26 %)

D Devising lesson plans and staging teaching sequences in microteaching – 72 (64 %)

Figure 7.2
One of the 60 questions in the final examinations of the physics teaching methods course relating the experience of components didaktik analysis assignment

Question (ii) in Table 7.6 was asked again to the participants during the first half of school placement, but this time through 'written reflections': *Did the assignment of didaktik analysis have any influence in your physics teaching? What are the influences?*

Of the 61 participants, 46 responded to this question, with 40 agreeing that didaktik analysis influenced their teaching practice in the classroom, and the remaining six being "unsure", providing "no comment", or saying "not really" or "no". Some 40 out of 61 participants noted that didaktik analysis assignment has resulted in positive comments: "In deep understanding of specific physics content knowledge" (R2, 4^{th}) and that it was helpful in identifying students' alternative conceptions of specific physics content as meaning "I was able to detect students' alternative conceptions" (R46, 4^{th}), making it easier to write "a lot yearly and daily lesson plans" (R6, 4^{th}). These influences meant the students might then understand physics concepts better, as "[Now] I know what is to be in the lesson to success in the teaching" (R11, 3^{rd}). They also resulted in an increased science vocabulary among the participants "it helped me to know science vocabulary" (R17, 3^{rd}), which in turn resulted in increased confidence to teach physics as "I did a lot of reading and preparation before teaching the lesson" (R23, 4^{th}). Some noted that they now "understood more of the syllabus" (R27, 4^{th}), but were unable "to practise due to time constraints" (R31, 3^{rd}). However, it was easier "to teach physics" (R43, 4^{th}) and the experiences resulted in "improved teaching practice" (R44, 4^{th}), because it enabled them "to compare the contents from reference books, syllabus and textbook" (R47, 3rd). It was also noted that more effort was needed "to master all concepts in physics and mathematics" (R53, 4th) because the "physics text book is not good and enough resources for students" (R60, 4th). Lastly, the participants commented that the "conceptual analysis of physics content and students' alternative conceptions are essential and they seemed to correct the content of physics textbook" (R61, 4th).

Finally, the second question in Table 7.6 was again asked during individual interviews with seven participants after classroom observations at secondary school during their school placement: *Did the assignment of didaktik analysis have any influence in your physics teaching? What are the influences?*

Six participants said the influence of didaktik analysis - particularly that from the textbook analysis – was that it did not provide enough examples or explanations: "A textbook does not provide enough examples, the explanation is not clear, and sometimes students did not understand what is in the textbook" (Diana, 3rd, F). As a result of this, further conceptual analysis from both the curriculum specifications and textbook by the participant pointed to a big gap: "I did the conceptual analysis from the curriculum specifications and textbook because I found in the curriculum specifications, they have a big a gap" (Bertha, 3rd, F).

A perceived benefit of didaktik analysis from the methods course was that it provided them with the opportunity to learn more science content: "I think assignment of didaktik analysis gives me the opportunity to learn more science content" (Helen, 3rd, F). One participant, although saying that didaktik analysis helped, in practice actually developed a lesson plan that was not based on didaktik analysis, but derived from the textbook and curriculum specifications: "I did not develop lesson plan based on didaktik analysis, but according to what is in the textbook and curriculum specification [meaning] I took some information from the assignment if the content area was coincided with the lesson [and] I think students did not understand [because] I only imparted basic physics to them" (Camela, 3rd, F). The other participant thought didaktik analysis was related to physics only: "[Because] it is only related to physics, but not in mathematics [I] taught this subject during my school placement" (Issac, 3rd, M).

7.2.2 Examination of Individual Lesson Plans

This section presents the examination of the individual lesson plan from a member of one group (Alice's lesson plan, see Figure 7.1) who dealt with the learning outcome, 'the force in equilibrium'. Alice's lesson plan, consisted of; a general section, teaching sequence, and reflection. Her general section included information about the students, form level (years of schooling), the amount of time allocated in the time table, and the date. Her teaching sequence as part of the teaching process included an *opening section*, a *development section*, and *closure*.

The opening section in the lesson plan (see Figure 7.1) consisted of: induction, introduction, and learning objectives and learning outcomes - in this case, 'the force in equilibrium' which demonstrates students' knowledge (cognitive) and their ability (psychomotor) after being taught, as well as values (affective). These seemed similar to her learning area – force and motion from the curriculum specifications, which showed the depth and width of knowledge and skills to be acquired during the period of learning.

The development and closure sections contained the teaching sequence which describes: what is to be done in teaching the lesson or learning activities - how the lesson is to be introduced, what actual teaching methods are to used to promote maximum student participation in the learning process, how to bring about closure of the lesson, what specific learning activities students will do during the lesson, and a summary for the students; pre-requisites (knowing about students' characteristics, students' alternative conceptions, what they already know or able to do in order to success in the lesson, and what kind of learners they are); assessment; and follow-up activities. Ways of achieving the learning outcomes are presented through her stated methods and teaching aids.

Reflections serve to record post-lesson observations, such as problems or difficulties experienced, and suggestions for improvement in teaching practice or resource management. Alice's reflection on her lesson plan is presented in Section 7.2.4.

The following are findings based on examination of the individual lesson plan and how it was influenced by the assignment on didaktik analysis. The analysis of the lesson plan was cross-checked with the ‘written reflections in the lesson plan’ at the end of individual microteaching, and data from the focus group interview after the microteaching, and the observations of microteaching. This was done through investigation of the influence that development of individual lesson plans have on participants’ beliefs concerning their lesson plans and experiences about teaching practice in the microteaching.

‘Written reflections in the lesson plan’: Examination of ‘written reflections in the lesson plan’ (see Section 7.2.4) indicates that Alice’s and her group’s reflections in the microteaching were more to do with teaching practice than on their assignment on didaktik analysis.

Observations of microteaching. Through written observations of teaching practice made in the microteaching, it seems that the Alice’s group who worked on ‘the force in equilibrium’ concept developed sound content knowledge about this topic. She herself seemed confident when she used a PowerPoint presentation, but needed to interact more with the students (i.e., her peers) particularly when asked questions “What happen to the boy if the force of the car engine is greater than the force from an elephant?, What happen to the boy if the force from the elephant is greater than the force from the car engine? (see Figure 7.1).

The influence of group assignment on individual lesson plan. Interviews held after the microteaching, were conducted with 10 participants and these interviews focussed on their lesson plan, and subsequent teaching sequence. Four participants said they were not sure or uncertain as to whether or not the teaching practice was difficult, another four believed that it was difficult, and the remaining two believed it was easy (question i, Table 7.8). The remaining five participants noted that they were not sure or uncertain as to whether or not they were confident, three were confident, and two were not confident to teach physics. The interviews helped to reveal participants’ views of their own teaching experiences, and to relate these views to their prior assignments on didaktik analysis experiences.

Table 7.8
The interview protocol about lesson plans and teaching sequences

i.	How would you rate your feelings towards physics during the process of teaching in the microteaching? easy _1_ _2_ _3_ _4_ _5_ difficult
ii.	How would you rate your confidence to teach secondary school physics? confident _1_ _2_ _3_ _4_ _5_ not confident
iii.	What specific teaching skills or techniques do you feel you are performing very well? On which teaching skills or techniques do you need to improve?
iv.	How do you plan to improve your teaching skills? Did you develop these plans on your own, with the aid of your colleagues, supervisor or others?

Several themes emerged from the interviews in response to questions (iii) and (iv). Through their experiences of microteaching, the participants felt that they performed well when illustrating with examples: "I think technique of illustrating with examples helped" (Farah, 3rd, F); using cooperative learning "I was a teacher before, I can say that I can perform very well [and] cooperative learning [it seems] helped the weak students [because] they can give me a feedback [and] they can help each other " (Bertha, 3rd, F); using contextual learning "as we can lead the students to our daily life" (Diana, 3rd, F); and getting students' attention "to get students pay attention on physics teaching" (Esther, 4th, F). On the other hand, teaching skills that they considered needed improvement in the microteaching were the asking of questions especially those focused on physics content: "I was lacking exposure in physics teaching [and] I think techniques of asking questions are essentials in effective physics teaching and especially focused on physics content. Discussions with colleagues are important to improve our teaching skills" (Geetha, 3rd, F). Finally, findings from both group assignments and lesson plans enabled matching with the participants' actual beliefs and experiences. Both may influence didaktik analysis-based teaching practices in the microteaching and during the school placement, and are discussed in the following section.

7.2.3 Summary of Findings for Research Question Two

This section presents summary of findings, about the physics teaching methods course generally, and specifically the assignment on didaktik analysis and the introduction of didaktik-based analysis through the microteaching and practicum. It seems that the participants' teaching practices were shaped by their beliefs about, and experiences of, the physics teaching methods course generally, and the didaktik analysis assignment in particular. With regard to the methods course, the participants appreciated the practical application of didaktik analysis in their experiences from the microteaching, and during the practicum.

When actually doing the microteaching, the participants noted the importance of; physics content knowledge in preparing a daily lesson plan and teaching aids, understanding the ideas of their students, gaining knowledge of techniques in asking questions in the classroom, finding ways of gathering information about students' alternative conceptions for a specific content area, understanding difficulties encountered by physics students, and ways of improving teaching practice. Similar trends were found in the teaching practice in the classroom during the practicum. In addition to that noted above, the participants felt the didaktik analysis assignments helped their students understand physics concepts better, and improved their understanding of the syllabus' requirements. This led to an improvement of the participants' attitudes toward physics and increased their confidence to teach physics. However in practice, a few participants' lesson plans were not based on didaktik analysis, but were more in accord with the textbook and curriculum specifications, and some thought didaktik analysis was related to physics only.

Thus, the data presented above suggest that factors from assignments that influence the effectiveness of didaktik analysis-based teaching practice - specifically for the participant group assignment on 'the force in equilibrium', were their conceptual understanding of force and motion topics and their understanding that resulted from the components of didaktik analysis. Thus, conceptual analysis, analysis of textbooks, and analysis of literature on students' alternative conceptions impacted positively on teacher practice. Some participants believed that the conceptual analysis and analysis of textbooks resulted in an improvement, not only for their students, but also their own understanding of physics content, and their teaching practices, increasing their confidence to teach, and improving their teaching methods. Interestingly, the participants' analyses of literature on students' alternative conceptions from websites or journals resulted in, not only, their deep understanding of specific physics content but were also useful in preparing lesson plans in terms of taking into account students' alternative conceptions, and using this information to guide when planning of a teaching sequence, and finding ways of correcting alternative conceptions. Overall, it seems this part of the methods course generally helped to improve participants' understanding of specific physics content, improved their attitude-toward-physics and teaching, and helped them to identify problems with students' learning of physics concepts, and improve their teaching practice. These factors subsequently meant participants would become more confident in teaching secondary school physics.

However, it is important to note that as the topic of the assignment differed for each group, and the participants' experiences and their beliefs about conceptual analysis, analysis of textbooks and analysis of literature on students' alternative conception also varied. Some participants who had negative experiences of the didaktik analysis assignment perceived the methods course as being difficult, not only because they lacked understanding of didaktik analysis, but also in their analysis of specific physics content. They did not understand, or were confused about the analysis of textbooks, and had difficulties in understanding and finding out about students' alternative conceptions. This it seems was mostly because they were confused about the term 'students' alternative conceptions', resulting in difficulty when gathering information from electronic sources, journals, or reference books, because this material is not related to specific physics content at the secondary school level. An additional factor here may be the use of different terms (e.g., misconceptions) in the literature. These difficulties were linked to a perception of the inaccessibility of resources or lack of references and that some of these sources were found not to be related well to the specific physics content required in an assignment. Other factors included problems with English, limited cooperation occurring in some groups making it difficult to do analysis on all the specific physics content, figuring out how to transform specific physics content into a suitable teaching sequence, and a fear of not being able to cover the syllabus (part of the summary is shown in Figure 7.3).

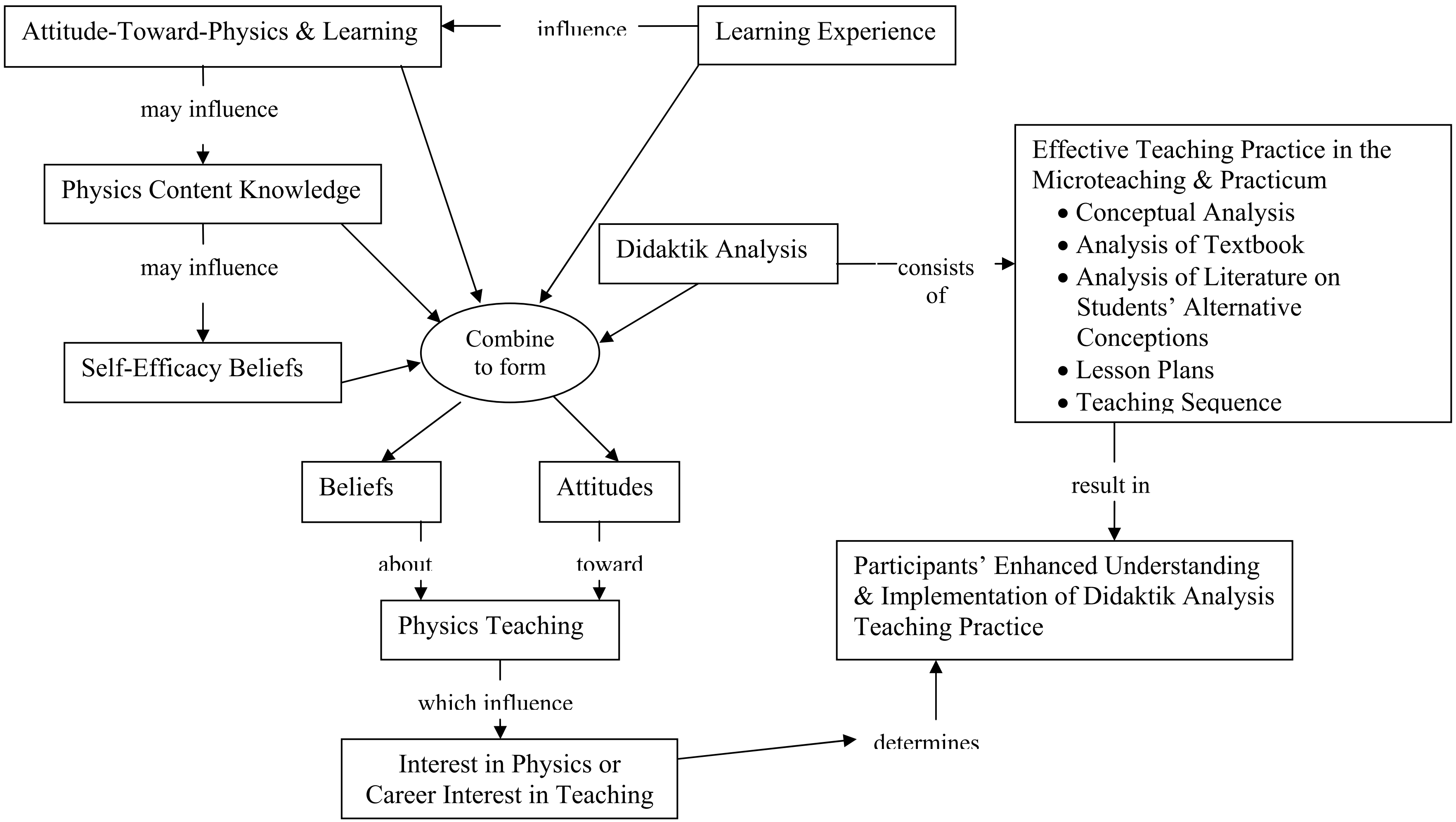


Figure 7.3
Concept map of enhancing understanding of didaktik analysis teaching practice

7.2.4 Research Findings for Research Question Three

Research question three, the findings of which are presented in this section, dealt with whether or not participants were able to engage in reflections on the experiences of the didaktik analysis assignment in their physics teaching methods course and teaching practices in the microteaching and during the practicum. These reflections could be linked with the self-efficacy beliefs participants hold about their learning experiences in the physics teaching methods course, and how the results of their experiences in the microteaching and classroom during practicum, influenced their confidence to teach secondary school physics. Finally, participants' reports of reflections on didaktik analysis indicate whether or not they understood reflective teaching.

The research findings for the participants' reflections on their didaktik analysis were derived from a number of sources: 'written reflections in the lesson plan' at the end of individual microteaching; written reports on the group assignment of didaktik analysis (see Tables 7.4 & 7.5) – participants reflected on and analysed their experiences in the conceptual analysis of physics content, analysis of textbook, analysis of literature on students' alternative conceptions, physics teaching methods, and microteaching (participants' reflections on individual written reports about their experienced didaktik analysis assignment were anonymous); focus group interviews after microteaching (see Tables 7.6 & 7.8) and individual interview after classroom observation (see Table 7.6, question ii & iii); and 'written reflections' on practicum concerning developed lesson plans and teaching sequence in the middle of practicum conducted at the university (see Table 7.6, question ii). Finally, the results of two questions from the final examination (Figures 7.2 & 7.4) served not only to identify what was considered problematic, unsuccessful or successful components of didaktik analysis of specific physics content area, but also provide indicators of participants' understanding about their reflective teaching generally.

Reported 'written reflections of the lesson plan': The participant group for 'the force in equilibrium' topic reported their 'reflections of the lesson plan' at the end of the microteaching; one was from the participant who did the staged teaching, and the others from group members who acted as 'students' as well as observing the lesson. The following individual reflection (reflecting on her teaching), written in the lesson plan (see Figure 7.1), is from the participant who staged her teaching practice in the microteaching:

> Students helped each other to solve questions. Besides, they can present their answer well; needed to improve pronunciations; less interaction with students; have to master well with the content knowledge; confident in teaching; voice clear and student can hear very well; the example given by the teacher were quite attractive; dressed professional; students involved in the induction set activity; had an eye contact; needed to improve questioning skills; and give motivation to students (Alice, 4th, F).

In reflecting on her teaching practice in the microteaching, Alice, a fourth year female talked of her teaching experiences and the (staged) student learning (i.e., of her colleagues), in particular about her use of examples in teaching 'the force in equilibrium'. What Alice reflects upon here thus illustrates her personal beliefs and experiences that motivated her to improve her teaching practice. Her teaching practice was shaped by what she believed about student learning, and about pedagogical interactions between the 'teacher' and 'students' during the microteaching. She believed she needed to improve her English and questioning skills. She sensed that her teaching looked professional, and felt that she maintained good eye contact with the students. She felt that she was lacking in terms of her interaction with the students, but felt she had the capacity to influence her students to learn.

Reflection on Alice's teaching 'the force in equilibrium' was produced by her group after discussing among them in her absence. The following reflections were produced as a result of discussion from Alice's group members, they wrote:

> In the class, students showed positive response to the lesson; tension arises when teaching because of having video captured; not confident in teaching; voices have to be louder; examples were quite attractive; less interaction with students; dressed professional; related to daily life; had a cooperative learning; less eye contact; had to improve the font size on the white board; pay attention with learning environment and make it comfortable; not enough teaching experience; good preparation; had enough content about this skill; less related the scientific terms with daily term; dare to try; and give motivation to students (Alice's group reflections on her teaching 'the force in equilibrium').

These reflections from Alice's group on her teaching of 'the force in equilibrium' seem similar to her own reflection, except the above mentioned 'tension' and that she was seen as 'not confident' with the use of 'video capture'. Other group members commented on Alice's teaching, and noted strengths and weaknesses of her teaching practice. They credited her in that her teaching was related to daily life, there was cooperative learning in the class, that she had done good preparation, and was enthusiastic and knowledgeable about the content. On the other hand, they noted that she was lacking in teaching experience, made little connection between scientific terms and daily terms, was lacking in skill when using whiteboard, and did not seem to care about her learning environment. These 'written reflections in the lesson plans' indicate that participants reflected in the microteaching more on the teaching practice rather than the assignment on didaktik analysis.

Reflections on the Assignment of Didaktik Analysis: As a result of participants' experiences of conceptual analysis of Form 4 physics content (question ii, Table 7.4), their understanding of physics content improved, and this meant they developed perceptions of a need to learn more about physics, "I need to learn more about physics" (R30), indicative of genuine reflection on their own teaching and learning: Participants' experienced difficulties with the conceptual analysis of specific physics content and came to challenge their established thinking about other physics content, the need for different teaching sequences for different physics content, the importance of understanding specific physics content and English language, as well as accessing resources, and materials.

Similarly, as a result of their analysis of the Form 4 physics textbook (question iii, Table 7.4), they then became "aware of the weaknesses in the textbook and curriculum specifications" (R17, 4th, F), and they suggested more research needed to be done on physics textbooks: "Teachers have to do more research and help the students to understand"(R16). As a result of gathering research findings for students' alternative conceptions (question iv, Table 7.4), participants encountered difficulties with a lack of resources such as electronics journals, journals and reference books, and content in such resources not being related to specific physics content at secondary level, and were confused with students' alternative conceptions.

In response to question (v), Table 7.4: *What experiences based on didaktik analysis would you want to add?*, some 44 out of 59 participants reflected specifically on the assignment of didaktik analysis in their physics teaching methods course. There were five things identified as influential on their beliefs about their capability to do an assignment of didaktik analysis: didaktik analysis experiences; increased confidence to teach physics; influence of physics teaching; improved attitude towards physics; and microteaching experience. A summary of findings from written reports about didaktik analysis assignment for question (v) is shown in Table 7.9. These are now discussed in turn.

Table 7.9
A summary of beliefs and experiences from physics teaching methods course

	N=59
Comments on assignment of didaktik analysis experience	44
Improved teaching practice	10
Improved attitude towards physics	2
Increased confidence to teach physics	6
Influence in teaching physics	2
Microteaching experience	31

Didaktik analysis experiences: The content analysis from 44 participants' comments, suggests that their experiences in the didaktik analysis assignment ranged from positive to negative. Positive experiences were that the didaktik analysis assignment was "good for physics teaching" (R2), as it covered "methods**,** approaches, strategies and teaching aids" (R20), which had not been learned before, "I never learnt this before" (R22). It differed from other teaching methods courses in that "the methods employed were rather different" (R55). In terms of improving skills in the teaching practice, it helped in preparing a daily lesson plan "I really gained a lot of knowledge [and] teaching skills [in] make a daily lesson plan" (R37). Other positives were that it helped participants in revising their own content knowledge of Forms 4 and 5 physics topics meaning they were "able to revise again Forms 4 and 5 physics topics" (R37), and as a consequence they "gained some experience in conceptual analysis of physics content and analysis of textbooks" (R53). This latter experience was seen as difficult initially, but was found to "complement and integrate prior courses" (R31). The assignment was thought to provide useful knowledge of teaching techniques "I got knowledge [about] techniques about teaching methods" (R43), and ideas gained from journals and websites "journals and websites these have improved my knowledge" (R45), and experience of learning in English "[because the] lectures [were] conducted in English language" (R55).

Negatives were that the didaktik analysis assignment meant “more time was needed to complete this course” (R31). Also, some participants felt it was boring, especially “[the] first time I felt it was boring because there was so much notes to be copied” (R35), and some did not understand the assignment: “It was really a burden when I actually did not understand” (R6). This it seems was because “there were so many components involved in didaktik analysis” (R53), as well as the fact that the “lectures were in English” (R54), and they had some difficulty of surfing the net “to search for specific physics content” (R7). Some participants “did not like this course” (R9) due to “the lectures being of almost three hours’ duration” (R6) which were “too long” and because “the class was too crowded” (R8). These latter issues meant “the researcher did not show how to solve all Forms 4 and 5 physics problems” (R54), a particular problem for the third years who “lacked of basic physics content knowledge” (R54).

Increased Confidence to Teach Physics: The content analysis from some 44 participants’ comments suggests that participants’ felt increased confidence to teach secondary physics. Some commented that “it made me more confident to teach physics” (R2), “I have the confidence to teach physics later” (R22), and they “gained knowledge and make me confident in teaching” (R44), and that “examples from the assignment and teaching practice in microteaching help to boost my confidence to teach physics” (R49). It also “boosted my confidence to use the English language in physics teaching” (R56). The increased confidence to teach physics here seems clearly linked to positive experiences in the assignment on didaktik analysis, and these comments again point to the capacity of the participants to reflect upon what they think they gained from the methods course and didakik analysis in particular.

Microteaching Experiences: The content analysis from 31 participants’ comments suggests that most comments expressed concern about their experiences in the microteaching. Thus it seems the microteaching “was good for practice but the time allocated too short” (R6) and some “felt nervous and reluctant to teach “because their “English language and physics not that good” (R7). But they said they would “try to learn from friends especially the physics” (R12), as “it would really help in my teaching practice” (R9). Finally it was noted that some felt low in certain skills, for example that they "need to improve communication skills" (R41).

Influence on Physics Teaching, and Attitude-Toward-Physics and Teaching: The content analysis from some 44 participants' comments suggests that the assignment on didaktik analysis influenced their beliefs about their physics teaching. Some participant's experiences of the didaktik analysis assignment influenced their established their thinking about secondary physics: "I have to learn again secondary physics" (R7), meaning these participants held low self-efficacy beliefs about, for example, how to attract students' attention "I feel I fail[ed] to attract students' attention during my teaching" (R7). Other self-efficacy issues were that "some students are cleverer than the teacher" (R7), and a perception that students want "learning based on what is to be asked in the examinations" (R7). They also were concerned about their students' ability to learn especially "those from the rural areas" (R49). On a positive note, some participants felt they "gained knowledge through this course", and that "this course exposed me to physics teaching in English" (R20) and that if they could "get a good grade in this course and possibly become a good physics teacher" (41). Anxiety was evident in their comments about trying to do their best in teaching practice: "I hope can do better in the coming teaching practice" (R38). These latter beliefs meant some at least came to the view that "physics is not really tough because physics is fun and lovely but the problem is how to make students interested" (R46), and "understand and love physics" (R47). Some of these beliefs influenced participants' teaching practices and subsequently improved their attitude-toward-physics and teaching.

Reflections on Physics Teaching Methods Course. As reported earlier in the focus group interview was held after the microteaching of the nine participants (see question iii, Table 7.6). Six said they found the physics teaching methods course helpful, two said they were not sure or uncertain as to whether or not physics teaching methods was useful, and one said it was not helpful.

The 'written reflections' from the physics teaching methods course, as part of the course requirements, were conducted in the middle of the school placement*: Would you like to comment on physics teaching methods course, TT4133?*

Out of 61 participants, 52 of commented on this part of the course. Of this 52, 15 believed that the physics teaching methods course helped them in teaching practice during the practicum. The content analysis of 18 participants' comments point to positive learning experiences and valued guidance in terms of "improved pedagogical skills " (R1), the capacity to "develop a lesson plan", and "learned physics content knowledge" (R2). Others noted that they learned how to analyse textbook meaning "at least we know that depending on textbook is not enough" (R11). Some reported increased confidence to teach physics "through practice in the classroom" (R54), and "the microteaching experience" (R55). Although the methods course might help in teaching practice, some 18 participants suggested to it was necessary to have "more microteaching to get participants act as problematic students" and "to have actual students [and] to observe the actual teacher in the classroom" (R46). It also was considered helpful to have "more activities related to classroom environment" (R54), and to "emphasize more physics contents so that can be more confident to teach physics" (R15), as well as complaints about "lack of pedagogy skills [due to huge number of participants enrolled in the course that resulted in time constraints]" (R40) gained through the methods course.

This same question (ii) in Table 7.6 was asked again in individual interviews after classroom observations at secondary school: *Did the assignment of didaktik analysis have any influence in your physics teaching? What are the influences?* One participant believed that physics teaching methods course had provided a positive learning experience, covering both theoretical and practical aspects: "The course was good, we went through both theory and practical - that was interesting, I found that there were some differences" (Leslie, 3rd, M). This is supported by another participant who said she learned most of the methods content and became interested in physics: "I learned most of the contents in this course [and] especially how to teach physics [which] previously I really did not know about physics [but] after this course, I found that I gained more skilled, and get interested in physics" (Camela, 3rd, F). Another participant who said he understood the concepts of didaktik analysis, went on to comment that he felt didaktik analysis could readily be applied in other subjects: "I still remember when I did didaktik analysis assignment in physics [and] when I relate to mathematics I found that this didaktik analysis also can be used in mathematics"

(Jalang, 3rd, M). Reported benefits from the methods course include understanding of how to teach physics better, and improved physics lesson plans: “But when I enrolled physics methods course, then I understand how to teach physics better [and] how to improve a developed physics lesson plan” (Issac, 3rd, M). However, one participant felt that teaching practice in the microteaching was not able to cover the whole content: “Through microteaching - I think I cannot deliver content in every topic but in the classroom I was able to teach the whole content in each topic [using approaches other than didaktik analysis]” (Geetha, 3rd, F).

Reflections on Teaching Practices in the Microteaching and Practicum: The ‘written reflections’ in the middle of practicum conducted at the university asked: *What are your views of the actual classroom with the microteaching sessions, and any significant events occur during the practicum, and how the two are different?*

Out of 61 participants, 55 commented on both teaching practices. The content analysis from 55 participants’ comments suggested they believed that teaching practices of the microteaching and in the classroom during practicum were different in terms of: “the use of technology” (R2), “giving notes” (R10), “students’ background” (R12), “situations [learning environment]” (R13), “discipline” (R17), “students’ ability” (R26), and “teaching experiences” (R35).

In the microteaching, the participants reported that it was “easier to set the time” (R1), as the “situation has already been planned” (R38), meaning it took “less than 30 minutes finish the teaching” (R50). Since the microteaching involved “a small group” it was “easier to control the class” (R52) as “students’ discipline (i.e., of their peers) was better” (R17), because they were “well mannered and able to answer questions” (R31), “understood the lesson” (R12) and they already had “firm prior knowledge” (R61). However, the microteaching did involve “a lot of time preparing thoroughly for lesson plans and notes in PowerPoint” (R7), which were “presented using the LCD” (R9), and this resulted in “more stress” (R30), although it “helped to see how to apply this in the actual classroom” (R13), and “colleagues’ interests were various ” meaning the experience was helpful in terms of seeing other “thinking about their own microteaching” (R47).

During the practicum, some 55 participants believed that "it was difficult to control the class as students hard to understand the topics "because some students "were naughty [and] they did not want to listen to the lesson"(R1), "always tried to test teacher's patience" (R31), making it "hard to get their attention and [get their] participation in any activities" (R14). It also was noted that not all of them "were interested in the subject", some "were very active" (R54), others "make noise or went out to toilet [wanted to] meet [the] other teacher" (R34), and "sleep or talk in the back of classroom" (R46). Also that "different classes, there were different attitudes and reactions" (R11), in which "some students were not really responsive and [I] did not know whether or not they understood the lessons" (R44). It seems the participants felt that if the "students were more attentive [if] the teacher was more assertive" (R47), then things were better. However, in some cases there were "no or limited LCD and computer or notebook" (R5), which instead had "to be borrowed and there was no proper room for setting up the equipment" (R9), and there was "not enough time preparing for lesson plans as physics had [only] five periods a week, [and because] preparations [had to be done] at least a day before lesson - tension arises" (R7). The environment in the classroom other than being "challenging and fun as students lack of basic knowledge [and] did not understand English language [and so were very] quiet " (R15), the students were "not mature" (R16), and did not "appear to understand when the teacher explained but when did the exercise [and] they had problems in to solving it" (R24), but also the classrooms were "hot, dirty and untidy and not comfortable" (R34). Three participants commented that classroom and microteaching "are the same in terms of teaching strategies. However, teaching practice in the practicum gives more experiences" (R35).

Finally, as noted in Figure 7.2, analysis of responses to this question on reflective didaktik analysis of specific physics content area indicates developing lesson plans and practicing these teaching sequence were the most prevalent experience commented on and participants felt both were difficult tasks, whereas conceptual analysis from the curriculum specifications was the least common experience mentioned in the assignment.

Analysis of responses to the question in Figure 7.4 indicates that participants chose answers other than A (the correct answer) and that about 75% of participants did not understand the meaning of reflective teaching.

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i. Which of the following is not related to reflective teaching?

A to record to what extent the students have achieved teaching objectives – 29 (26 %)

B to record problems or difficulties encountered – 2 (1 %)

C to record of particular student who performed or participated actively – 70 (62 %)

D to record suggestions for improvement – 12 (11 %)

Figure 7.4
One of the 60 questions in the final examinations of the physics teaching methods course related to the understanding of reflective teaching

7.2.5 Summary of Findings for Research Question Three

This section presents a summary seeking to understand whether or not the participants were able to engage in reflection on their experiences of didaktik analysis assignment of their physics teaching methods course, and on their teaching practices in the microteaching and during school placement. These reflections were linked with self-efficacy beliefs as to whether or not the participants felt they had the confidence to teach secondary school physics. Finally, it seeks to determine whether or not participants understood the meaning of reflective teaching within the notion of didaktik-based analysis teaching. Evidence sources of participants' reflections were; 'written reflections in the lesson plan', reflections on individual written reports on assignment of didaktik analysis, and reflections on teaching practices in the microteaching and classroom.

The data suggest overall that the participants were able to engage in reflection on didaktik-based analysis teaching practice, with the exception of the final examination results. Specifically, data from 'written reflections in the lesson plan' indicate that the group and individual participants reflected on the microteaching and their teaching practice more than on the didaktik analysis assignment. They reflected on their personal beliefs and experiences; beliefs about student learning, beliefs about physics teaching, and physics teaching self-efficacy beliefs. These 'reported written reflections in the lesson plan' on teaching practice may have been influenced by the fact that the 'reflections' were part of the lesson plan requirement to be submitted to the researcher – thus it was seen as 'high stakes' because it was going to receive some scrutiny and marks.

Data from these reflections indicate participants reflected on their beliefs and experience on physics teaching methods course; didaktik analysis assignment, and microteaching experiences. These reflections on their experiences of the didaktik analysis assignment indicate participants' conceptual understanding of specific physics content, their beliefs about physics teaching, and their attitude-toward-physics and learning. Many participants were more positive about their learning experiences with the didaktik analysis assignment, but this did not necessarily result in lesson plans or teaching sequences based on didaktik analysis, due to a perception of limited amount of time to learn physics teaching methods compared with learning physics content.

Data from the reflections of participants' experiences of conceptual analysis of Form 4 physics content indicate that participants established their attitude-toward-physics and learning, beliefs about physics teaching, and improved conceptual understanding, from which participants may increase confidence to teach and subsequently improve their physics practicum. This is shown through their difficulty of doing the conceptual analysis of specific physics content which was influenced by their views of cooperation amongst group members when analysing specific physics content, as well as an awareness of a need to cover the syllabus and to transform specific physics content into a teaching sequence. Overall, participants' reflections on the conceptual analysis seemed to be influenced by the participants' thinking about other physics content, the accessibility of resources and materials, and potential different teaching sequences for specific physics content. All of this was seen as being important in motivating participants to teach secondary school physics. Data from reflections on experience from the analysis of the Form 4 physics textbook suggest that the participants' knowledge about textbooks and the Curriculum Specifications was low, and they themselves suggested more research needed to be done on physics textbooks (other cohorts of pre-service teachers in future) in order to improve students' attitude-toward-physics and learning. Data from the reflections on analysis of literature on students' alternative conceptions points to difficulties associated with a perceived lack of resources such as electronics journals, journals and reference books, relevancy of such sources to the specific physics content at secondary level, and participants' confusion about what is meant by the term *alternative conceptions*.

Participants reflections on the didaktik analysis assignment seemed to influence their beliefs about physics teaching in the microteaching and practicum; their experiences of their teaching, and the importance of didaktik-based analysis teaching, but it was hard to find any example of participant who implemented this (didaktik analysis) in their lesson plans and teaching sequence. In other words, there was lack of coherence between what participants' reported as their beliefs about didaktik-based analysis teaching, and their practicum. Most participants were constrained by the physics content specified in the Curriculum Specifications, and this subsequently impacted on their lesson plans and teaching sequence. In these circumstances participants were likely to teach without having had the opportunity to apply fully the didaktik-based analysis teaching practices. Thus, as might be expected, it would seem that having experiences with didaktik analysis assignment and teaching practice are not enough to ensure that participants will use didaktik-based analysis teaching practice in their future classroom.

When participants reflected on their teaching practices in the microteaching and practicum, they noted that the experiences were very different. The data suggest that both reflection on teaching practices in the microteaching and practicum were perceived as beliefs about physics teaching and student learning (participants as teachers and learners). Participants' confidence in their ability to teach secondary school physics varied with their experience, and their beliefs about teaching and learning. Specifically, their learning experiences at secondary school and university which influenced their attitude-toward-physics and learning; their attitude-toward-physics; their attitude-toward, and beliefs about, physics teaching; and their conceptual understanding of specific physics content. Analysis of the data about the participants' capacity for reflection indicates that the participants reflected on the microteaching more on their practicum rather than their assignment on didaktik analysis. The data also suggest that some participants were not able to engage in reflections on didaktik-based analysis teaching practice. However, the data also suggest that the participants may be able to adopt a didaktik-based analysis teaching practice if they are provided with more accessible resources and their content knowledge for specific content is developed (part of the summary is shown in Figure 7.3).

7.3 SUMMARY

This chapter presented findings for the second and third research questions - factors from assignments influencing the effectiveness of implementing didaktik-based analysis teaching practices in the microteaching and during practicum, and engaging in reflections on the methods course and experiences of teaching practices in the microteaching and practicum, which all subsequently influenced participants' confidence to teach secondary school physics. Participants' teaching practices seem to be shaped by their beliefs and experiences of the physics teaching methods course generally, and the didaktik analysis assignment specifically. These seem to influence their attitude-toward-physics and learning, their physics teaching self-efficacy beliefs, and their conceptual understanding of specific physics content. Self-efficacy beliefs about methods course and assignment of didaktik analysis illustrate the way in which these influences on teaching practices to teach physics are interrelated. The next chapter focuses on to whether or not a teaching sequence based on didaktik-based analysis teaching practices can be used by the participants for other physics content areas.

CHAPTER 8

RESEARCH FINDINGS: PRE-SERVICE TEACHERS TEACHING EXPERIENCES

CHAPTER OVERVIEW

Following on from Chapters 6 and 7, this chapter presents the research findings for research question four, namely:

- What is the ability for pre-service physics teachers to develop a teaching sequence based on didaktik analysis and enacted for other physics content areas by the pre-service physics teachers during their microteaching and practicum?

  a. How successful were pre-service physics teachers in implementing a teaching sequence based on didaktik analysis in their microteaching and practicum?

  b. What factors inhibit or facilitate the use of didaktik analysis in a teaching sequence in their microteaching and practicum?

The findings presented here are concerned with a teaching sequence based on didaktik-based analysis teaching practices that the participants used in their microteaching. In particular, it was of interest to see if whether or not they could draw upon didaktik analysis and apply it to a variety of physics content in their classroom during their practicum. As noted earlier, didaktik analysis treats physics content as ‘problematic’ which involves activities *before* (e.g., conceptual analysis of specific content, analysis of textbook material, analysis of literature on students’ alternative conceptions, and development of lesson plans which includes developing teaching sequence – Chapter 7), *during* teaching practice (implementing a teaching sequence in the microteaching and during a practicum– Chapter 8), and *after* (reflections on teaching experiences – Chapter 7).

This chapter consists of three sections. Section 8.1 describes researcher observations of microteaching and classroom for selected participants, based on the researcher's field notes. Section 8.2 presents the findings based on examination of participants' written reports about their teaching practices in the microteaching activity, 'written reflections' in the middle of the school placement, researcher observations of teaching in the practicum classroom, individual interviews at the end of classroom observation, and interviews with three Form 4 physics students. Section 8.3 summarizes the findings for research question four.

8.1 Description of Microteaching and Classroom Observations

This section presents the research findings from observations of microteaching, and during the practicum. Here, the researcher sought not only to look at how well the written lesson plans translated into teaching, but also to see how effective the teaching sequence developed from the didaktik analysis was realised in teaching. Data were interpreted from examination of participant assignments on lesson plans (see Section 7.1.2), field notes taken during observations of microteaching and the practicum (in the 7 weeks of lectures and 7 weeks of observations during the microteaching) and interview data from participants' meetings with the researcher individually or as a group after their practice teaching and microteaching, discussion, and with colleagues, and participants' mentors during visits to their classrooms.

8.1.1 Microteaching Observations

Microteaching consists of the 'staging' of activities by participants to practise particular teaching skills (see Appendix VII) by teaching a short lesson to a group of peers. Participants were required to practise teaching based on lesson plans they developed from their didaktik analysis assignment. As noted in Chapter 7, there were 29 groups of participants who completed the didaktik analysis assignment. These consisted of two cohorts: 35 participants (15 males & 20 females) in the three year programme called special conversion for non-graduate teachers, and 78 participants (18 males & 60 females) in the four year programme.

As the number of participants was large, the microteaching was conducted during the second seven week block of the physics teaching methods course, for two sessions each week for 180 minutes duration. A representative of each group was required to practise his or her lesson in a microteaching activity which lasted about 10 to 15 minutes. Some third years did not practise teaching in the microteaching, at their request, since they had nearly 10 years teaching experience in primary schools. As noted in Section 7.1.2, the researcher observed each lesson together and captured data by means of video recording (assisted voluntarily by one of the participants in each session) and additionally assessed the lesson based on a record sheet prepared in advance (see Appendix VIII).

Overall, the researcher's observations of the microteaching revealed that the participants were able to apply a teaching sequence based on their own didaktik analysis assignment. They were able to identify their own strengths and weaknesses in their teaching practice, but they felt that was a normal part of a successful physics teaching methods course – whether it involved didaktik analysis or not. They also considered that the time allocated to microteaching was insufficient, and anticipated that the teaching sequence based on didaktik analysis may not be able to be implemented in the classroom as their assignment only focused on some specific physics content. This worried them, as they might not have time to do didaktik analysis on other specific physics contents during their school practicum.

8.1.2 Classroom Observations

The participants involved during the school practicum totalled 11 pre-service teachers (4 urban & 7 rural). This part of the study also involved three Form 4 physics students (i.e., Year 10 - about 16 years in age) from five secondary schools. These students were involved in focus group interviews after the observations of the practicum. Some five pre-service teachers (3 urban & 2 rural) were video taped during their teaching practicum by the researcher and interviewed afterwards, and the remainder were only interviewed. The researcher here uses two vignettes to illustrate two contrasting teaching sequences that sought to facilitate small group discussion, and involved students answering teacher's questions, carrying out experiments, teachers answering students' questions, handling students' responses, problem-solving, and examining the role of the pre-service teachers in mediation of teaching activities through English and Malay languages.

Urban Secondary School (a pseudonym) is located in the middle of Kota Kinabalu city, where Camela (a pseudonym) was posted for her school practicum. This school is an 'ordinary' or national school (in Malaysia there are other six types of secondary schools; national, fully residential, MARA Science Junior College, religious, special, technical), and drew its students from a combination of middle and low income families, and for whom English language skills are not strong. The ethnic groups present in this classroom were Bumiputera (mainly consisting of Melayu, Kadazan, Dusun, Murut and Bisaya people), and Chinese, with the majority of students being female. The number of students in the class was around 35, and there were eight large tables in the laboratory, each which could accommodate 5-6 students, and one teacher's table.

Camela taught Form 4 physics on the topics of kinetic and potential energy at the end of 'force and motion' topic as in the curriculum specification. As this topic was not done in her assignment of didaktik analysis during physics teaching methods course, her lesson plans were different from earlier plans based on didaktik analysis. Her lesson plan format was based on what her mentor teacher provided. She taught using both computers and LCD, and employed a rolling blackboard. Her teaching sequence activities conducted in the laboratory consisted of small group discussions, with students answering the teacher's questions, and engaging in problem-solving activities. In these activities, Camela employed both English and the Malay language, with the latter being the most frequent. She seemed to be in a hurry to finish her 80 minute lessons, and the data indicated that she used wrong pronunciation for some of the scientific terms when speaking in English. For example she confused heavy, weight and light; fast and slow; and weak and hard. She also seemed uncomfortable when she pronounced some terms in English. Generally, the students were active, asking Camela about the topics she taught. The researcher interviewed three of her students after the classroom observation (see Section 8.2.2).

Rural Secondary School is a school in a rural suburb more than ten kilometers from Keningau, Sabah, where Leslie (a pseudonym) was posted for his school placement. The ethnic group in this classroom was Bumiputera, mainly consisting of Kadazan and Murut peoples, with around 20 students in the class. Students' socioeconomic status was low and some students were Christians, and they all typically spoke in their native language (Kadazan) when they were not in the classroom. Leslie taught Form 4 physics on the topic of 'the effect of force' using a computer and LCD, and a blackboard in the classroom. His lesson plans seemed to be not much different from Camela's, although he stressed the importance of students' alternative conceptions. He did not talk much, but relied heavily on what was presented on his PowerPoint presentation together with animations his presentation. His teaching sequence activities consisted of small group discussion, students answering the teacher's questions, and problem-solving exercises. Most of the time in the classroom he spoke in English and he looked confident even in the presence of the researcher and his supervisor who observed his teaching. None of his students asked questions on the lesson he taught. Three of his students were interviewed after the classroom observation (see Section 8.2.2).

The researcher now summarises observations from these two vignettes in the form of another vignette. In *urban secondary school* it seemed the small group discussion went smoothly and most of the participants were eager to answer questions posed by Camela, whereas in Leslie's lesson, although the time provided for small group discussion was longer, the students seemed to discuss topics other than what Leslie was interested in. Leslie's students' talked in Malay to him continuously when he went round from one group to another, and overall his attempts to establish small group discussion seemed unsuccessful. Some of Leslie's questions on 'the effect of force' were not answered correctly by his students, and the only answers from the students were 'yes' or no'. It was quite difficult to get students to express their views during Leslie's lesson, but prior to his lesson during the recess, the researcher observed that his students interacted well with him. One possible explanation here then is that Leslie's students might not have been able to understand Leslie's questions because the formal interactions in the classroom occurred solely in English.

8.1.3 Field Notes

This section outlines findings based on researcher field notes taken during the intervention. First the three pre-service teachers mentioned above who were involved in this part of the study came to see the researcher, complaining that they found it quite difficult to get resources about the refraction of light, particularly material on students' alternative conceptions. In addition, they said they found it inconvenient to get help from the librarian and asked if the daily lesson plans could be reduced from three to one. The researcher advised them this was not possible, and encouraged them to try their upmost to obtain whatever materials related to their specific physics content (light refraction). However, this group seemed disappointed and anxious about achieving these tasks.

The participants in the other group also asked whether what was said in the interview might result in disciplinary action against them. The researcher assured them that this was not the case and that their confidentiality would be protected. One male participant seemed very interested in the study, saying he wanted to learn what the researcher was doing in his research.

The researcher also asked all of the participants about their physics teaching experiences in secondary schools during the practicum. One participant commented that she felt she was unlucky because she had not done enough physics courses, noting that her cohort did not study physics at the School of Science and Technology. The researcher commented that the current fourth year students were using the old curriculum, unlike the third years (particularly the non-conversion programme trainees), who were the first cohort of trainees to use the new physics curriculum. The researcher also asked how confident they felt about their physics teaching. The responses showed that they were not confident, mostly because the physics was to be taught in English. These responses resonate with similar comments received from one of the researcher's colleagues who said that feedback from trainee teachers about physics teaching in the practicum contained references to concern about lack of conceptual understanding of basic physics. Another colleague commented that examination of the 2005 National examinations (Secondary Lower Assessment - PMR) showed that about 33 % of PMR students used English when answering science examination questions, suggesting that not many teachers used English when teaching science.

8.2 PRESENTATION OF FINDINGS ABOUT THE TEACHING SEQUENCE

This section presents the findings about the teaching sequence which was a part of the lesson plan; with data based on participants' written reports, and focus group interviews after the microteaching, 'written reflections' in the middle of practicum, and individual interviews at the end of classroom observation during the practicum. The researcher analysed the participants' written reports as to whether or not their teaching sequence based on didaktik analysis was applied for other physics content areas. This includes data about the influence of the didaktik analysis assignment, and difficulties that arose when participants implemented their teaching sequence. The findings from the written reports were cross-checked with focus group interviews after their microteaching was completed, whereas the written reflections in the middle of practicum were cross-checked with individual interviews at the end of classroom observation during the practicum. Comparison of participants' views is also made between practice of the teaching sequence in the classroom and microteaching. Interviews with three Form 4 physics students from each school visited also were conducted. This was intended to enable comparison of the teaching sequence detailed in the lesson plan with the actual teaching sequence used in the classroom.

8.2.1 Research Findings from Written Reports and Interviews on Teaching Sequence in Microteaching

This section presents findings for participants' teaching sequence based on didaktik analysis as used in their microteaching. The question used in the written reports about teaching sequence is presented in Figure 8.1. Fifty nine out of 105 participants responded in the written reports administered at the end of the semester. The following is a summary of the responses of 59 participants in the written reports and 10 selected participants who were interviewed.

Can a teaching sequence based on didaktik analysis be used to a variety of physics content areas?

Figure 8.1
Participants' written reports about their teaching sequence in the microteaching

Of the 59 participants, 37 agreed that a teaching sequence based on didaktik analysis could be applied to a variety of physics content areas. Analysis of some 37 participants pointed to two benefits reportedly gained from the didaktik analysis assignments, specifically on developing a teaching sequence and subsequently applying this to practice. First, they thought that examples from analysis of specific physics content could be applied directly in the teaching sequence: "All of the examples that have been produced from didaktik analysis assignment can be used" (R2). Next they felt that "didaktik analysis can be employed as guidance for a teacher to make teaching sequence more effective" (R6). However, the constraints of applying the teaching sequence were linked to participants' ability to engage with the didaktik analysis assignment, First, "it took time to do it [and] needed more time to find the materials before teaching" (R28), and second that "some skills and knowledge are needed to make teaching sequence successful" (R27).

After the microteaching was completed, focus group and individual interviews were conducted with 10 participants and these concerned the development of the teaching sequence when preparing lesson plans. The question used in interviews is presented in Figure 8.2.

What specific steps, in the teaching sequence, do you follow in preparation for teaching a lesson?

Figure 8.2
The interview protocol about participants' experienced developing teaching sequence before practicing in the microteaching

The participants commented specifically that developing a teaching sequence in the lesson plan involved "three main stages; induction set [i.e., triggering activities used to attract students' attention], development, and closure (Helen, 3rd, F). This begins with "searching for the content" (Esther, 4th, F), or "thinking what concepts are to be taught, what hands-on activity are to be conducted, and what pre-requisites are needed" (John, 3rd, M). Focus also was on "student previous knowledge" (Camela, 3rd, F), which needed to be included in the lesson plan. The preparation requires participants having "good content knowledge" (Camela, 3rd, F), and "conceptual understanding … and teaching skills" (Bertha, 3rd, F), together with engaging in the tasks of "looking for the textbook and references, and surfing the Internet" (Alice, 4th, F) and collecting information as suggested by "didaktik analysis from this course" (Bertha, 3rd, F). Such tasks, other than preparation for teaching sequence, also helped participants "master the content knowledge very well [and] understand the curriculum specifications [to] determine whether the content of the textbook is enough or not and become aware of the level of students' previous knowledge when preparing teaching aids" (Bertha, 3rd, F).

The preparation also involved participants' thinking of doing activities step-by-step during teaching such as knowing "how to start with students' previous knowledge" (Bertha, 3rd, F), and finding "ways of asking [about] students' previous knowledge inviting students to be involved actively in the activity [and] preparing examples or teaching aids related to daily life as to whether or not they were enough within the allocated time" (Camela, 3rd, F). Finally, these participants felt that they should "write lesson plans beginning with induction" (John, 3rd, M), and once lesson plans were completed, participants should "double-check with curriculum specifications to see what was lacking" (Alice, 4th, F), and also consider "how to do team teaching [due to time constraints]" (Bertha, 3rd, F) arising from this developing teaching sequence.

8.2.2 Research Findings from 'Written Reflection' and Interviews about the Teaching Sequence During Practicum

Written Reflection: Further examination of participants' 'written reflection' on their teaching practice when they returned to the university was conducted. Some 45 out of 61 participants responded to the assignment about their experiences of developing and implementing a teaching sequence in the classroom during the practicum. Several themes emerged from participants' responses. First, it seems they felt the teaching sequences "were guided by the curriculum specifications and were based on a good daily lesson plan which was based on assignments" (R61, 4th). This "started from induction set, development and closure" (R10, 3rd). Some participants suggested that "the development stage needed to be improved in terms of time allocation" (R19), but cautioned about the need to have a good content knowledge and time management: "It must be based on content that you want to teach. If the time is too long, you have to think about the activities. If not, the student might find it to be boring" (R17, 3rd). Participants reported positive experiences when developing and implementing the teaching sequence in the classroom, but this varied with some stating the "lesson went smoothly" (R8, 4th), and those with good content knowledge enjoyed the teaching sequence as they felt "it helped the students to understand better" (R27, 4th), resulting in "students' responses were encouraging" (R47, 3rd). Others felt that teaching sequence is good for classes with high achievers: "It was easy in a good class compared to weak class" (R60, 4th).

Other participants' experienced difficulty with the teaching sequence based on didaktik analysis saying "it was quite difficult to implement teaching sequences based on lesson plans because the real class situation was unpredictable. Most of the time the teacher implement spontaneous actions" (R2, 4th). One problem was that some students were not cooperative "due to various students' background and disciplinary problems" (R14, 4th). Another issue was that some students were "poor in English language" (R5, 4th), and struggled because the "teaching was conducted in English" (R35, 3rd). Students were reported to struggle to understand the concepts as they were unfamiliar with physics: "students' weakness in understanding the [physics] concepts" (R26, 4th). This was exacerbated because "the time allocated was not adequate" (R20). Some 45 participants suggested teaching needed to be bilingual: “In classroom, bilingual [teaching] should be used” (R5, 4th).

Interviews: Several themes emerged from the interviews that were conducted after classroom observation of the practicum. First, the teaching sequence “was based on the physics teaching methods course, and followed the content of the curriculum specifications, which followed the steps in the lesson plans. This included students’ alternative conceptions, and started with [the] induction set” (Bertha, 3rd, F). The aim of induction set was “to get students interested in learning, in particular to link the lesson to daily life” (Jalang, 3rd, M). Following on from the induction set, “the topics were explained one by one introducing scientific terms, followed by reinforcement with them working in pairs, and ending with the worksheet” (Jalang, 3rd, M). The teaching sequence from didaktik analysis thus resulted in students “learning more and thinking that physics is lovely but that working with one’s friends is essential” (Jalang, 3rd, M).

The participants became “more confident compared with prior to the practicum initially because I did not know physics content as well or how to teach physics” (Diana, 3rd, F). Although some participants had problems speaking English they addressed this by “explaining scientific terms in English, and other things in Malay language” (Helen, 3rd, F). However, student factors occurred, such as “constraints in understanding English language because the school is situated in rural area” (Jalang, 3rd, M). Some “disciplinary problems intervened” (Jonathan, 3rd, M), and some students seemed “more interested in doing experiments and did not have any interest in reading books” meaning they were “interested in physics which involved more calculation than explanation” (Camela, 3rd, F).

8.2.2.1 Research Findings from Interviews with Form 4 Students

Camela’s three Form 4 students’ who were interviewed interestingly made comments somewhat contradictory to hers, saying “there are chapters which are not of interest to me, especially those that involve calculation” (Hannah, F). The three felt physics was interesting overall, “but there are some topics which are not interesting” (Fanny, F), but this “depends on the teacher, if the teacher taught well and makes students understand” (Emma, F). However, Camela’s Form 4 students commented on her teaching confirming that: “she taught us well, but it was difficult to understand” (Fanny, F); “her teaching was fine, but her English was not well understood” (Hannah, F); and “her teaching was difficult to understand because of the language [i.e., English]” (Emma, F). Her students also agreed that physics taught in English as Fanny said “can improve students’ English”, while Hannah argued that “it makes me difficult to understand, if it is shifted again to Malay language because it is essential in learning.

Three of Form 4 Helen’s students commented on her teaching that “although physics is too difficult, but her teaching make me understand better, only then her voice needs to be louder” (Tony, M). It also was noted that “she has a systematic way of physics teaching and was trying to make students understand physics, and she was willing to explain outside the school hours” (Margaret, F), and “her teaching was accurate, and the objective of learning [was] achieved” (Sonya, F). Tony noted that physics is challenging, but it depends on the topics whether it is easy or difficult, whereas Margaret claimed that physics was interesting and challenging “because it has many formulae to be employed in the calculation”, and Sonya felt that “although physics is difficult and worthwhile future, she had to make this subject interesting”.

Diana’s three Form 4 students commented on her teaching “her demonstration and detail explanation more interesting” (Blair, M), “she was more easy to communicate with” (Marry, F), and “her teaching much better than the existing physics teacher in this school [she will be] able to teach physics better in the future” (Lorna, F). All three of her students said that physics was interesting due to “her demonstration, lots of explanation, and notes” (Lorna, F), “her teaching with demonstration make me understand physics” (Blair, M), and “lots of experiments easier to understand physics” (Marry, F). Lorna and Blair agreed that physics should be taught in English, but Mary disagreed as she felt the Malay language was easier to understand.

8.2.2.2 Research Findings from Staging the Teaching Sequence

This section presents the findings for the staging of the teaching sequence during the practicum, and details what happened specifically during 'the development stage' of the teaching activities: small group discussion; answering teacher's questions; handling students' responses; carrying out experiments; problem-solving; and the role of the participants in mediating of these activities through English and Malay languages (although the medium of instruction is supposed to be English). During the staging of the teaching sequence, participants were asked about the performance of their participating students in the above activities.

Written Reflection on Small Group Discussion: 58 out of 61 participants responded to this type of teaching activity. The content analysis suggests that participants' experiences in small group discussion activities with their students were both positive and negative.

Positive experiences in small group discussion were that "some students sometimes participated very well [and] were active in class activity" (R8), that they "tried to answer questions either orally or written" (R3). The students were "cooperative in every learning activities (R38), "willing to be involved" (R14), "interested in the learning activities" (R18), and "enjoyed the session" (R27). The students were reported to be "more attentive" (R59), "brave enough to ask lots of questions either in a group or individually" (R52), and "very excited about learning" R42), possibly because the "questions employed were consistent with the students' competencies" (R18), although "some of activities were quite new to them" (R31). Overall the students were "able to give good answers [and] felt happy and motivated" (R35). The participants suggested that the students understood the physics being taught" (R46), and "they enjoyed interacting with friends" (R26). As a result of these positive experiences, the participants felt "motivated to teach" (R28). Some issues were that the students under instruction "seldom answered the teacher's questions" (R44), but that this "depends on the class environment" (R40), since students "become bored if long explanations are given" (R17), "especially when teaching in English" (R1).

Negative experiences were that "students were unable to work independently. The teacher had to guide them all the way" (R2), as they "did not know how to conduct a group discussion" (R20), meaning that "the weak students in lessons were not active" (R7) and were "very passive and did not do the activities" (R5), with "only one or two [being] really involved" (R23). This inactivity also was evident in that some students "did not respond to teacher questions" (R45)**,** did not "follow the instructions" (R54), or "did not know what the teacher explained" (R1). As a consequence, "some of them tried avoiding to be asked questions" (R12), meaning that "group and class discussion could not be held" (R9). There was some frustration expressed about inactive students in that a "frequent response given was 'I do not know' " so the teacher "did not conduct a group discussion as they were low achievers (R61)**,** in which case it was felt "they needed more support from the teacher (R24). Language issues surfaced again in that the students seemed to "like to use Malay language to answer the questions" (R50) as "some of them did not have confidence to answer in English" (R11).

Interviews on small group discussion: Interviews were conducted during the practicum with 10 participants and these concerned their students' participation in small group discussion. The interviews revealed common experiences with students in the classroom. Through their experiences of conducting small group discussion, the participants felt that "not all of them got involved" (Bertha, 3rd, F), and "only some of them discussed the questions provided from the worksheet" (Helen, 3rd, F). Those students who were more involved "gave very good responses because they enjoyed the group work" (Bertha, 3rd, F). Those groups who were not much involved in small group discussion "were not good in English, and so they did not understand the lesson" (Diana, 3rd, F).

Interviews on Answering Teacher's Questions: The interviews conducted with the 10 participants also concerned their students' participation in answering the teacher's questions; again several themes emerged. First, the participants found that encouragement was essential for the students in order to get "their response" (Helen, 3rd, F), as "they did not have the confident to answer questions loudly, and were scared and a bit shy" (Diana, 3rd, F). This was probably because they "did not understand English as well as the questions" (Helen, 3rd, F). Although "few of them were very smart" (Bertha, 3rd, F), and "they tried to answer in English"

(Jonathan, 3rd, M), they were still "worried about their English" (Bertha, 3rd, F). As a result of students' problems speaking in English, if they understood the questions "asked in English [and] if they said they can't then [they] asked them in Malay language but [they] had to explain in English [and were] finally asked to repeat the answer in English" (Bertha, 3rd, F).

From *Written Reflection on Carrying Out Experiment*: Some 7 of the 61 participants commented about carrying out experiments in the laboratory with one participant saying that "lack of experience in the laboratory resulted in the students being unable to carry out the experiment" (R20). The other participants said "the 'experiment' was very controlled in nature" (R12).

Interviews On Carrying Out Experiments: The interviews conducted with the 10 participants also concerned their students' participation in carrying out experiments; again several themes emerged. As a result of lack of experience in the laboratory, one participant commented on "the importance of steps in doing experiments" (Helen, 3rd, F), and another said "every time the participant was the one who demonstrated the experiment" (Bertha, 3rd, F), as "the [laboratory] space was not very suitable" (Diana, 3rd, F).

Written Reflection On Problem Solving: only 3 out of 61 participants commented with one participant said problem solving was "very weak since their Lower Secondary School or Primary School's basic [science] was weak" (R1, 4th), whereas the other two participants noted "the questions were more individual and good [students normally prefer personal to group questions from the the teacher]" (R6, 4th), and students were "cooperative, they were able to solve [the] problem" (R22, 4th).

From *Interviews on Problem Solving*, the participants noted that problem-solving was "done after an experiment was completed" (Helen, 3rd, F), and after students had to be "taught and reminded what was the important points about the topic" (Diana, 3rd, F). The problems were "discussed and solved in groups" (Bertha, 3rd, F), with some students "not [being] able to solve the problem as they did not understand English and the content" (Jonathan, 3rd, F) unless "the question was translated into the Malay language" (Bertha, 3rd, F).

Written Reflection On Answering Students' Questions: Some 45 of 61 participants commented on issues about participants answering students' questions. Several themes emerged from participants' comments about answering their students' questions. Some participants commented that their students who were active in posing questions either "during the teaching process" (R23), or "personally in the staffroom" (R2). However, there were students "who seldom or never hesitated to ask questions" (R61), "although they did not understand" (R44), and this may have been due to "their poor knowledge of the subject meaning they did know what to ask" (R61). Some participants answered their students' questions "directly in a simple way according to the content of the subject" (R10). Their answers were "in English if it involved numbers" (R3), some "explained in detail [and] solved solutions step by step until they understood" (R43) by "giving examples so that they satisfied" (R12). Some participants prepared the content of the lesson "early so it was easy to give good answers so they felt more confident" (R17). If participants could not answer students' questions on the spot, they "would answer on the following day" (R9). However, some participants preferred to answer students' questions in the Malay language because "it was easier [because] some students did not understand an explanation in English" (R57).

Interviews On Answering Students' Questions: In the interviews the participants reported that their "students rarely asked questions again but the participant was the one who asked questions" (Helen, 3rd, F). In order to get their students to ask questions, one participant "asked and asked the students again to ask questions" (Jalang, 3rd, M). If the students asked a question, the participants either "tried to answer the question"(Jonathan, 3rd, M), but if they "could not answer on the spot, they referred to the other colleagues or other teacher" (Diana, 3rd, F). Another strategy was if there was "no straight forward answer" [they] presented another situation or other examples in order to get the students to think" (Camela, 3rd, F).

Written Reflection On Handling Students' Responses: Some 48 out of 61 participants responded to the issues of handling students' responses in the classroom. The participants commented on aspects which they found difficult to handle in students' responses, indicating perhaps that they did not know the answer, or lack of teaching skills. The first difficulty was that it was "very hard to get students' responses" (R59), because the students were "passive during teaching and learning process" (R2) and "most of the students did not show any interest" (R55), again probably because they "did not understand English" (R9).

Some participants suggested that students needed to be "motivated and encouraged to try again" (R12)**,** and that it was important when their "responses [were] good to congratulate them. If they did not give a good response, prepared the alternative ways [skills of asking questions]" (R17). Students' responses "should be treated equally, and the teacher should never ignore wrong or inappropriate answers" (R27), and instead "give suggestions rather than one answer" (R34). Participants should "employ lessons in bilingual Malay language and English language" (R4), "think of the students' needs and their prior knowledge" (R10), in order to "get responses from the students" (R18), and the participants needed to make sure that they "understand what had been learned and this indirectly increases their participation" (R9).

Participants with positive experiences mentioned students who were "active and interested in the lesson" (R60), meaning their "responses were quite good" (R33), and that the participants "handled their responses in a well-mannered way, encouraging them to give their opinion and respecting their point of view" (R25). Some participants "always responded to questions posed, and never ignored students' questions going on to correct the wrong answers from students and accepting the answers that were almost correct" (R46).

Interviews On Handling Students' Responses: In the interviews one participant reflected on her weakness in responding to student questions, saying that she felt she "did not giving all students the opportunity to think because of choosing a student, then asking him or her to answer" (Helen, 3rd, F). If students gave good answers, the participants said they responded encouragingly saying, "that was good" (Diana, 3rd, F), but if "the answer was wrong or not exactly correct" (Diana, 3rd, F), then they encouraged them to "have another try" (Bertha, 3rd, F), or by "asking easier questions for them to understand in order to get answers" (Helen, 3rd, F). However, the participants said that if they "explained in English then, students just answered 'Yes' or 'No' due to their lack of understanding or confusion about the content in English" meaning they "had to explain the content in Malay language too which is why most of the time they answered in Malay but I did encourage them to use English" (Bertha, 3rd, F).

Written Reflection On Mediating Physics Instruction Activities in English: These reflections dealt with participants' beliefs about their physics teaching practice in English during the school placement. Some 49 of the 61 participants commented on issues to do with physics instruction in English, with five saying that they had no problems with this medium of instruction and that it was "not a problem to teach in English but students did not understand" (R57), because of that "I explained to them in Malay language" (R56), and "it all depends on whether the students have a good and strong basic in English. If the students have problems in understanding lesson conducted in English, it is useless for the teacher to conduct the lesson in English" (R25), because "students asked to translate into Malay language" (R59). The rest had English difficulties either on the part of the participants [pre-service teacher] or their students.

Some 18 participants believed that the difficulties of physics instruction in English during their school placement were on the part of the students: learning both physics and English simultaneously "learning physics is a task, [and] learning English is yet another task" (R2, 4^{th}); some students from the weak class did not understand both the language, and physics terms in the textbook or did not understand participants' explanations in English. "Some did not understand the content as a result of physics instruction in English "especially when they involve explanations" (R7, 4^{th}) and because "they had difficulty with physics terms in the textbook" (R6, 4^{th}), as well as lacking or poor basic English language vocabulary or words such as "understanding, writing, reading or spelling and pronunciation" (R14, 4^{th}). These difficulties led to lessons becoming uninteresting: "Lessons did not attract students' interest [and] lessons became one way communication". Because of "limited communication with the students as a result of English medium instruction, the students tended to be quiet and were not active in class" (R31). The reason why some participants inevitably conducted instruction in Malay language was because "most of them needed me to explain in Malay language" (R43).

Suggestions to overcome the difficulty were: physics concepts taught bilingually either "explained both in Malay language and English" (R8, 4^{th}); "translated from English to Malay language" (R23), using "repeated explanations in Malay language" (R21), or taught in English but "used simple language" (R37), or "appropriate teaching aids and [physics] explained to the students slowly" (R12, 3rd). In addition, the difficulties of physics teaching in English on part of the participants meant that "it takes a long time to finish the syllabus because students have to learn both physics and English at the same time" (R12, 3rd), repeated explanations in English and Malay language, and English proficiency was not that good due to secondary learning experience in Malay medium.

Suggestions to overcome the difficulty on part of the participants were "an on-going practices in English on part of the participants. I hope after this break, I would be able to teach 50% in Malay language but I still need to practise due to my secondary learning experience in Malay language [and] I have to do the revision to translate my knowledge into English [for] terminologies which I do not know how to pronounce in English [I am] fortunate to have English dictionary installed in my computer which can read and pronounce" (R61). However, some participants were optimistic that their English was improving and started gaining confidence to teach secondary school physics "I had no confident to teach in English but since now, everything seems better" (R22).

Interviews On Mediating Physics Instruction Activities in English. This same question in the 'written reflections' about mediating physics instruction activities in the classroom was again asked in an individual interview after classroom observation at secondary schools. Interviews again revealed that physics instruction in English was influenced by the participants' confidence gained from their students' expectations, but delivering content bilingually was preferred. Interviews were conducted with 10 participants concerning physics instruction in English and several themes emerged. The participants "employed two languages" (Camela, 3rd, F), as some of them were not good at English "taught physics in English based on prepared text" (Helen, 3rd, F), as well as "kept trying referring to colleagues" (Issac, 3rd, M), "but when I entered the classroom I gained confidence because of high expectation from the students [because the participant has a good command of English]" (Bertha, 3rd, F), as well as anticipating that "if I were teaching for a long time then I might be able to teach physics in English better" (Helen, 3rd, F). The problem was that "if I taught in English some students did not understand, and I spent a lot of time" (Jonathan, 3rd, M).

8.2.3 Summary of Findings for Research Question Four

The responses presented above suggest that the teaching sequence in the microteaching can be applied for a variety of physics content areas (they have a lot resources and materials from other groups), but this did not occur in the classroom during the participants' practicum. Participants' concerns about the teaching sequence on specific physics content, in particular, during their practicum revealed that they experienced constraints to the implementation of their teaching sequence based on didaktik analysis. First, from the researcher's observations, participants had to adhere to rules set by the respective schools. During the teaching sequence, activities such as small group discussion, answering teacher's questions, carrying out experiments, answering students' questions, handling students' responses, problem solving, and the role of the participants in mediating of those activities through English and Malay languages, were not really conducted following the didaktik-based analysis teaching practice. Four factors seemed to influence this - participants' content knowledge, understanding the concepts of didaktik analysis, mediating teaching sequence through English language, and the acceptance or not of these strategies and activities by experienced physics teachers (didaktik analysis) in respective schools. However, the researcher found that some participants' views of the use of the teaching sequence based on didaktik analysis showed greater awareness of a more advanced understanding of physics content knowledge.

8.3 CHAPTER SUMMARY

This chapter presented the research findings about the influences of a variety of factors including physics content knowledge on participants' use of a teaching sequence based on didaktik analysis. It began by discussing how the didaktik analysis assignment of specific physics content was *only* applied in the microteaching and in the classroom practicum experience *only if* it was based on specific physics content done in the assignment, and then followed by the teaching sequence and associated activities in the classroom. The following chapter, Chapter 9, presents the researcher's reflections on the study and discusses the research findings for this thesis with respect to relevant literature. It also contains a discussion of the limitations of the study, and makes conclusions and recommendations for future research in the area of didaktik analysis generally, and the use of a teaching sequence specifically.

CHAPTER 9

DISCUSSIONS, CONCLUSIONS, REFLECTIONS, AND RECOMMENDATIONS

CHAPTER OVERVIEW

This final chapter summarizes the findings for the study by discussing the four research questions from the previous three chapters, and reflecting on the study with respect to the literature. It begins with a summary of the methodology and conclusions from the research findings, followed by reflection on the implications of the findings for teaching and learning, together with a discussion of the limitations and recommendations for future research. The chapter ends with some concluding thoughts.

The chapter is in four sections. Section 9.1 revisits the research methodology, linking the intervention specifically with the four research questions by presenting conclusions concerning: the influences of learning experiences on participants' attitude toward, and beliefs about, physics teaching prior to the intervention, and the effect of didaktik analysis on their beliefs and experience in terms of personal content knowledge and pedagogical content knowledge after the intervention; factors from assignments influencing the effectiveness of didaktik-based analysis microteaching and practicum; the ability to engage in reflections and whether this was due to methods course generally, the assignment on didaktik analysis specifically or the microteaching and practicum; and whether or not the teaching sequence can be implemented for other physics content areas, its successful as well as factors inhibit or facilitate the use of didaktik analysis the use of didaktik analysis in a teaching sequence in microteaching and practicum. Section 9.2 deals with reflections on the implications of the findings for teaching, learning and research. Section 9.3 is a discussion of the limitations of the study, and recommendations for future research. The chapter ends with Section 9.4 which contains the concluding thoughts.

9.1 DISCUSSION AND CONCLUSIONS

9.1.1 Summary of Methodology

This research involves secondary teacher education and the researcher adopted an interpretive paradigm for the work. This decision was based on consideration of the research questions, research paradigms and the theoretical framework. A subjectivist epistemology suggested by von Glasersfeld (2002) seems consistent with an interpretive view, and was thus adopted. Here, data that emerged were constructed by participants rather than gathered from them. Although the intervention took place over six months, participant constructs consist of knowledge derived from their many experiences. In a similar manner, what the researcher himself experienced as a student, physics teacher and teacher educator, helped him to appreciate the importance of the context of an inquiry, and from this he developed awareness, knowledge and sensitivity to many of the issues subsequently encountered as a teacher and teacher educator when working with the participants. As a teacher educator of these participants in their final year of undergraduate study, the researcher thus attempted to reconstruct or interpret the data from his insights and "experience" in accord with the views of Patton (1990, p. 27), who asserts that the researcher himself acts as 'the instrument'. The researcher is responsible for his data, and consistent with the theoretical basis to the work (i.e., didaktik analysis), it is also essential to include aspects of his experiences and perceptions, within the data collection and subsequent analyses.

Participants' constructions were elicited through interpreting text, questioning it, taking into account the researcher's situation, and elucidating the context of the participants. Phenomenology analysis was used in terms of coding and content analysis. These constructions then were compared and contrasted in 'on-going meetings' between the researcher and participants, and examination of data constructed from participants' group assignments, lesson plans, self-written reports, interviews, evaluation, 'written reflections', and observations of microteaching and the practicum. Inspections of group assignments and lesson plans enabled the researcher to identify the actual beliefs and experiences of participants about didaktik analysis. Examinations of self-written reports, interview transcripts, evaluation, 'written reflections', and observations yielded many significant insights, not only into the participants' prior physics learning experiences, attitude-toward-physics and learning, physics teaching self-efficacy beliefs and conceptual understanding of physics, but also participants' experiences of practicum. Themes of participants' views on their beliefs and experiences were summarized into a report of the research findings. The themes, in turn, sought to increase trustworthiness and authenticity of the data and findings (Lincoln & Guba, 2003). A concept map of enhancing understanding of didaktik-based analysis teaching practice is shown in Figure 7.3, on page 287.

9.1.2 Participants' Learning Experiences of their Teacher Teaching Methods, Content Knowledge, Personality, and Motivation; and Environment

The data suggest that for the third and fourth years there was considerable variation in their beliefs and their prior physics learning experiences with their teachers at secondary school and lecturers in the university. In particular their experiences varied with respect to the classroom and/or lecture hall and laboratory; their teachers' or lecturers' teaching methods, content knowledge, personality, and motivation; and the learning environment.

Participants' physics classroom learning experiences of their teachers' physics teaching methods were found to affect their attitude-toward-physics and learning, consistent with the findings reporting in the literature. Thus, the use of textbooks, lectures and notes, teacher demonstration and experiments, and problem-solving have a direct impact on participants' attitude-toward-physics and learning (Nolen, 2003; Osborne & Collins, 2001; Sadler & Thai, 2001). In this work there were a variety of secondary physics classroom learning experiences described. For example, one of the important findings was that the over-use of textbooks makes physics learning difficult and boring, consistent with the views of Magnusson, Krajcik and Borko (1999) who suggest that such teaching of science is the goal of 'didactic' teaching, which is aimed at transmitting the facts of science. Another finding related to the over-use of the textbook was that the teachers wanted to make sure they covered the syllabus, suggesting that the teachers were bound by the curriculum, a similar finding to that reported by Tobin, McRobbie and Anderson (1997). The findings here suggest that one factor that contributed to physics learning being seen as difficult and boring, was that the teacher talked by looking at the textbook and sometimes taught wrong concepts of physics – consistent again with a 'chalk-and talk' approach (Osborne & Collins, 2000). Such an approach is highly teacher-centred in nature (Angell, Guttersrud, Henrikson & Isnes, 2004), and involves straight information-transmission approaches (Hashweh, 1987). Niedderer (1992) considers this sort of transmissive teaching as consisting of the teacher attempting to transfer correct scientific theories and concepts directly from the teacher to the students. These approaches according to Barros and Elia (1998), and others (e.g., Hashweh, 1987), are likely to be due to a teacher's lack of confidence, as a result of poor conceptual understanding of physics.

Participants physics classroom learning experiences associated with their teachers' teaching methods also were classified either as academically rigorous, 'didactic', or discovery in nature (Magnusson, Krajcik & Borko, 1999). Similar learning in this work deemed boring, related to learning a lot of formulae, the teacher imparting too much physics knowledge that was too abstract in nature, and that did not grasp the students' attention. Sometimes the teacher did not know how to manipulate formulae, or taught wrong physics concepts, they seldom asked the students any questions, or asked the students to study on their own. This learning again is categorised in the literature as the rote learning of science concepts and facts (e.g., Elby, 1999; Novak, 2001). The learning experiences mentioned seem to be mostly related to the university learning experiences, probably because they were the most recent. Previous research about pre-service teachers' learning experiences suggest they are dominated by experiences of teaching methods that are either teacher-centered or student-centered, with the teacher on 'one side' and the students on 'the other side', and an emphasis on cognitive processes (Kansanen, 2002). Lijnse (2000) as a didaktik scholar, identifies these findings as consistent with the psychological, sociological, linguistic, and philosophical contexts of the *learning*, but not with the *teaching*.

With regard to their tertiary level learning experiences, the lectures and notes were perceived by participants as making physics learning difficult and boring. The experiences reported here of an approach that requires students to just copy notes from transparencies without explaining them, and the lecturer always writing on the blackboard, is similar to other findings in the literature (see, e.g., Osborne &

Collins, 2001). However, for some participants in this work, getting ‘crucial’ notes from the lecturer was seen as making physics learning easier if the teacher explained things clearly, and encouraged students to summarise notes from reference books. This rather positive view of such learning contrasts with other research (e.g., Osborne & Collins, 2001), which is rather dismissive of such teaching.

In the case of laboratory learning experiences, one of the findings in the present work was that teachers seldom asked students to do experiments, and instead typically performed demonstrations, either to save time and or because of a lack of equipment, or large numbers of students. In addition, the teachers commonly emphasized scientific methods found in experiments, and conducted physics experiments incorrectly, or imposed scientific findings from the textbook when the results did not come out as expected. This is similar to work by Angell, Guttersrud, Henrikson and Isnes (2004), who also link laboratory work with fun, but suggest that if participants find such work ‘fun and easy’, it may indicate they were not fully exposed to the nature of science. In the laboratory, their teachers teaching methods in the present work seemed to be similar to those reported by Kang and Wallace (2005) which were “to prove the veracity of scientific knowledge; to provide the opportunity to apply the concepts; to motivate students; to provide first-hand experience to assist learning; to train the scientific way of thinking, and to prove the exploratory power of scientific theories” (p. 9).

Previous research suggests physics learning experiences in secondary school and university classrooms and laboratories are seen as interesting by students if a variety of teaching methods are employed (Angell et al., 2004; Kempa & Diaz, 1990; Sadler & Thai, 2001). However, many of these studies failed to explore the variety of physics content reported from this work. The best thing to make physics learning interesting, according to the participants in this work, is to relate the physics concepts to everyday life, similar to other reported work (e.g., Angell et al., 2004; di Sessa, Gillespie & Esterly, 2004). However, everyday things may not involve phenomena that participants observe in the same way as scientists do. For example, participants cannot quite believe that there are any forces on a book caused by a table, but physicists assert that there is a force on the book caused by the table. In this work, the participants said they passed their exams in secondary schools well, teachers provided sample questions together with the solutions, and showed them how to use formulae to solve physics problems. The findings thus indicate that the use of mathematics is seen as finding the right formula(s), and doing the necessary manipulations which is similar to work by Angell et al. (2004. p. 692), who categorise this type of learning as meaning that students "with an orientation towards 'physics content and basic laws' " pass exams well.

With regard to teaching methods, the participants also said that their teachers' personality traits and own motivation toward teaching, influence their attitude-toward-physics and learning, similar to other work (e.g., Barros & Elia, 1998; Nolen, 2003). For example, teachers that make students work hard, may in fact help students understand physics. Likewise, requiring students to work at home, or explaining physics to students personally, makes the subject interesting, even if conceptually demanding as reported by Angell et al. (2004). Teacher personality traits and motivation seems strongly associated with positive learning experience (Woolnough, 1994), and subsequently leads to participants enjoying physics, physics learning, and understanding physics better.

In summary, participants reported both positive and negative learning experiences, both of which seemed to influence their attitudes, knowledge, thinking, feeling, creativity, and expectations (Vosniadou, 1999). The reported learning experiences here are similar to other research which suggests pre-service teachers link positive experiences with activities that are interesting, fun, exciting, and enjoyable, and are thereby seen as making content easier to understand and subsequently to lead to interest in physics and physics teaching. On the other hand, negative experiences were linked with a view of physics learning as being difficult and boring (Kansanen & Meri, 1999).

9.1.3 The Influence of Participants' Learning Experiences on Physics Teaching Self-Efficacy Beliefs, Conceptual Understanding, and these Influence their Attitude Toward, and Beliefs About, Physics Teaching

The research findings here derive from both a theoretical and practical sense, from previous research about physics learning experiences influence on pre-service teachers' attitude toward, and beliefs about, physics teaching.

The participants' physics teaching self-efficacy seemed to be influenced by their prior learning experiences. Although no statistically-significant correlation between learning experience and physics teaching self-efficacy was found for either cohort in the quantitative data, observations of the microteaching and practicum support the findings of the BAPT questionnaire that the third years were forced to enrol in physics courses, and they lacked physics learning experiences at secondary school. In addition, the low achievement of the third years in the TUG-K and FMCE tests (suggesting a limited grasp of kinematics graphs and Newtonian concepts) led them to view physics teaching (but not teaching per se) as something of a last resort, career-wise. This was at least in part due to their belief that teaching physics in English would be difficult, not only due to language problems, but also the physics content. These beliefs about the difficulty of teaching physics, and subsequent low self-efficacy towards physics teaching, may have cognitive and affective roots, which seem to influence their confidence and ability to teach secondary school physics. Although the third years had experienced primary school teaching, they seem influenced, in terms of career interest, as a result of their low interest in teaching physics resulting in a negative attitude-toward-physics teaching. However, some participants at least seem to feel better prepared for physics teaching as a result of the intervention (i.e., the didaktik analysis-based methods course), and, for example, tried to improve their physics content knowledge.

Examination of self-efficacy in relation to science teaching has been the focus of much study by other researchers (e.g., Bleicher & Lindgren, 2005; Rice & Roychoudhury, 2003; Tosun, 2000). Self-efficacy is context-specific and related to specific tasks (e.g., Dalgety, Coll & Jones, 2003; Pajares, 2002; Riggs & Enochs, 1990). So feeling confident during the early stages of the participants' methods course can influence their preferences, either physics teaching or mathematics teaching (Bleicher, 2006) before they go into the classroom to teach physics as reported in this work. So they may see physics as interesting, and have a career interest in physics teaching. Interest is defined here as "a phenomenon that emerges from an individual's interaction with his or her environment" (Krapp, Hidi & Renninger, 1992, pp. 5). Krapp et al. (1992) characterise interest both as a characteristic of a person (i.e., individual interest or topic interest), and as a psychological state aroused by specific characteristics of the learning environment (the situational interest). For example, participants' physics learning experiences for teachers possessing low self-efficacy, were more likely to be teacher-centred in nature, consistent with a of lack of strong science content background in physics, as reported in the literature (Enochs & Riggs, 1990), and as noted above.

At the start of the physics teaching methods course, participants who reported positive learning experiences were confident about teaching physics. They were more likely to have high self-efficacy, and seemed to prefer physics teaching to secondary school. Participants with low self-efficacy, appeared to lack physics learning experiences, or hold limited or weak conceptual understanding of physics making them under-confident about their ability to teach secondary school physics. Bleicher and Lindgren (2005) suggest such people see physics teaching (but not necessarily teaching as such) as a last resort in terms of their career interest. Such teachers engage in science instruction whenever possible that avoids their lack of content knowledge being exposed, and as reported in this work, are often forced to enrol in physics courses and experience stress when asked to teach secondary physics (see also Enochs, Scharmann & Riggs, 1995).

However, by the end of the semester and during the practicum, the participants' low outcome expectancy in terms of teaching physics in the third year students seemed to abate somewhat, suggesting that the didaktik analysis assignment and experiences influenced their physics teaching self-efficacy beliefs. In other words, participants' self-efficacy improved through their experiences of the methods course, specifically not only in terms of career interest, but also their interest in physics teaching. Experiences that may have contributed to this, included the conceptual analysis of physics content, the analysis of textbooks, the analysis of the literature on students' alternative conceptions, developing lesson plans, and implementing the teaching sequence in the microteaching and practicum.

It is of some concern here that some of these participants who hold negative attitudes towards physics teaching and seemingly little interest in physics teaching, will soon be teaching physics in Malaysian secondary schools. Therefore, the physics teaching methods course needs to be concerned with preparing participants with better conceptual understanding of physics, which might then lead to higher physics teaching self-efficacy beliefs which may then improve their attitudes toward physics, and subsequently physics teaching as something of interest.

According to the literature, developing pre-service teachers' self-efficacy is an essential part of physics teaching methods courses, and this occurs through four sources of experience (Bleicher, 2006; Pajares, 2002; Richardson, 1996). The four experiences noted above categorised as mastery experiences, or performance accomplishment exercises, when participants encountered difficulty doing the assignment on didaktik analysis, they actively responded asking the researcher for help, and as a consequence they felt responsible for their own learning. After these actions they felt more confident about teaching physics, as they felt they understood both the content and teaching methods. It was, however, the vicarious experiences when the participants discussed their assignment in a group or cooperative among group members – that made them more confident about teaching physics. The last source of self-efficacy beliefs are the physiological states and indexes, and the stress reduction or emotional arousal that occurs when participants come to appreciate the weaknesses and strength of their teaching practice through their reflections after the methods course was completed. Finally, positive comments, in terms of support, praise, and positive reinforcement from the researcher, mentor teacher, supervisor and students in their classrooms, act as a form of social or verbal persuasion – and this helped foster more positive attitudes towards physics teaching. However, it is important to note that positive physics teaching self-efficacy can also prove problematic in some cases. Wheatley (2000) identifies eight things: "traditional methods, traditional goals, too certain efficacy, overly-optimistic novices, hypothetical future efficacy, pretend teacher efficacy, competitive teacher efficacy, and independent teacher control" (pp. 18-21), that he says can lead to over-confidence resulting in high self-efficacy, but low teaching competence.

Although, participants achieved well in their physics courses in the university, it seems many did not have sound conceptual understanding as noted in the findings from the TUG-K and FMCE tests. Bleicher (2006) notes that conceptual understanding involves students understanding the interrelationships among facts, concepts, and principles in the form of propositions which, when used as constituents within procedures, algorithm or rules, becomes the form of procedural knowledge necessary for problem solving proficiency. Hestenes, Wells and Swackhamer (1992) point out that 'teaching to the test' normally means "students do better on *quantitative problems* (numerical) where the answer is a number obtained by substitution into an appropriate equation, and even on harder problems that require some algebraic manipulation" (p. 150). The participants in this work seemed to fall under this category. McDermott (1993) and others (e.g., Bao, Hogg & Zollman, 2002; Niedderer, 1992) support such a view saying "solving standard quantitative problems is not [an] adequate criterion for functional understanding" (McDermott, 1993, p. 2), even if the aim was related to the use of formulae. Likewsie Bao et al. (2002) comment on the importance of the context dependent nature of conceptual learning (i.e., the ability to understand the concepts within a particular context of learning), if instruction to be effective, consistent with the views of Minstrell (1989) who calls for teaching science for understanding.

In summary, the research findings reported here suggest that these participants' previous learning experiences were linked with their attitude-toward-physics and learning, and conceptual understanding of physics content area, and these are associated with their physics teaching self-efficacy beliefs. Within the didaktik tradition such factors are important in that they impact upon didaktik-based analysis teaching practice when participants experience their microteaching and practicum (Dijk & Kattmann, 2007), and this is explored next.

9.1.4 Factors from Assignments Influencing the Effectiveness of Didaktik-Based Analysis Teaching Practices; Conceptual Analysis, Analysis of Textbook, Analysis of Literature on Students' Alternative Conceptions, and Lesson Plans

Teaching practices, it seems, were shaped by the participants' beliefs about their experiences of the methods course generally, and the didaktik analysis specifically. Successful outcomes were enhanced conceptual understanding of specific physics content, as a result of the components of the didaktik analysis done in the assignment. These components were; conceptual analysis of specific content, analysis of textbooks, analysis of the literature on students' alternative conceptions, and lesson plans. It seems these activities enhanced the participant's ability to access such existing resources and materials, and provided them with the opportunity to learn more physics content. As the topic of the assignment differed for each group participant, experiences and beliefs about their didaktik analysis assignment also varied from content to content, such as force and motion, force and pressure, heat, and light. Such topics may to some extent reflect some different participants' conceptual understanding, and subsequently their interest in physics teaching.

Participants believed that the conceptual analysis of specific physics content done during the assignment on didaktik analysis improved their teaching practice in the microteaching and practicum. Along with improving their understanding of specific physics content, the assignment increased their science vocabulary, improved their understanding of the syllabus' requirement, and improved their attitude-toward-physics and physics teaching. It also helped them in identifying problems of student learning, and increased their confidence to teach physics because they felt they had a better understanding of the problems their students might encounter.

Difficulty in conceptual analysis was linked generally with lack of understanding of some of the methods course content, and specifically with the conceptual analysis component of didaktik analysis, including specific physics content as well as the English language barrier. Other difficulties with the assignment were to do with a perceived lack of reference material in textbooks, difficulty in locating material in electronic journals and journals related to specific physics content, and knowing how to transform specific physics content into a teaching sequence.

Analysis of textbooks revealed their strengths and weaknesses, as well as understanding of the curriculum specifications. The advantages of this analysis were deeper study of specific content as a result of comparing a variety of material from textbooks or journals, and having the opportunity to choose good textbooks. Some identified weaknesses of the textbooks were: insufficient specific physics content; some content was outdated; there were few activities; not much on problem-solving; and the presentation was unattractive and boring. Other problems with textbooks were a lack of examples, and a lack of clear explanations or detail about the content such as the concepts, laws and principles, meaning instruction based on the textbook would probably result in students having difficulty understanding the physics content.

The participants' ability to analyse the literature on students' alternative conceptions from websites or journals suggests that this was useful in terms of preparing lesson plans, changing prior views about how to do lessons, and improving teaching practice in the microteaching and practicum. This didaktik analysis component, like the analysis of textbook, seemed to improve participants' understanding of specific physics content, improved their attitude toward physics, and helped them in identifying problems of students' learning. Subsequently participants were more confident to teach secondary school physics. This component of didaktik analysis (analysis of literature on students' alternative conceptions), together with the conceptual analysis of physics content, thus seems essential.

Finally, the participants developed a lesson plan, but generally did not fully follow the format established by the researcher, although their plans did consist of 'learning outcomes', a teaching sequence, assessment procedures, and reflections. However, during the practicum the lesson plans developed were not strongly based on didaktik analysis, but were more in accord with the textbooks and curriculum specifications, and with only some thought of didaktik analysis.

These data suggest that the participants' teaching practices in the microteaching and during the practicum were influenced by their beliefs about their previous learning experiences, the didaktik analysis assignment, and mastery experiences. This is consistent with previous research on students' alternative conceptions as discussed by Driver (1983). Although the participants in the present work were students (albeit pre-service teachers) in physics education, it is reasonable to believe that if their physics conceptions are contrary to those of scientists, and if these are not sufficiently addressed, they may carry these over into in their physics teaching. It is widely recognised that conceptual understanding of specific physics content (e.g., Hammer, 1994; McDermott, 1984, 1993; McDermott & Redish, 1999) and understanding of didaktik analysis components in teaching methods courses play an important role in the development of a positive attitude-toward-physics and learning, and physics teaching self-efficacy beliefs. For example, the conceptual analysis conducted in this work as part of the assignment on didaktik analysis resulted in participants' obtaining a deeper understanding of specific physics content, as proposed in Klafki's (2000) first, second and third sets of questions – which relate to consideration of the specific science knowledge to be taught (Kansanen, 2002; Leach & Scott, 2002; Mėheut & Psillos, 2004; Savinainen, Scott & Viiri, 2005), and suitable teaching sequences (Klafki's fourth and fifth sets of questions). Kansanen (2002) and Uljens (1997) stress the importance of the cognitive processes that are involved between the teacher and the students during the teaching sequence.

A recent review (Fensham, 2004) suggests that didaktik analysis is vindicated when pre-service physics teachers in physics education say "only now do they know what they learnt in physics!" (p. 158). The findings in the present work support that view that the use of didaktik analysis as used here places emphasis on conceptual analysis of specific physics content, analysis of textbook, and analysis of literature on students' alternative conceptions, and subsequently leads to the improvement of classroom teaching practice. A key feature of the present work then is that the pre-service physics teachers engaged with physics specific content (Niedderer, 1992), looking at research findings of students' alternative conceptions about force, the history of scientists' thinking about force, and textbook presentations of force.

In this study, similar to the work of Niedderer (1992), some participants were found to be quite capable of accessing existing resources and materials and this provided them with the opportunity to learn more physics content which in turn resulted in the following outcomes:

- improved understanding of specific physics content
- improved attitude toward physics
- identification problems of students' learning difficulties and understanding of specific physics concepts
- improved teaching practice in the microteaching and practicum, and
- more confidence to teach secondary school physics.

Ultimately, it is important, as Fensham (2004) points out, that in didaktik analysis, the transposition (Gundem, 2000; Tiberghien, 2000) or learning demand (Leach & Scott, 2002) of the content of school science should be "determined by what is accepted as lying within the content of the corresponding disciplinary science" (p. 158). This argument contrasts with the view of Black (1986), who argues for the importance of integrated or coordinated science, but Fensham (2004) adds that due to the socioscientific problems there need to be linking between the knowledge in the sciences and other knowledge.

The researcher suggests here that Shulman's (1986) claim that science content knowledge is indeed the 'missing paradigm' in the School of Education in which this study was conducted. In the past we have focussed on the 'process-product', and "only see pedagogy of the content topic as the problematic focus", meaning we "ignore the problematic nature of the content" (Fensham, 2004, pp. 152-153). Kansanen (2002) notes that it is not knowledge or content that is missing, but "the centrality of character" (see also Shulman, 1992). This issue is central to the concept that has been investigated in this thesis, and interestingly, this is an accord with Fensham's (2004) view that "an important point is misunderstood when exemplary teachers are chosen for study by the grades their students achieve, and not by an evaluation of their didaktik interpretation" (pp. 153).

This study has raised many questions about the notion of didaktik analysis and its features. Buchberger (2000) describes didaktik analysis as the science of/for the teaching profession, and Uljens (1997) argues that didaktik analysis is regional-based theory within the framework of Nordic and German research traditions, and as such it is strongly culture-bound (Hudson, 2002). Uljens (1997) describes this in terms of cognitive learning theory, in which he says didaktik analysis places particular emphasis on the interaction between the teaching, studying and learning processes. The researcher thus suggests that there are many insights within this tradition about teacher education that can be learned from Klafki's (2000) model of didaktik analysis. Thus, the concept of *transformation* in didaktik analysis is central, and the curriculum specifications provided by the Malaysian Ministry of Education need to be seen not only in terms of specific content, but also in terms of the theory of that content and the educational goals one is seeking to achieve when teaching that content.

9.1.5 The Role of Reflections on the Physics Teaching Methods Course, Didaktik Analysis and Teaching Practices

It seems that the participants were able to engage in reflections on their didaktik-based analysis teaching practices. They were beginning to reflect more thoughtfully on their actions by the end of physics teaching methods course, and during their teaching practices in the microteaching and the practicum. Some participants engaged in 'technical reflection', where the focus was on the physics teaching methods course, and teaching practice issues in the microteaching and practicum. Others engaged in 'practical reflection', where the focus was on didaktik analysis issues (how to teach effectively based on didaktik approach).

Participants' reflections, not only on their physics learning experiences at secondary school, but also at the School of Science and Technology, and School of Education, at the University of Malaysia Sabah, were linked to their self-efficacy beliefs, and gave indications as to whether or not the participants felt they had the confidence to teach secondary school physics. Participants' experiences of the teaching practice in the microteaching indicate that their didaktik analysis assignment resulted in improved physics teaching self-efficacy beliefs. However, the participants also reflected on the constraints of the practice teaching in the microteaching, and gave fresh perspectives on the relative differences between the microteaching and the actual classroom in the practicum. Reflections on teaching practices in the microteaching and practicum were perceived as beliefs about physics teaching and student learning, and their confidence in their ability to teach secondary school physics varied because of these experiences and beliefs. The researcher believes that the participants would be able to adopt the didaktik analysis-based teaching practices if their confidence to teach secondary school physics increased, and if they were provided with accessible resources and had good content knowledge in specific content.

Participants engaged in reflections on the physics teaching methods course and highlighted their own experience and beliefs about the didaktik analysis assignment, such as the conceptual analysis of physics content, analysis of literature on students' alternative conceptions, lesson plans, and teaching sequence. Generally, references on didaktik analysis assignments, meant there was a perceived need for them to re-visit the secondary school physics content.

Some felt that getting a good grade in this course might influence their teaching practice and possibly mean they would then become a good physics teacher. These reflections seemed to influence participants' beliefs about physics teaching practice in the microteaching and practicum, and they said they believed in the importance of didaktik analysis-based teaching. However, it was hard to find examples of participants who implemented this in their lesson plans and teaching sequence. Most participants seem bound by the physics content contained in the curriculum specifications, and subsequently this impacted on their lesson plans and teaching sequence. It would seem then that having experiences with didaktik analysis assignments, and microteaching and practicum, are not enough alone to ensure that participants will actually use didaktik analysis-based teaching practice in their future teaching upon graduation.

The findings presented here suggest that the participants' physics learning experiences factors were influential in terms of developing their capability to be reflective teaching practitioners. This finding within the notion of didaktik analysis-based teaching practice is seen as 'context-dependency', in that the teaching-studying-learning process is intentional, that actions are based on values and purposes, and that the process is located in the classroom and teacher training programme (Kansanen, 2002). Reflective teaching practice within this notion is seen as a continuous shifting between reflection and decision making, planning and action, and evaluation and action (Kansanen, 2002; Uljens, 1997). The participants' reflections were linked with their self-efficacy beliefs with respect to whether or not the participants felt they had the confidence to teach secondary school physics. Other researchers have identified four contexts of reflections (e.g., Abell, Bryan & Anderson, 1998): reflecting on others' teaching; reflecting on one own teaching; reflecting on expert opinions; and reflecting on self as learner. These ideas are now discussed in relation to the findings from the present work.

Reflections on the Physics Teaching Methods Course: Participants engaged in reflections in the physics teaching methods course, and highlighted their own experiences and beliefs about the didaktik analysis assignment. In particular they commented on; the conceptual analysis of physics content, the analysis of literature on students' alternative conceptions, the lesson plans, and teaching sequence, and these in turn seemed to influence their attitude-toward-physics and learning, and subsequently their beliefs about physics teaching practices in the microteaching and practicum.

Here, the participants' reflections were thus on their own learning, and they sought to gain a better and deeper understanding of the methods course content, their own teaching profession and interest including career interest, and their own personal and professional goals (Bengston, 1995; Carr & Kemmis, 1986; Schön, 1983, 1987).

Reflections on the Didaktik Analysis Assignment: Participants' reflections on the conceptual analysis, analysis of the Form 4 physics textbook, and analysis of literature on students' alternative conceptions are best described as self-understanding or 'reflection in action' (Bengtsson, 1995; Schön, 1983, 1987). These experiences involve all the special thoughts, intellectual activities, memories, emotions, expectations, and difficulties that led to the phenomenological reflections – and consist of trying to grasp the essential meanings of the didaktik analysis components (Alexandersson, 1995; Bengston, 1995). All of this was seen as being important in motivating participants to teach secondary school physics. The motivation in this work is linked with 'intentionality' in that different participants have different conceptions of didaktik analysis components as a result of their different learning experiences (Alexandersson, 1995).

Reflections on Teaching Practices. Participants' confidence to teach secondary school physics, to some extent, seemed influenced by the didaktik analysis assignment; their conceptual understanding of specific physics content; their attitude-toward-physics and learning; their self-efficacy beliefs; and their attitude toward, and beliefs about, physics teaching. All of this was linked with the participants' learning experiences at secondary school and at university. They reflected on their microteaching and practicum more than on their didaktik analysis assignment. These reflections can be described as 'self-reflection', and 'reflection in action' or 'self-understanding' (Bengston, 1995; Carr & Kemmis, 1986; Schon, 1983, 1987). For example, 'reflection on action' here included thinking about preparing reports on the didaktik analysis assignment, the lesson plans and teaching sequence in the microteaching and practicum, examinations, evaluation of the course, and on the value of their teaching practice. Here, they reflected on their personal beliefs and experiences about their teaching in the microteaching and practicum as the experiences were very different in nature. Their beliefs about student learning, beliefs about physics teaching, and physics teaching self-efficacy beliefs, may of course have been influenced by the fact that 'reflections' were part of the lesson plan requirement. As noted above, although, the participants believed in the importance of didaktik analysis-based teaching practice, and seem to have the capability to do didaktik analysis and to reflect on didaktik analysis, few implemented this in their lesson plans and teaching sequence, and some were unable to engage in reflections on their didaktik-based analysis teaching practice.

Finally, the findings presented here point to two interesting trends which the researcher hopes may be practised nationally in the future. First, it would seem that physics content knowledge was the determining factor of the conceptual analysis. This suggests that the draft Form 4 physics curriculum specifications in English which were implemented in 2006, can be used to give pre-service physics teachers experience in the analysis of other specific physics content based on experiences of didaktik analysis. Second, it appears existing research findings on students' alternative conceptions could be used as an alternative to the use of prerequisite knowledge usually written in a daily lesson plan in Malaysia.

Specifically, the participants' experiences of the physics teaching methods course and teaching practices in the microteaching and practicum, led them to think about the constraints of covering the syllabus, and ways of transforming specific physics content into a teaching sequence.

9.1.6 Teaching Sequence

The data suggest that the teaching sequence based on didaktik analysis in the microteaching can be applied for a variety of physics content area, but that this did not occur in the classroom during participants' practicum. There were a number of reasons for this, most of which were beyond the control of the participants. First, in the individual schools the mentor teacher 'set the rules' to be followed, and these were based on the curriculum specifications. Second, the teaching sequence itself was difficult to implement as specific physics content requires different teaching sequences. It seems the participants could only apply a teaching sequence in the classroom if didaktik analysis on the specific content to be taught was done before. Lijnse and Klaassen (2004) report little evidence for the use of a didaktik analysis-based teaching sequence after exposure to didaktik analysis, and suggests this is probably due to a belief that there is no best way to 'teach a specific topic'. Lijnse (2000) also refers to this as the 'didaktik of science' used to enhance the practice of teaching and learning in the classroom, and which is different from research in science education. Didaktik of science consists of describing and understanding what is, or should be, going on in science classrooms in terms of a content-specific teaching/learning process, and trying to interpret them in terms of didaktik theory.

However, as Lijnse (2000) and Fensham (2000) argue research in science education is almost completely lacking in attention to science content, but too often merely emphasizes its educational aspect. Lijnse (2000) specifically, lists a number of things lacking in research in science education. He says research in science education:

- aims primarily at a content-independent, meta-position that links closely with general research in education, particularly on pedagogical strategies
- there is in the literature a lack of studies that deal with the interrelation of teaching and learning activities, and little attention paid towards a conceptual analysis in terms of 'learnability' and 'teachability'
- there is also a lack of descriptions and discussions of the quality didaktik teaching sequences
- does not aim to develop content-specific didaktik knowledge, but contributes to general educational and/or psychological theories
- seeks to 'understand' learning processes or describing learning processes in terms of detailed cognitive processes, and
- places emphasis on conceptual change theory, theories concerning 'general' problem solving and/or other 'general' meta-cognitive skills.

9.2 REFLECTIONS ON THE IMPLICATIONS OF DIDAKTIK-BASED ANALYSIS FOR TEACHING AND LEARNING

This section seeks to bring together the main conclusions from the literature described in Chapters 3, 4 and 5 with the conclusions of the research findings for the present work as detailed in Section 9.1. As suggested in Chapter 1, one aim of this research was to investigate the use of didaktik analysis in enhancing the practice of teaching and learning in the classroom. The work was based on Klafki's (2000) model of didaktik analysis.

The participants' concerns about enacting the didaktik-based analysis teaching sequence during their practicum revealed that they had constraints in the practice that were not related to a more advanced understanding of physics content knowledge required, rather it was whether or not their more experienced physics teachers accepted their didaktik-based analysis in their schools that were influential in its implementation.

With regard to physics content knowledge, some researchers report taking a very long time to design a didaktik-based analysis teaching sequence, as this requires them to check the consistency of the teaching sequence in the classroom in terms of the theoretical framework, hypotheses, 'priori' and 'posteriori' analyses, students' initial conceptions, the critical role of the teacher, and feasibility of the context (see, e.g., Buty, Tiberghien & Le Maréchal, 2004; Leach & Scott, 2002; Mėheut & Psillos, 2004). Indeed, previous research of a purpose-designed designed teaching sequence for specific content on mechanics (Savinainen, Scott & Viiri, 2005), optics (Buty, Tiberghien & Le Maréchal, 2004), heat, electricity (Leach & Scott, 2002), structure of matter, and fluids (Méheut & Psillos, 2004), have been reported, and these each in turn produced various teaching activities; 'a problem-posing approach' and 'developmental research' (Lijsne, 1995, 2000), 'learning demand' (Leach & Scott, 2002), 'modelling and semiotic registers' (Tiberghien, 2000), and 'the grid' – a tool for the design of a teaching sequence (Buty, Tiberghien & Le Maréchal, 2004). Thus, based on these few literature reports on designed teaching sequence, the researcher suggests that development and use of successful teaching sequence takes time, and depends on the characteristics, as noted above.

In addition, according to Lijnse and Klaassen, (2004), the design of a didaktik-based analysis teaching sequence is value-laden in context (i.e., it has content specific goals and aims). The teachers' view of teaching and learning, of science in particular (Millar, Leach & Osborne, 2000) is either practical in nature (e.g., learning to cope with everyday life), theoretical (e.g., learning to understand nature), technical/industrial (e.g., learning to design technical artefacts or industrial products; or societal (e.g., learning about science and society) (Lijnse & Klaassen, 2004). In summary, a developed teaching sequence can be based on views of learning such as behaviourism, discovery, inquiry, contextual, mastery, constructivism, and Science, Technology and Society (STS) (Kementerian Pendidikan Malaysia, 2004).

From the findings reported in this thesis, the researcher believes that a teaching sequence based on didaktik-based analysis is compatible with the context of Malaysian secondary physics education systems, and holds good promise for making teaching, studying and learning more meaningful for pre-service physics teachers at higher education institutions, and for practising secondary physics teachers, physics curriculum developers and physics educators.

9.3 LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

9.3.1 Limitations of the Research

This section outlines the methodological limitations of the study established by the particular research paradigm and problems that arose during the intervention in the physics teaching methods course and during data analysis. The limitations identified before embarking on this study have been discussed in Chapter 1, and these represent the 'initial anticipated threats' to the intervention. In Chapter 5 the assumptions held by the researcher along, with the literature review in terms of the study's confirmability, subjectivity, credibility, transferability, dependability, trustworthiness and authenticity, were presented. In this final chapter are presented limitations based on 'reflection in action', and 'reflection on action, as they relate to problems or difficulties encountered before and during the intervention.

Perhaps, the most severe limitation was the participants' teaching sequence in the classroom during their school placement. It is not known whether or not all participants involved in the physics teaching methods course actually applied what they learned from didaktik analysis of physics. In addition, it is also not known whether or not the didaktik-based analysis teaching sequence impacted upon, or provided evidence of student learning, as actual student learning outcomes were not measured (although interviews were conducted with a selection of Form 4 physics student). This all means that in essence the teaching sequence was not fully validated. Most research on the use of a didaktik-based analysis teaching sequence is validated through 'a priori' and 'posteriori' analyses (i.e., does the previous activity really connected with the next activities, and is the next one really sufficiently prepared for by the previous activities). This is 'epistemological' in terms of analysing the content to be taught, the problems answered, and historical genesis. It is 'psycho-cognitive' in terms of analysing students' cognitive characteristics; and 'didaktik' in terms of analysing the functioning of teacher training programmes (e.g., Lijsne, 2000; Mėheut, 2004; Mėheut & Psillos, 2004). Additionally, in discussing this limitation with regards to the validity, Buty, Tiberghien and Le Maréchal, (2004) posed questions to be answered: Does the pre-service teacher consider that he or she can teach in the real classroom? (i.e., is it feasible?); Can teachers who did not participate in the elaboration of the sequence, teach this sequence? (i.e., is it extensible?); Can a given teacher teach the same sequence for several years consecutively? (i.e., is it reproducible?); and Do students pass the external examinations? Finally, although Fensham's emphasis is similar to the notion of *didaktik analysis* as described by Klafki (2000), there is the need to develop content from the primary source of scientific knowledge such as scientific experts. This aspect (i.e., the use of scientific experts) is not included in this thesis as the seven weeks allocated for the pre-service teachers is too short to fully utilise all aspects of didaktik analysis as noted by Klafki (2000).

9.3.2 Recommendations for Future Research

This study adds to the growing literature on didaktik-based analysis teacher training. The researcher has come to believe that it is the participants themselves, their beliefs and attitudes, their specific content knowledge, their practices with their students in the classroom that are the heart of the successful application of didaktik-based analysis teaching practices. The introduction of didaktik analysis in the physics teaching methods course described in this work is just the beginning. Although the application of didaktik analysis covers a wide range of aspects of teacher education, the researcher believes that the main aim in the Malaysian education context is to improve the practice of physics teaching in the classroom, and to help the nation in enhancing students' understanding and positive attitudes towards learning science.

Thus, this work represents a new direction in the physics teaching methods course, in the School of Education. Although it may be implemented only by some participants in this work, it would also be useful to carry out further research on didaktik analysis involving other specific secondary physics content, with a new cohort of pre-service physics teachers, experienced secondary physics teachers, and physicists at the School of Science and Technology, University of Malaysia Sabah. It also would be of interest to investigate the use of didaktik analysis for other subjects such as chemistry.

9.4 CONCLUDING THOUGHTS

The notion of didaktik analysis initially entered the researcher's mind when he read Fensham's (2004) book on 'defining identity' and White's (1994) chapter on 'the content of science'. A picture of Fensham's work is presented in the following quotes:

> To prepare for my exam in Pedagogy as a student teacher, I read a book by Martin Wagenschein, *The Pedagogical Dimension of Physics*, in which the idea was that physics offers only one facet of the world outside. To learn physics is to reduce the worldview. Physics is a reduced aspect of the world. (Reinders Duit, German, cited in Fensham, 2004, p. 157).

> The Driver and Osborne books stimulated me to do more research evaluating the physics content to be taught, rather than more psychological or more general educational research or just more research in physics. (Sung Jae Pak, South Korean, cited in Fensham, 2004, p. 145).

At the end of this thesis and based on the quotes above, the researcher realised that the idea of developing a 'didaktik-based analysis teaching sequence' for specific physics content needs practice in contexts which are different from its origins, because students learn more effectively if the contexts are appropriate, and are related to their own experiences outside the school environment. The researcher also believes that by shifting towards this 'new approach', the move to produce more 'genuine scientists' might be realised, and the Nation's Vision 2020 to have at least, one Nobel laureate in science may become a reality.

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APPENDIX I

A letter to the Dean of the School of Education requesting permission to conduct the intervention at the University of Malaysia Sabah

Mohd. Zaki Ishak
School of Education & Social Development
University of Malaysia Sabah
88999 Kota Kinabalu,
Sabah.

Ph: 088-320000, ext: 2475
Email: mzi1@waikato.ac.nz

Centre for Science and
Technology Education
Research (CSTER)

The University of Waikato
Private Bag 3105
Hamilton, New Zealand

Ph: 64-7-838 4035 (Centre direct line)
Fax: 64-7-838 4272
Email: cster@waikato.ac.nz

The Dean,
School of Education & Social Development,
University Malaysia Sabah,
88999 Kota Kinabalu, Sabah
MALSYSIA.

21st September 2005.

Dear Sir,

To seek an approval to conduct intervention of Physics Methods Course

With reference to the above matter.

I am currently enrolled as a doctoral student at the CSTER, University of Waikato, Hamilton New Zealand.

The topic of my thesis is didaktik analysis of physics. The study focuses on the practice of teaching and learning of pre-service physics teachers. I would be expected to do intervention on pre-service physics teachers at the University of Malaysia Sabah, in the middle of January 2006. A draft research proposal is enclosed for the school's information. Therefore, I would be grateful if you could give me the permission to conduct intervention on pre-service physics teachers during their physics methods course.

Your support and cooperation is very much appreciated and I look forward to hearing from you soon.

Thank you.

Yours Sincerely,

(Mohd.Zaki Ishak)

cc Assoc. Prof. Dr. Richard K. Coll
Chief Supervisor, CSTER
Director, Cooperative Education
Science & Engineering
University of Waikato.

Prof. Dr. Alister Jones
Supervisory Panel (2nd. Supervisor)
Director, Wilf Malcolm Institute of Educational Research
School of Education
University of Waikato.

The Dean,
Centre for PostGraduate Studies
Universiti Malaysia Sabah.

Registrar (Training Division),
Universiti Malaysia Sabah.

APPENDIX II

A letter to the Education Planning and Research Division (EPRD) requesting permission to conduct research in secondary schools

Mohd. Zaki Ishak
School of Education & Social Development
University of Malaysia Sabah
88999 Kota Kinabalu,
Sabah.

Ph: 088-320000, ext: 2475
Email: mzi1@waikato.ac.nz

Centre for Science and
Technology Education
Research (CSTER)

The University of Waikato
Private Bag 3105
Hamilton, New Zealand

Ph: 64-7-838 4035 (Centre direct line)
Fax: 64-7-838 4272
Email: cster@waikato.ac.nz

The Director,
Education Planning and Research Division (EPRD),
Ministry of Education, Aras SB1-4, Blok E8, Parcel E
Pusat Pentadbiran Persekutuan, 62640 PUTRAJAYA

23rd January 2006

Dear Sir,

To seek an approval to conduct study on secondary physics students during pre-service physics teachers' practicum

I am currently enrolled as a doctoral student at the CSTER, University of Waikato, Hamilton New Zealand, and lecturer at the School of Education, University Malaysia Sabah.

The topic of my thesis is the didaktik analysis of physics. The study focuses on the practice of teaching and learning of pre-service physics teachers. In my research, I propose to include didaktik analysis in the physics teaching methods course (TT4133). I am currently doing the intervention on pre-service physics teachers at the University of Malaysia Sabah. They are expected to do the practicum teaching at selected Sabah secondary schools for 8 weeks. During the pre-service physics teachers' practicum, the researcher proposes to do the following:

- Classroom observation (80 minutes or 2 periods in each occasion) for two occasions with 10 teachers in total, and
- Interviews of three Form 4 secondary physics students in each school (10 -15 minutes), for 10 schools in total.

A draft research proposal is enclosed for the EPRD's information. Therefore, I would be grateful if you could issue an official letter of approval to enable me to do a research at selected secondary schools. Your support and cooperation is very much appreciated and I look forward to hearing from you soon.

Thank you.

Yours Sincerely,

(Mohd.Zaki Ishak)

APPENDIX III

The letter of approval from the EPRD

BAHAGIAN PERANCANGAN DAN PENYELIDIKAN DASAR PENDIDIKAN
KEMENTERIAN PELAJARAN MALAYSIA
ARAS 1-4, BLOK E8
KOMPLEKS KERAJAAN PARCEL E
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
62604 PUTRAJAYA

Telefon : 03-88846000
Faks : 03-88846439
Laman Web : http://161.142.144.5

Rujukan Kami : KP (BPPP)603/008(19)
Tarikh: 21 Februari 2006

Ketua Pengarah
Unit Perancang Ekonomi,
Jabatan Perdana Menteri,
Blok B5 dan B6,
Kompleks Jabatan Perdana Menteri,
Pusat Pentadbiran Kerajaan Persekutuan,
62502 PUTRAJAYA.
(up: Pn. Munirah bt Abd. Manan)

Tuan,

Permohonan Untuk Menjalankan Penyelidikan di Malaysia
MOHD ZAKI BIN ISHAK

Dengan hormatnya saya merujuk kepada perkara di atas.

2. Adalah saya diarah memaklumkan bahawa Bahagian ini tidak mempunyai apa-apa halangan dan menyokong penuh ke atas cadangan yang dikemukakan oleh penyelidik berkenaan untuk membolehkan menjalankan penyelidikan:
" Didaktik Analysis Of Physics ".

3. Setelah selesai kajian dijalankan, penyelidik perlulah mengemukakan senaskah laporan dapatan kajian tersebut ke Bahagian ini.

4. Bersama-sama ini disertakan ulasan Bahagian ini ke atas cadangan penyelidikan yang dikemukakan.

Sekian dimaklumkan, terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Saya yang menurut perintah,

(DR. AMIR BIN SALLEH @ MOHD SALEH)
Timbalan Pengarah, Sektor Penyelidikan Dasar
Bahagian Perancangan dan Penyelidikan Dasar Pendidikan
Kementerian Pelajaran Malaysia.

Ulasan Tentang Cadangan Kajian

Nama Penyelidik: **Mohd Zaki Bin Ishak**

Nama Institusi: **University of Waikato, New Zealand**

Tajuk Kajian: **Didaktik Analysis of Physics**

a) Setelah membaca cadangan kajian seperti yang dinyatakan di atas, padangan Bahagian ini terhadap cadangan kajian adalah seperti berikut:

i. **Bidang yang akan dikaji: Sesuai**

Bidang kajian ini sesuai dijalankan dalam konteks pendidikan di Malaysia sungguhpun ianya merupakan satu bidang yang tidak begitu banyak diaplikasikan dalam konteks pedagogi.

ii. **Kawasan-kawasan kajian yang telah dikenalpasti: Sesuai**

Kawasan-kawasan kajian merangkumi proses bagaimana pendekatan didaktik dijalankan dalam pendidikan perguruan, apakah faktor yang mempengaruhi keberkesanan pendekatan ini, dan bagaimana guru yang mengajar fizik boleh menggunakan pendekatan ini dalam proses pengajaran dan pembelajaran.

iii. **Faedah-faedah yang mungkin dapat diperolehi dari kajian ini: Berfaedah kepada Kementerian Pelajaran**

Kajian ini menang berfaedah kepada Kementerian Pelajaran kerana ianya memberi sumbangan ilmu baru dalam pendidikan perguruan di Malaysia terutamanya dalam pengajaran dan pembelajaran fizik.

b) Bahagian ini tidak mempunyai apa-apa halangan bagi penyelidik menjalankan kajian di sekolah.

(DR. SOON SENG THAH)
Unit Penyelidikan Dasar
Bahagian Perancangan dan Penyelidikan Dasar Pendidikan
Kementerian Pelajaran Malaysia.

Tarikh: 20 Februari 2006

APPENDIX IV

The letter of approval from the Economic Planning Unit

UNIT PERANCANG EKONOMI
Economic Planning Unit
JABATAN PERDANA MENTERI
Prime Minister's Department
BLOK B5 & B6,
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
62502 PUTRAJAYA
MALAYSIA

Telefon: 88883333
Fax: 603-88883798

Ruj. Tuan:
Your Ref.:
Ruj. Kami:
Our Ref.: UPE: 40/200/19/1455
Tarikh:
Date: 17 APRIL 2006

Mohd Zaki Ishak
Kg. Raganan Timbok
Off Jalan Mengkabong
89200 Tuaran
Sabah

APPLICATION TO CONDUCT RESEARCH IN MALAYSIA

With reference to your application dated 1 March 2006, I am pleased to inform you that your application to conduct research in Malaysia has been approved by the **Research Promotion and Co-Ordination Committee, Economic Planning Unit, Prime Minister's Department.** The details of the approval are as follows:

Researcher's name	:	**MOHD ZAKI ISHAK**
Passport No. / I. C No:		**631201-05-5069**
Nationality	:	**MALAYSIA**
Title of Research	:	**DIDAKTIK ANALYSIS OF PHYSICS**
Period of Research Approved:		**SIX MONTHS**

2. Please collect your Research Pass in person from the Economic Planning Unit, Prime Minister's Department, Parcel B, Level 4 Block B5, Federal Government Administrative Centre, 62502 Putrajaya and bring along two (2) passport size photographs. You also required to comply with the rules and regulations stipulated from time to time by the agencies with which you have dealings in the conduct of your research.

3. I would like to draw your attention to the undertaking signed by you that you will submit without cost to the Economic Planning Unit the following documents:

a) A brief summary of your research findings on completion of your research and before you leave Malaysia; and

b) Three (3) copies of your final dissertation/publication.

4. Lastly, please submit a copy of your preliminary and final report directly to the State Government where you carried out your research.

ATTENTION

This letter is only to inform you the status of your application and **cannot be used as a research pass**.

Thank you.

Yours sincerely,

(MUNIRAH ABD. MANAN)
b.p. Ketua Pengarah,
Unit Perancang Ekonomi,
(Seksyen Ekonomi Makro)
Email: munirah@epu.jpm.my
Tel: 88882809/2818/2827

C.c:

Pengarah
Bahagian Perancangan Penyelidikan & Dasar Pendidikan
Kementerian Pelajaran Malaysia
Aras 1-4, Blok E8
Kompleks Kerajaan Parcel E
Pusat Pentadbiran Kerajaan Persekutuan
62604 Putrajaya
(u.p: Dr. Amir bin Salleh @ Mohd. Saleh) (Ruj. Tuan: KP(BPPP)603/008 (19)

Prof. Dr. Nik Meriam Nik Sulaiman
Pengarah,
Institut Pengurusan Penyelidikan dan Perundingan
Universiti Malaya,
C 313, Bangunan IPS,
50603 Kuala Lumpur.

Timbalan Naib Canselor
Bahagian Penyelidikan
Universiti Malaysia Sabah
Beg Berkunci No 2073,
88999, Kota Kinabalu,
Sabah (Ruj. Tuan: UMS/CN-1.3/P25/5 Jld 14)
(u.p: Lt. Kol. Prof Datuk Dr. Hj. Kamaruzaman Ampon)

APPENDIX V

TUG-K and FMCE tests

UNIVERSITI MALAYSIA SABAH

School of Education & Social Development

TT4133: Physics Teaching Methods

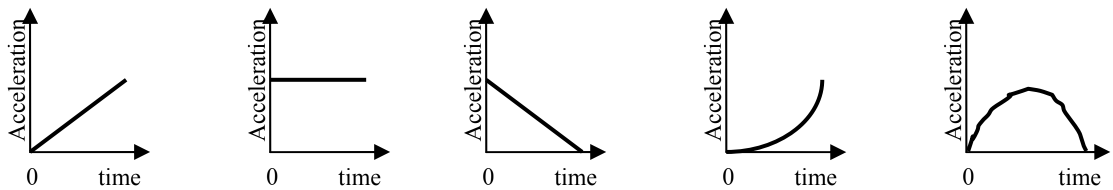
Semester II, 2005/2006

Instructions: These questions are not to test your achievement in your physics teaching methods course, but merely to test a conceptual understanding of Form 4 physics. Read each question carefully, then choose the best choice from among those provided.
Part A consists of 21 questions, part B, 39 questions.

Matrix No. : _________________

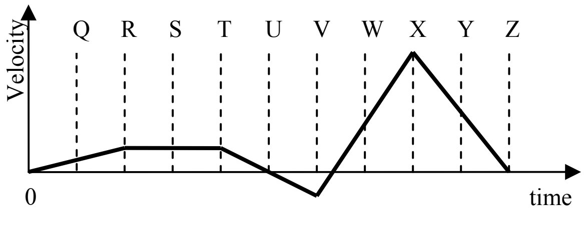
Part A: Testing Understanding of Graphs – Kinematics

1. Acceleration versus time graphs for five objects are shown below. All axes have the same scale. Which object had the greatest change in velocity during the interval?



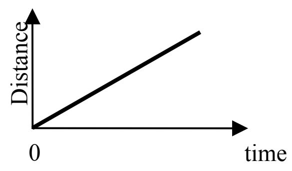
A **B** **C** **D**
E

2. The graph below shows the motion of an object during the periods, OR, RT, TV, VX, and XZ. When the acceleration of the object is the most negative?



A R to T **B** T to V **C** V **D** X **E** X to Z

3. The graph below shows an object's motion. Which sentence is the best interpretation?



A The object is moving with a constant, non-zero acceleration.

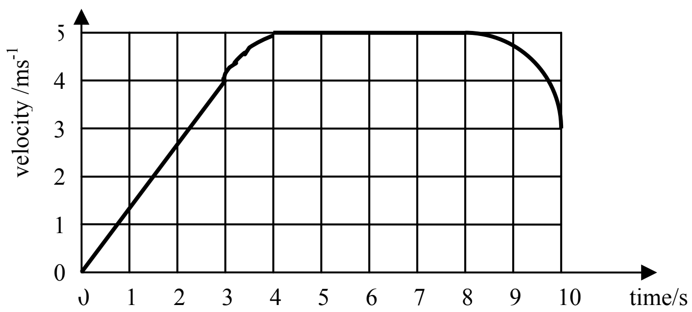
B The object is not moving

C The object is moving with a uniformly increasing velocity.

D The object is moving at a constant velocity.

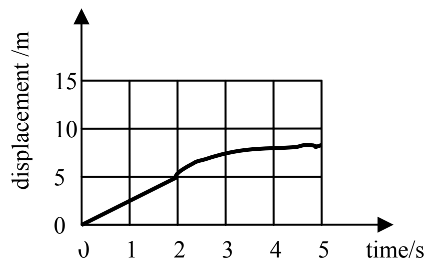
E The object is moving with a uniformly increasing acceleration.

4. An elevator moves from the basement to the tenth floor of a building. The mass of the elevator is 1000 kg and it moves as shown in the velocity-time graph below. How far does it move during the first three seconds of motion?



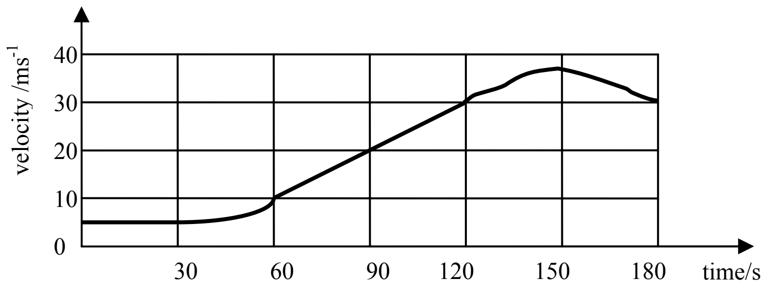
A 0.75 m **B** 1.33 m **C** 4.0 m **D** 6.0 m **E** 12.0 m

5. The graph below shows an object initially at rest, moves during 5 second time interval. The velocity at the 2 second point is:



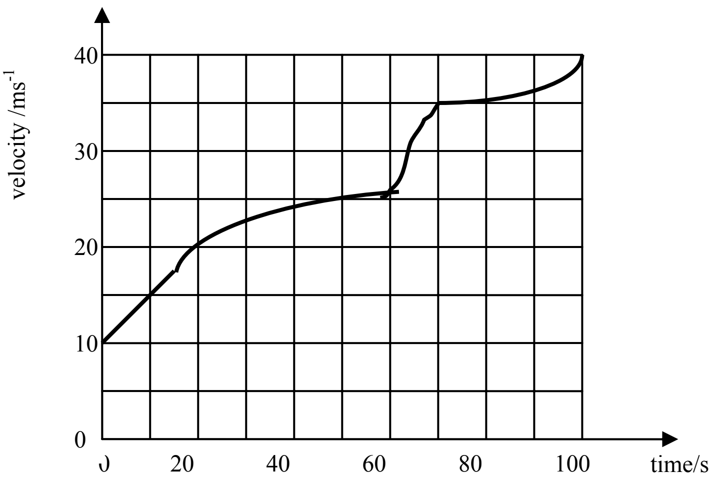
A 0.4 ms^{-1} **B** 2.0 m s^{-1} **C** 2.5 m s^{-1} **D** 5.0 m s^{-1} **E** 10.0 m s^{-1}

6. The graph below shows velocity as a function of time for a car of mass 1.5×10^3 kg. What was the acceleration at the end of 90 s?



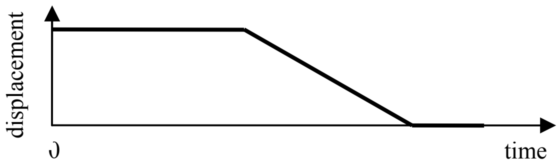
A 0.22 ms^{-2} **B** 0.33 ms^{-2} **C** 1.0 ms^{-2} **D** 9.8 ms^{-2} **E** 20.0 ms^{-2}

7. The motion of an object traveling in a straight line is represented by the following graph. At time = 55 s, the magnitude of the instantaneous acceleration of the object was most nearly:



A 1 ms^{-2} **B** 2 ms^{-2} **C** +9.8 ms^{-2} **D** +30 ms^{-2} **E** +34 ms^{-2}

8. Below is a graph of an object's motion. Which sentence is the best interpretation of this graph?



A The object rolls along a flat surface. Then, it rolls forward down a hill, and then finally stops.

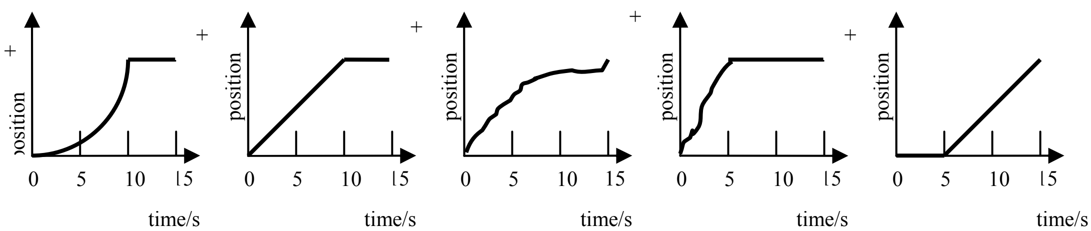
B The object doesn't move at first. Then it rolls forward down a hill, and finally stops.

C The object is moving at a constant velocity. Then it slows down and stops.

D The object doesn't move at first. Then it moves backwards and then finally stops.

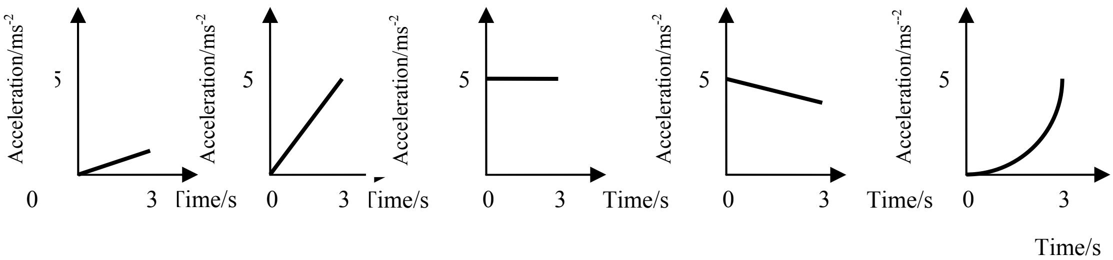
E The object moves along a flat area, moves backward down a hill, and then it keeps moving.

9. An object starts from rest and undergoes a positive, constant acceleration for 10 seconds. It then continues on with constant velocity. Which of the following graphs correctly describes this situation?



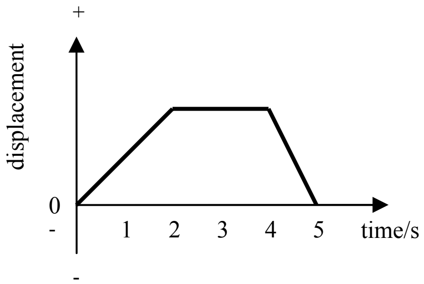
A **B** **C** **D** **E**

10. Five objects move according to the following acceleration versus time graphs. Which object has the smallest change in velocity during the three second interval?

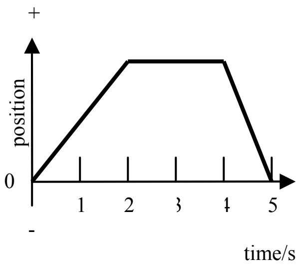


A **B** **C** **D**
E

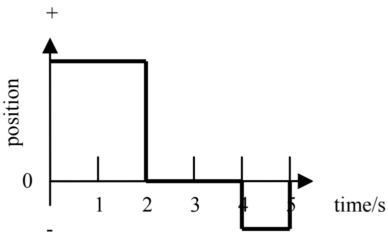
11. The following is a displacement-time graph for an object during a 5 s time interval.



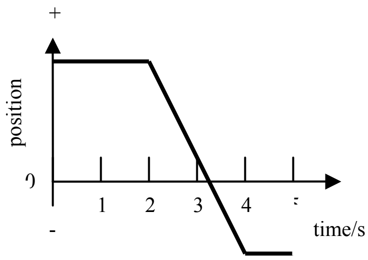
Which one of the following graphs of velocity versus time would best represent the object's motion during the same time interval?



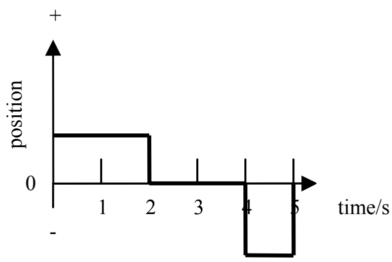
A



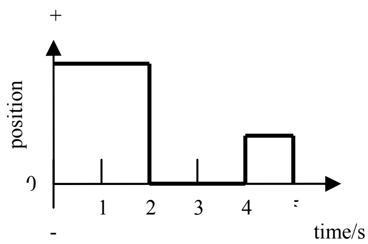
B



C

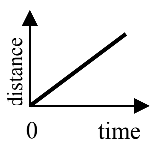


D

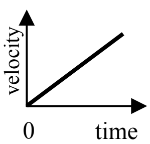


E

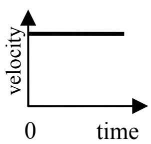
12. Consider the following graphs, noting the different axes:



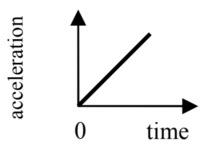
A



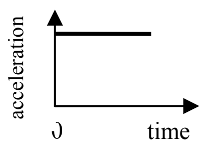
B



C



D

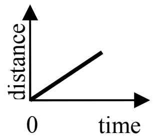


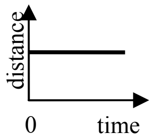
E

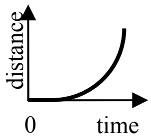
Which of these represent/s motion at constant velocity?

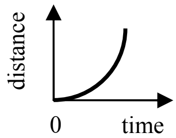
A I, II and IV **B** I and III **C** II and V **D** IV only **E** V only

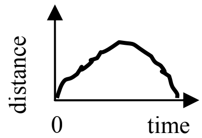
13. Distance versus time graphs for five objects are shown below. All axes have the same scale. Which object had the highest instantaneous velocity during the interval?







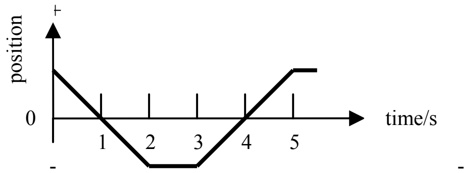




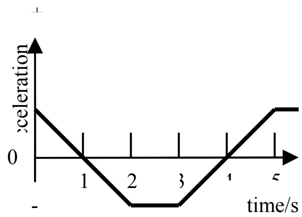
A **B** **C** **D**

E

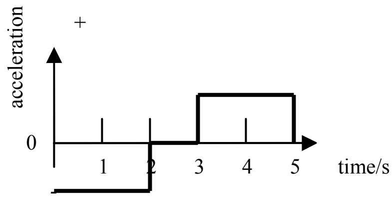
14. The following graph represents a velocity-time graph for an object during a 5 s time interval.



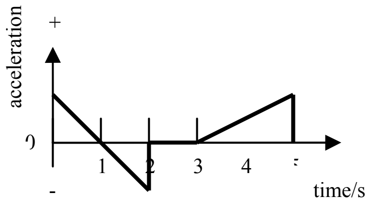
Which one of the following graphs of acceleration versus time would best represent the object's motion during the same time interval?



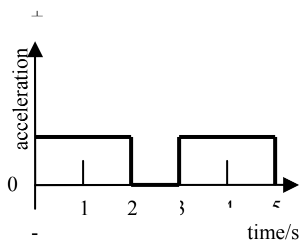
A



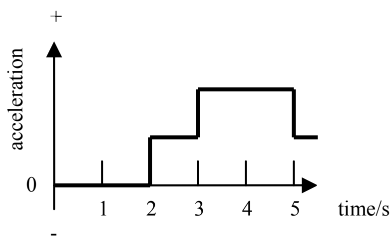
B



C

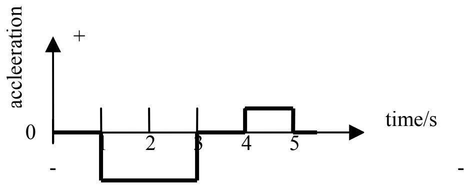


D

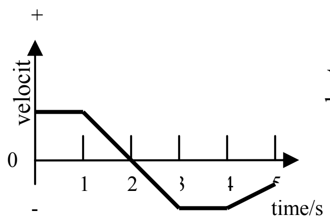


E

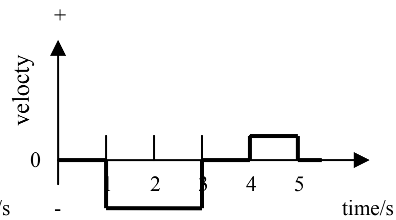
15. The following graph represents an acceleration graph for an object during a 5 s time interval.



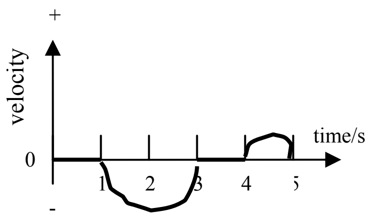
Which one of the following graphs of velocity versus time best represents the object's motion during the same time interval?



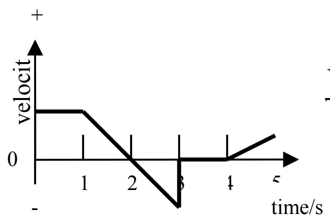
A



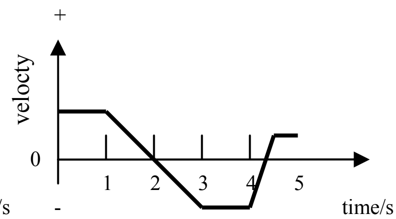
B



C

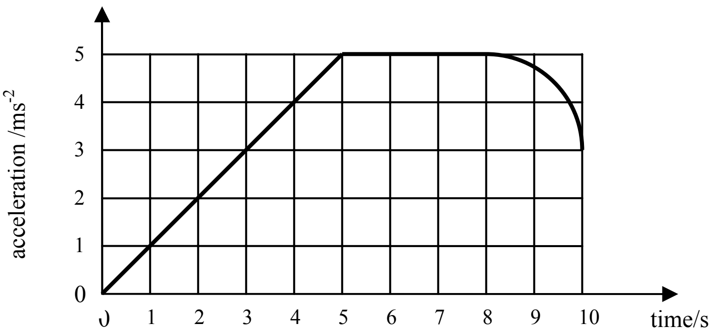


D



E

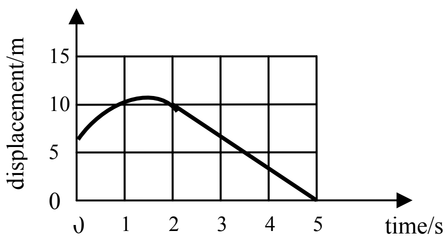
16. An object moves according to the graph below:



The object's change in velocity during the first three seconds of motion was:

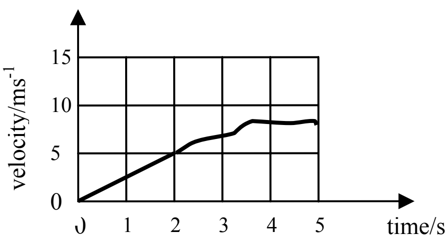
A 0.66 ms^{-1} **B** 1.0 m s^{-1} **C** 3.0 m s^{-1} **D** 4.5 m s^{-1} **E** 9.8 m s^{-1}

17. The graph below shows an object moves during 5 second time interval. The velocity at the 3 second point is about:



A -3.3 ms^{-1} **B** -2.0 ms^{-1} **C** -0.67 ms^{-1} **D** 5.0 ms^{-1} **E** 7.0 ms^{-1}

18. If you wanted to know the distance covered during the interval from t = 0 s to t = 2 s, from the graph below you would:



A Read 5 directly off the vertical axis

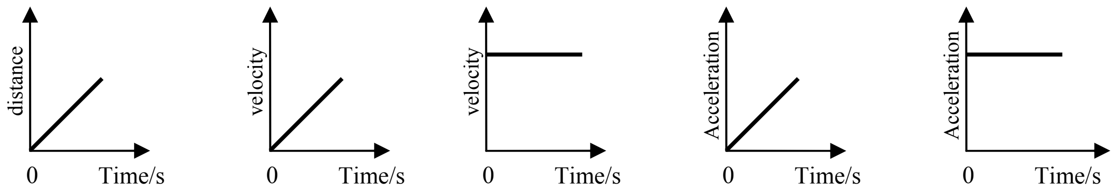
B Find the area between the line segment and the time axis by calculating (5x2/2)

C Find the slope of that line segment by dividing 5 by 2

D Find the slope of that line segment by dividing 15 by 5.

E there is not enough information to answer this question

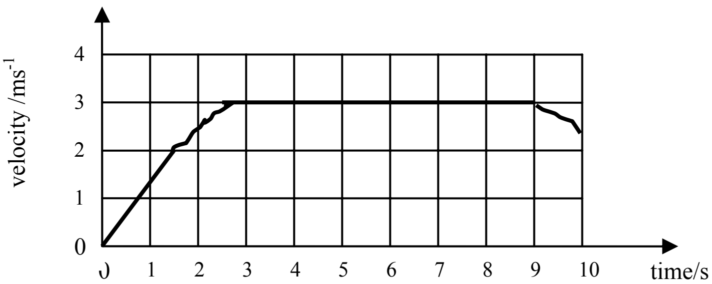
19. Consider the following graphs, noting the different axis:



Which of these represent/s motion at constant, non-zero acceleration?

A I, II and IV **B** I and III **C** II and V **D** IV only **E** V only

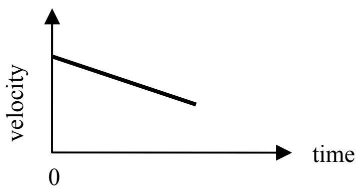
20. An object moves according to the graph below:



How far does it move during the interval from t = 4 s to t = 8 s.

A 0.75 m **B** 3.0 m **C** 4.0 m **D** 8.0 m **E** 12.0 m

21. The graph below shows an object's motion. Which sentence represents the best interpretation of this graph?



A The object is moving with constant acceleration

B The object is moving with a uniformly decreasing acceleration

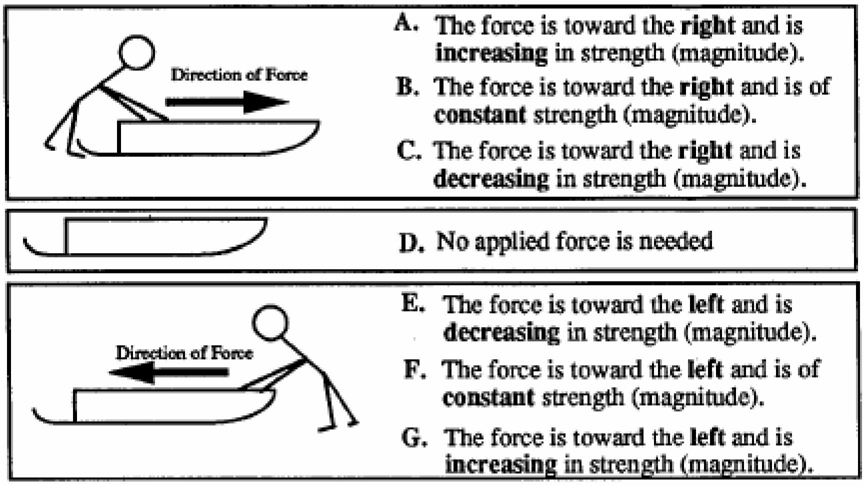
C The object is moving with a uniformly increasing velocity

D The object is moving at constant velocity

E The object does not move.

Part B: Force and Motion Conceptual Evaluation

A sled (a vehicle used for traveling across ice) on ice moves in the ways described. Friction is so small that it can be ignored. A person wearing spiked shoes standing on the ice can apply to the force to the sled and push it along the ice. Choose the one force (A through G) which would keep the sled moving as described in statement below in questions 22-28.
You may choose a choice more than once or not at all but choose only one answer for each question. If you think none is correct, answer choice J.



22. Which force would keep the sled moving to the right and speeding at a steady rate (constant acceleration)?

23. Which force would keep the sled moving at a steady (constant) velocity?

24. The sled is moving toward the right. Which force would slow it down at a steady rate (constant acceleration)?

25. Which force would keep the sled moving toward the left and speeding up at a steady rate (constant acceleration)?

26. The sled was started from rest and pushed until it reached a steady (constant) velocity toward the right. Which force would keep the sled moving at this velocity?

27. The sled is slowing down at a steady rate and has accelerated to the right. Which force would account for this motion?

28. The sled is moving to the left. Which force would slow it down at a steady rate (constant acceleration)?

Questions 29 - 31 refer to the toy car shown below. This car is given a quick push so that it rolls up an inclined ramp. After it is released, it rolls up, reaches its highest point and rolls back down again. Friction is so small that it can be ignored.

Use one of the following choices (A through G) to indicate the net force acting on the car for each of the cases described below. Answer choice J if you think none is correct.

A Net constant force down ramp
B Net increasing force down ramp
C Net decreasing force down ramp
D Net force zero
E Net constant force up ramp
F Net increasing force up ramp
G Net decreasing force up ramp

☐ 29. The car is moving up the ramp

☐ 30. The car at its highest point

☐ 31. The car is moving down the ramp.

Questions 32 - 34 refer to a coin which tossed straight up into the air. After it is released it moves upward, reaches its highest point and falls back down again.
Use one of the following choices (A through G) to indicate the force acting on the coin for each of the cases described below. Answer choice J if you think none is correct.
Ignore any effects of air resistance.

A The force is down and constant
B The force is down and increasing
C The force is down and decreasing
D The force is zero
E The force is up and constant
F The force is up and increasing
G The force is up and decreasing

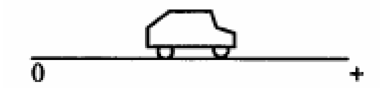
☐ 32. The coin is moving upward after it is released

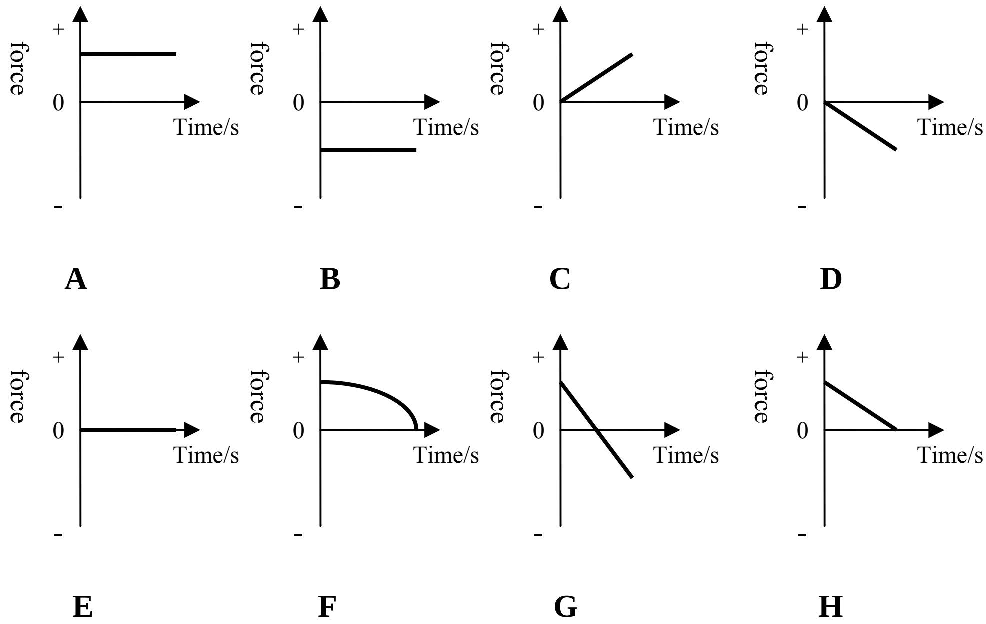
☐ 33. The coin is at its highest point

☐ 34. The coin is moving downward

Questions 35-42 refer to a toy car which can move to the right or left along a horizontal line (the positive part of the distance axis). Friction is so small that it can be ignored.

A force is applied to the car. Choose the one force graph (A through H) for each statement below which could allow the described motion of the car to continue. You may choose a choice more than once or not at all. If you think none is correct, answer choice J.





☐ 35. The car move toward the right (away from the origin) with a steady (constant) velocity.

☐ 36. The car is at rest.

☐ 37. The car moves toward the right and is speeding up at a rate (constant acceleration).

☐ 38. The car moves the left (toward the origin) with a steady (constant) velocity.

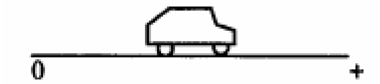
☐ 39. The car moves toward the right and is slowing down at a steady rate (constant acceleration)

☐ 40. The car moves toward the left and is speeding up at a steady rate (constant acceleration)

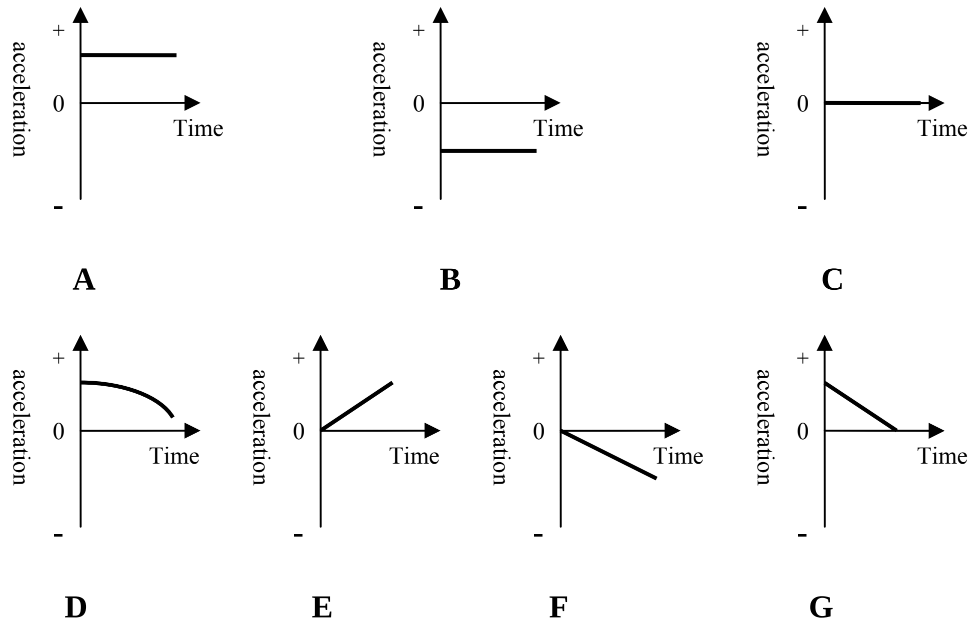
☐ 41. The car moves toward the right, speeds up, and then slows down.

☐ 42. The car was pushed toward the right and then released. Which graph describes the force after the car is released?

Questions 43-47 refer to a toy car which can move to the right or left along a horizontal line (the + distance axis). The positive direction is to the right.



Different motions of the car are described below. Choose the letter (A to G) of the acceleration-time graph which corresponds to the motion of the car described in each statement. You may choose a choice more than once or not at all. If you think none is correct, answer choice J.



J None of these graphs is correct

☐ 43. The car moves toward the right (away from the origin) speeding up at a steady rate.

☐ 44. The car moves toward the right, slowing down at a steady rate.

☐ 45. The car moves toward the left (toward the origin) at a constant velocity.

☐ 46. The car moves toward the left, speeding up at a steady rate.

☐ 47. The car moves toward the right at a constant velocity.

Questions 48-50 refer to a coin which is tossed straight into the air. After it is released it moves upward, reaches its highest point and falls back down again. Use one of the following choices (A through G) to indicate the acceleration of the coin during each of the stages of the coin's motions described below. Take **up** to be the **positive** direction. Answer choice J if you think none that is correct.

A The acceleration is in the negative direction and constant
B The acceleration is in the negative direction and increasing
C The acceleration is in the negative direction and decreasing
D The acceleration is zero
E The acceleration is in the positive direction and constant
F The acceleration is in the positive direction and increasing
G The acceleration is in the positive direction and decreasing

48. The coin is moving upward after it is released

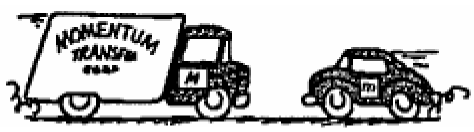
49. The coin is at its highest point

50. The coin is moving downward

Questions 51-55 refer to collisions between a car and truck. For each description of a collision below, choose the one answer from the possibilities A through J that best describe the size (magnitude) of the forces between the car and the truck.

A The truck exerts a larger force on the car than the car exerts on the truck
B The car exerts a larger force on the truck than the truck exerts on the car
C Neither exerts a force on the other, the car gets smashed simply because it is in the way of the truck
D The truck exerts a force on a car but the car doesn't exert a force on the truck
E The truck exerts the same amount of force on the car as the car exert on the truck
F Not enough information is given to pick one of the answers above
J None of the answers above describes the situation correctly

In questions 51 through 53, you can assume that the truck is **much heavier** than the car.

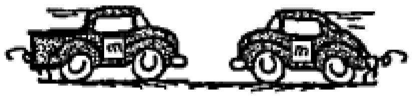


51. They are both moving at the same speed when they collide.
Which choice describes the forces?

52. The car is moving much faster than the heavier truck when they collide.
Which choice describes the forces?

53. The heavier truck is standing still when the car hits it.
Which choice describes the forces?

In questions 54 and 55 the truck is a small pickup and is the same weight as the car.



☐ 54. Both the truck and the car are moving the same speed when they collide.
Which choice describes the forces?

☐ 55. The truck is standing still when it when the car hits it.
Which choice describes the forces?

Questions 56-59 refer to a large truck which breaks down out on the road and receives a push back to town by a small car. Pick one of the choices A through J below which correctly describes the size (magnitude) of the forces between the car and the truck for each of the descriptions.

A The force of the car pushing against the truck is equal to that of the truck pushing back against the car
B The force of the car pushing against the truck is less than that of the truck pushing back against the car.
C The force of the car pushing against the truck is greater than that of the truck pushing back the car
D The car's engine is running so it applies a force as it pushes against the truck, but the truck's engine is not running so it can't push back with a force against the car
E Neither the car nor the truck exert any force on each other. The truck is pushed forward simply because it is in the way of the car
J None of these descriptions is correct.

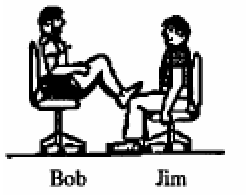
☐ 56. The car is pushing on the truck, but not hard enough to make the truck move.

☐ 57. The car, still pushing the truck, is speeding up to get to cruising speed.

☐ 58. The car, still pushing the truck, is at cruising speed and continues to travel at the same speed.

☐ 59. The car, still pushing the truck, is at cruising speed when the truck puts on it brakes and causes the car to slow down.

60. Two students sit in identical office chairs facing each other. Bob has a mass of 95 kg, while Jim has a mass of 65 kg. Bob places his feet on Jim's knees as show in the diagram.



Bob then suddenly pushes outward with his feet, causing both chairs to move. While Bob's feet are in contact with Jim's knees,

A Neither student exerts a force on the other.
B Bob exerts a force on Jim, but Jim doesn't exert any force on Bob.
C Each student exerts a force on the other, but Jim exerts the larger force.
D Each student exerts a force on the other, but Bob exerts the larger force.
E Each student exerts the same amount of force on the other.
F None of these answers is correct.

APPENDIX VI

Beliefs About Physics Teaching (BAPT) Questionnaire

Dear beloved prospective physics teacher,

This survey is part of a study intended to improve the teaching and learning of secondary school physics. You are going to be a secondary school physics teacher at the end of your practicum. Some of you may have completed, some may still be studying physics courses this semester.

Section 1 is related to experiences in general you had during physics lectures, what you have got from the lectures, laboratory classes, tutorial classes, the reasons why you are studying physics at the University of Malaysia Sabah, and some general statements of your experiences as a physics student in secondary school.

Section 2 concerns your attitudes towards physics teaching. You are asked to respond to some aspects of your feeling about being a prospective secondary physics teacher.

Section 3 asks you to respond in general about your confidence to teach secondary physics topics. This is followed by questions about your confidence in teaching the topic of "force and motion".

Section 4 asks you to complete about your general personal background.

Your responses in this questionnaire are completely confidential and will not in any way contribute to the assessment of the course, TT4133. Your cooperation is very much appreciated. Thank you.

Section One
Your Physics Learning Experiences

In this section your are asked to reflect on your own learning experiences **in any physics courses** enrolled at the School of Science & Technology during your three or four years of studying physics and your experience as a physics student in secondary school. It is important to remember that there are no right or wrong answers.

a. In general, my experiences learning physics at the university,

	strongly disagree				strongly agree
• the physics lectures were presented in an interesting manner	1	2	3	4	5
• the physics lecture notes were clearly explained	1	2	3	4	5
• the physics lectures were presented in English	1	2	3	4	5
• I get a thorough understanding of the lecture notes	1	2	3	4	5
• I get to know how to solve problems in physics	1	2	3	4	5
• I gain conceptual understanding of physics lecture notes	1	2	3	4	5
• I learn just to pass physics exams	1	2	3	4	5
• I learn through memorizing physics formulae	1	2	3	4	5
• I learn physics concepts through books	1	2	3	4	5
• I gain enjoyment of physics learning	1	2	3	4	5
• I gain greater confidence as a student of physics	1	2	3	4	5
• I gain very little experience in the laboratory	1	2	3	4	5
• the tutorial problems covered all parts of the course	1	2	3	4	5
• the tutorials help my understanding of physics lecture notes.	1	2	3	4	5
• I discuss physics problems with other students	1	2	3	4	5

Section One
Your Physics Learning Experiences

b. I am mainly studying physics at university

	strongly disagree				strongly agree
• because teaching is my first choice of my career	1	2	3	4	5
• because I want to be a physics teacher	1	2	3	4	5
• because I enjoy teaching physics	1	2	3	4	5
• because physics courses are easy for me to understand	1	2	3	4	5
• because I require physics for my degree/program	1	2	3	4	5
• only because I was required to enroll physics courses by the Ministry of Education	1	2	3	4	5
• because I taught science in primary school	1	2	3	4	5
• because my previous secondary physics learning experiences were good	1	2	3	4	5
• because I was good at physics in SPM	1	2	3	4	5
• because I was good at physics in Matriculation/ STPM (please circle which applies to you, and again tick on the appropriate box)	1	2	3	4	5

c. Did you learn physics in secondary school?

☐ Yes, If **Yes**, what was your level ☐ SPM/MCE

☐ STPM/HSC/Matriculation

and go to question **d**,

☐ No, If **No**, go to Section Two.

d. In my experience as a physics student in secondary school during my physics classes:

	strongly disagree				strongly agree
• a good student does well in his/her classes even if the physics teacher exerts little effort	1	2	3	4	5
• if students are under-achieving, it is likely due to ineffective physics teaching	1	2	3	4	5
• inadequacy in a student's physics learning background can be overcome by good teaching	1	2	3	4	5
• students' achievement is directly related to their teacher's effectiveness in physics teaching	1	2	3	4	5
• the teacher discussed from textbook	1	2	3	4	5
• the teacher discussed from revision books	1	2	3	4	5
• the teacher discussed the outlines of crucial notes	1	2	3	4	5
• the teacher explained the demonstration before the students carried out an experiment in a group	1	2	3	4	5
• the teacher did the experiment and the students noted down an observation, results, and conclusions by referring to the textbook	1	2	3	4	5
• the teacher employed "drill and practice" method in in his/her teaching	1	2	3	4	5
• I learned physics through memorizing	1	2	3	4	5
• learning physics was difficult to understand	1	2	3	4	5
• learning physics was boring because the teacher was in ineffective in his/her teaching	1	2	3	4	5
• I loved physics because the teacher had motivated me	1	2	3	4	5

Section Two
Your Attitudes Towards Physics Teaching

This section is about your attitudes towards physics teaching. Please indicate your ratings how do you feel about being a secondary school physics teacher.

Generally, I think:

	strongly disagree 1	2	3	4	strongly agree 5
• teaching physics is easy	1	2	3	4	5
• teaching physics in English is difficult	1	2	3	4	5
• although teaching physics in English is difficult, it is likely that I can improve my physics knowledge	1	2	3	4	5
• I would not teach physics if it was not required by the Education Ministry	1	2	3	4	5
• using physics apparatus in the laboratory is easier	1	2	3	4	5
• there is very little I can do to avoid teaching physics	1	2	3	4	5
• my physics teaching will result me having more stress	1	2	3	4	5
• the Education Ministry thinks I should teach physics	1	2	3	4	5
• my own lack of conceptual understanding may prevent me teaching physics better	1	2	3	4	5
• although it is likely that physics teaching may cause me stress, the stress also will make me more prepared	1	2	3	4	5
• problems I may encounter in my teaching are due to my lack of conceptual understanding of basic physics	1	2	3	4	5
• most people (parents, friends, headmaster - please) underline which applies to you) who know me think I should teach physics	1	2	3	4	5
• I want to teach physics because most people who are important to me think I should teach physics	1	2	3	4	5
• physics courses I have taken gave me enough knowledge for me to teach physics	1	2	3	4	5

Section Three
Your Confidence About Teaching Secondary Physics

Listed below are physics topics as contained in the Secondary School Physics Curriculum. As a prospective physics teacher, please indicate your ratings how confident do you feel about teaching the following secondary school physics topics.

In general, I think I have the ability to teach the following secondary physics topics:

	strongly disagree				strongly agree
• Introduction to physics	**1**	**2**	**3**	**4**	**5**
• Force and motion	**1**	**2**	**3**	**4**	**5**
• Force and pressure	**1**	**2**	**3**	**4**	**5**
• Heat	**1**	**2**	**3**	**4**	**5**
• Light	**1**	**2**	**3**	**4**	**5**
• Wave	**1**	**2**	**3**	**4**	**5**
• Electricity and Electromagnetism	**1**	**2**	**3**	**4**	**5**
• Electronics	**1**	**2**	**3**	**4**	**5**
• Radioactivity	**1**	**2**	**3**	**4**	**5**

Section Three
Your Confidence About Teaching "Force and Motion"

This section is about general, and some specific, learning outcomes for the topics of force and motion. The following general learning outcomes for the topics of force and motion are contained in the Form 4 Physics Curriculum Specification. As a prospective physics teacher, how confident do you feel about achieving the following general learning outcomes for your students.

a. I think I have the ability to achieve the following "general learning outcomes" for my students:

	strongly disagree				strongly agree
a. Linear motion	1	2	3	4	5
b. Inertia concept	1	2	3	4	5
c. The concept of linear momentum	1	2	3	4	5
d. The effect of force	1	2	3	4	5
e. The force of gravity	1	2	3	4	5
f. The balanced force	1	2	3	4	5
g. Work, power, potential energy & kinetic energy	1	2	3	4	5

Section Three
Your Confidence Teaching "Force and Motion"

As a prospective physics teacher, how confident do you feel about achieving the following "specific learning outcomes" for your students.

b. I think I have the ability to achieve the following "specific learning outcomes" for my students:

	strongly disagree				strongly agree
1. distant and displacement	1	2	3	4	5
2. speed and velocity	1	2	3	4	5
3. acceleration and deceleration	1	2	3	4	5
4. graphs of linear motion	1	2	3	4	5
5. equations of motion	1	2	3	4	5
6. Newton's first law	1	2	3	4	5
7. conservation of momentum	1	2	3	4	5
8. collisions and explosions	1	2	3	4	5
9. Newton's second law	1	2	3	4	5
10. impulse and impulsive force	1	2	3	4	5
11. free fall	1	2	3	4	5
12. weight	1	2	3	4	5
13. equilibrium	1	2	3	4	5
14. Newton's third law	1	2	3	4	5

Section Four
Your Personal Background

1. Are you PKPG student

☐ Yes

☐ No

2. Your Sex ☐ male

☐ female

Thank you for taking time to complete this questionnaire.

APPENDIX VII

Format of Microteaching

University of Malaysia Sabah
Sekolah Pendidikan dan Pembangunan Sosial
Semester I1, 2005/2006
Physics Teaching Methods(TT4133)

Name : **Matric No. :**
Date/ Time: **Topic:**

Components	Characteristics	Weak (1-5)	Mod (6-10)	Good (11-15)
Questioning Skills	i. ask questions clearly and concisely			
	ii. pausing			
	iii. prompting			
	iv. probing			
	v. asking for further clarification			
	vi. redirecting			
	vi. refocusing			
	Question Types:			
	i. recall			
	ii. comprehension			
	iii. application			
	iv. analysis			
	v. synthesis			
	vi. evaluation			
Illustrating with Examples	i. using simple examples			
	ii. using relevant examples			
	iii. using interesting examples			
	iv. using appropriate media for examples			
	v. students participation			
Explaining Skills	i. clarity			
	ii. emphasis (pointers, links, priorities)			
	iii. order of ideas or concepts			
Factual accuracy of content				
Frequent use of language or behaviour: right, understand? ok				
Overall Result and Comments:				

APPENDIX VIII

Format of Daily Lesson Plans' Assessment

Name: **Matric No. :**
Topic:

Components	Characteristics	Marks
General (3 %)	i. date, time, form, day	
	ii. learning outcomes	
	iii. pre-requisites	
Teaching Procedures/ Sequences (8 %)	**Opening Section**.	
	i. settle class (rules establish)	
	ii. induction set	
	iii. introduction	
	iv. apparatus, equipment or materials	
	Development Section	
	i. suggested learning activities	
	ii. specific teaching technique	
	iii. assessment	
	iv. follow-up activities	
	Closure Section	
	i. summarizing the lesson	
	ii. clarify any remaining doubts	
Reflection (4 %)	i. problems or difficulties encountered	
	ii. additional resource management	
	iii. the difference between what was planned and what was achieved	
	iv. the strength and areas of lesson plan needed improvement	