A CASE STUDY OF UNIVERSITY STUDENTS' EXPERIENCES OF INTRODUCTORY PHYSICS DRAWN FROM THEIR APPROACHES TO PROBLEM SOLVING

BUSISIWE PRECIOUS ALANT

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor Philosophiae in the Department of Physics, University of the Western Cape.

Supervisor: Prof. Cedric Linder
Co-supervisor: Prof. Delia Marshall

December 2001

To David Brookes
who taught me to be a teacher

KEYWORDS

Phenomenography

Actor-network theory

The experience of learning introductory physics through problem-solving

Institutional, physical and personal context of learning

Relevance structure

Spatio-temporal distribution of knowing

Students' problem-solving strategies

Approaches to introductory physics problem-solving

Students' intentions and conceptions of problem-solving in introductory physics

Introductory physics learning as convention or constituting understanding

ABSTRACT

A CASE STUDY OF UNIVERSITY STUDENTS' EXPERIENCES OF INTRODUCTORY PHYSICS DRAWN FROM THEIR APPROACHES TO PROBLEM SOLVING

B. P. Alant

Ph. D. thesis, Department of Physics, University of the Western Cape.

This thesis explores the experience of learning physics through a particular medium: problem-solving, which is seen by many educators as the primary medium in which physics is learnt at university. Situating itself within two theoretical perspectives: phenomenography and actor-network theory, the dissertation explores the variation in the ways of experiencing introductory physics learning through problem-solving. Phenomenography, which is the main theoretical framework, places emphasis on the variation of experience of a phenomenon at a supra-individual level. Learning is regarded as relational, which means that the act of learning is apprehended (in terms of *how* the learning is done as well as *what* is learnt) in the relation between the learner and the phenomenon. Rather than regard the *content* of physics learning as the phenomenon, the study proposes the *process* of learning physics through problem-solving as the phenomenon under investigation. The thesis draws on insights from actor-network theory, particularly with regard to the spatiality of learning. Learning is seen as a function of enrolment.

Fifteen students were interviewed on introductory physics problems encountered in four end-of-module tests. The data were analyzed on the basis of *strategy* - conceived as "moments" of problem-solving, as well as the factors (intentional and contextual) that could be seen to influence the strategy adopted. Two qualitatively distinct problem-solving strategies were identified, deriving from the relative presence of reflective awareness. Further, factors influencing the strategies were identified and found to be indicative of two qualitatively distinct ways in which the students focused on the problems - either on problem content (the physics concepts) or on problem requirement (the formal requirements of the task within the test setting). These findings are seen to constitute the structural aspect of the students' experience of physics learning through problem-solving. With regard to the referential aspect of the experience, the study derives two overall meanings that the students attached to their experience of physics learning through problem-solving, namely physics learning as "reconstituting understanding" and physics learning as "confirming convention".

It is argued that the variations identified in the strategies employed by the students, in the ways they focus on problems, in their perception of the problem-solving settings, in the meanings they attach to physics learning through problem-solving – call for a framework of learning that takes account of spatio-temporal intricacy. The notion of conceptual understanding in the learning of physics should be informed by the specific demands of the medium of problem-solving through which physics is learnt at undergraduate level

December 2001

DECLARATION

I declare that *A case study of university students' experiences of introductory physics drawn from their approaches to problem solving* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Busisiwe Precious Alant

December
2001

Signed: ... ...

ACKNOWLEDGEMENTS

I would like to thank the following people:

The fifteen first year physics students (year 2000) who willingly gave of their time to come for the interviews. Without their enthusiasm and cooperation this study would simply not have been possible;

The staff in the Department of Physics at the University of the Western Cape, in particular Prof. Danny Adams, Dr Roderick Julies, Prof. Dirk Knoesen; Prof. Robbie Lindsay; Dr. Andrew Green and Mr. Rudolph Nchodu, for their willingness to accommodate me with my myriad requests and needs. I appreciate their interest and co-operation as well as the space they provided for this research;

Prof. Cedric Linder and Prof. Delia Marshall for their support and guidance as the supervisors of the study;

Shirley Booth for the many occasions in which she gave invaluable comments on the progress of the study;

Tom Adawi, Anders Berglund, Åke Ingerman and Irene Moetsana for their most useful comments in the initial stages of the thesis;

Claudine Eiman for lending a hand in the transcription of the interview data;

Jaco and Tobias, and my parents, parents-in-law, friends and family for their encouragement.

This research was supported by funding from the National Research Foundation.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

BACKGROUND TO THE STUDY

1.1 Introduction

Redish and Steinberg (1999:24) argue that physics instruction should move away from considering "what are we teaching and how can we deliver it" to contemplating "what do students learn and how do we make sense of what they do". This shift in emphasis in physics education research, supported by many education research groups (for example at the universities of California, Göteburg, Lancaster, Massachusetts, Maryland, Surrey, Washington, Western Cape), pave the way towards the realization that in order to address students' learning difficulties in physics, a stronger emphasis should be placed on the students' experiences of learning physics. With regard to an interpretative framework, which could guide investigations into the different aspects of learning, the Göteburg research group has particularly focused on the importance of both the "what"[i] and "how"[ii] aspects of students' learning in programmes aimed at maximizing what students learn in the long term. An understanding of "how students respond to teaching, how they tackle the everyday demands of learning and studying, what difficulties ... they encounter" (Hounsell, 1984:189) can bring us closer to an understanding of what it means to learn in higher education.

Over the years, the tendency in physics education research has been on much needed, and indeed significant, work aiding our understanding of how physics students conceptualize various topics covered in a physics curriculum. Relatively few studies have focused on the relational aspect of physics learning. In other words, the exploration of what it means "to learn physics", looked at from the perspective of the students in the context of a specific learning experience, remains a relatively uncharted territory (Booth and Ingerman, 2000; Waterhouse and Prosser, 2001).

It is the aim of this research to focus on one of the taken-for-granted media through which undergraduate physics is learnt, i.e. problem-solving, and to explore the meanings that this experience of learning physics through problem-solving has for first year physics students at the University of the Western-Cape, South Africa. The study focuses on problem-solving in physics, yet it is not a conventional study of problem-solving. It does not seek to characterize the "cognitive processes" involved in problem-solving, nor does it seek to find out what makes some students more "efficient" problem-solvers than others. In fact, it is not primarily the intention here to explore students' understanding of physics concepts. Rather, the study seeks to explore the chief *medium* through which physics learning and teaching occurs: problem-solving, and to determine the ways in which the students relate this medium to their experience of learning physics. In other words, it is the students' experiences of the medium in which physics is learnt that this study hopes to explore.

Even if it is not the main aim of the study to explore how students understand physics concepts, this does not mean that students' understandings of physics concepts will play no role in the study. Students' understandings of physics concepts inform how they solve problems, and problem-solving provides a particular window through which students' understandings of physics concepts can be ascertained.

Problem-solving not only takes up a large part of university physics courses, but there is an assumption that students learn physics through doing problems – that successful problem-solving implies an understanding of physics concepts. Yet the relation between conceptual understanding and problem-solving is frequently – notably in the reality of the university physics course - more ambiguous than is generally assumed. This study seeks to explore the nature of this often uneasy relationship, as manifested in the experience of the university physics learner.

1.2 Personal background to the study

To situate the study I need to draw on my own experience as a physics learner. In March 1999, I registered for the course Physics 1 at the University of the Western Cape (UWC). I soon came to realize the prominence of problem-solving within the physics course. In fact, whatever "progress" I was making in my learning of physics was being evaluated constantly through my ability to solve problems - given as homework, as assignments, and in tests. It became evident that in order to "succeed" in the physics course I had to learn to become successful in problem-solving.

Before 1999, I had spent two years doing a first and second year course in "Conceptual Physics". Conceptual Physics had been introduced at the University of the Western Cape in the early 90's. Concerned with the qualitative exploration of physics ideas, the course was aimed, broadly speaking, at providing students with experiences they could use as a basis for making hypotheses related to physics phenomena in their daily lives. In other words, it emphasized the idea that physics phenomena were things that informed people's experiences; people participated in making sense of physics phenomena.

I thought the background that I had gained through two years of Conceptual Physics would provide me with a "flying start" in Physics 1. The reality was totally different. The concept of participation in sense-making that characterized Conceptual Physics was now replaced by the experience of physics learning as a verification or demonstration of a "frozen"[iii] physics content. In this sense, the outcome of what is to be learnt was predetermined by the objectives presented at the beginning of every new topic that was covered. Knowing what we were supposed to learn did not in any way make me understand the work any better. Given the time constraints associated with university learning which places enormous limitations on engaging in any exploratory discussions of new concepts and their understanding, my involvement in the process of learning physics seemed to be reduced to the application of the content of physics. Moreover, this application of physics content was always in a particular context predetermined by a physics problem.

We were initiated into first year physics learning via the model of imitation which aimed at familiarizing us with the disciplinary tools of physics. After a concept had been introduced, problems were selected from the prescribed text. The lecturers solved one or two problems on the board while we copied the problem-solving method. Even in other learning contexts, such as the tutorial and study groups, most of the students duplicated the lecturer's way of solving the problem. Those who were able to solve the problems set in the tests were awarded good marks (I was not always one of them). In the process, the need to solve the problems often appeared greater than the need to understand the physical laws and their relations, although the skill of problem-solving and the understanding of physical laws were assumed by the lecturers to be manifestations of each other.

Where Conceptual Physics had encouraged students to integrate principles conceptually, I soon noticed, in my association with the other students in the Physics 1 class, that the idea of linking things up did not seem to be high on their list of priorities. Getting through the course was their main priority and they were prepared to do so through whatever means they could. I was determined to find the link between what I was doing in class and the outside world - even if it meant being left behind. I had comparatively little pressure on me, unlike the other students in class who had to pass Physics 1 in order to gain entry into either Pharmacy or Dentistry. It became evident that even though I attended the same lectures and did the same work, my goal in learning physics was different from those of the other students in the class. My expectations of learning physics were different.

This insight had profound implications for my own research project on the learning of physics, which by mid-1999 had gradually begun to take shape. I realized that the data that I needed to collect would somehow have to be a collection of things that the students did that were different from what I was doing myself. I kept notes on observations I made in the lectures, in the tutorial sessions and in the laboratory sessions. These observations were crucial for the formulation of the research questions in this study.

1.3 Rationale of the study

My broader experience as a physics student in the context described above contributed to the formulation of the research project. In my own reflections on this experience – as well as in the discussions I had with the other students and staff members in the Physics Department at UWC - the following elements offered themselves as particular areas of investigation:

- my experience of learning physics – and how it seemed to be different to that of other students;

- the differences between myself and other students with regard to the reasons why we were doing the physics course. I was a post graduate Education student with an interest in physics learning; the other students were mostly first year students who required Physics 1 in order to proceed with their undergraduate degrees;

- the centrality of problem-solving within the Physics 1 course, and its ambiguous relation with the idea of "linking things up" (understanding). The lecturers seemed to assume this relation to be clear; many students, on the other hand, clearly regarded the ability to solve a physics problem as something distinct from – and also more important than – say, the ability to explain the physics ideas involved in the physics problems; and

- the fact that some of the spaces (settings) in which the students came into contact with physics seemed to be more closely associated with the idea of understanding than other settings. Of particular interest was the lecture. The lecture was to a large extent presented – by lecturers *and* students! - as the setting where the lecturers provided the students with a "map" which the students would (maybe) make sense of in their own time – somewhere else.

As these questions – stemming from my experience as a physics student - were becoming more apparent, Cedric Linder and Delia Marshall[iv] introduced me to phenomenography. I was by now keen that my doctoral project should provide some kind of "diagnosis" of the first year Physics course, to enable the lecturers to be confronted with – and better understand - what students *really* "take out of physics lectures". As Ramsden points out, "a relational perspective does not look for elegant general laws of learning, but for guiding hypotheses about typical conceptions and approaches that will help teachers convey particular subject matter in certain educational circumstances" (Ramsden, 1988:28). I was particularly impressed by the fundamental importance of *variation in the ways of experiencing* enjoyed within phenomenography, and the systematic way it provided to make sense of the bewildering array of elements that constitute the experience (including my own) of learning. At the same time, I was committed to exploring the learning of physics, not as a field of learning for its own sake, but the learning of physics within the real-life university environment in which I found myself[v]. This preoccupation meant that my study was to concern itself with what was, in my own experience, the chief characteristic of physics in the Physics 1 course, namely problem-solving. And problem-solving was not some "concept"; it was what physics students *did*. But of course, problem-solving was also *how students learnt physics* - or at least how they were supposed to learn physics. My study was about the relation between the aim of the Physics 1 course, physics learning, and its main instrument, problem-solving.

As a point of departure from other studies into student problem-solving with undergraduate students (see section 2.3.2), I have followed a phenomenographic orientation (see section 2.2) to develop the two research questions used in this investigation. The aim of these research questions is to draw extensively upon students' experiences at a collective level in a way not done before to contribute to the understanding of the nature of the learning which first year undergraduate physics students experience through problem-solving.

Research Question 1: What are the qualitatively different ways (strategies*) in which first year physics students go about solving introductory physics problems?

Research Question 2: What factors influence the strategy adopted by first year physics students during problem-solving?

Let me, at this point, state what I mean by "experience" – at least in a phenomenographic sense. As would be further discussed in Chapter 2, phenomenography is concerned, less with experience "in itself", than with *variation in the ways of experiencing*. As such, it addresses experience at an essentially collective (supra-individual) level (Marton, 1981). The following four aspects: discernment, variation, contemporaneousness and simultaneity, provide

* With regard to the meaning of strategy versus approach see glossary of terms, pg 1617.

the basis upon which the qualitatively different ways of experiencing can be understood (Marton and Pang, 1999:6). Discernment relates to awareness, which is always awareness of something (an object). In other words, there is "focal awareness". Discernment, however, cannot take place without variation, in the sense that focal awareness is awareness - not of an object as such, but, rather, of the extent to which that object is *different*. The object is focused upon (experienced) *in its variation*. Contemporaneousness refers to the fact that a way of experiencing is *bounded in time* (Marton, 1993). It is, quite literally, a snapshot – an "eternal present". Simultaneity, on the other hand, refers to the potentially relational nature of discernment, which consists of parts related by their *simultaneous* discernment.

Simultaneity, in fact, highlights a particular complexity (of experience), which is most relevant to the present study. Marton and Booth (1997:113) state, "Different aspects or parts of the whole may or may not be discerned as objects of focal awareness simultaneously". They argue, furthermore, that in cases where certain relevant aspects of the object of focus are not in focal awareness, these aspects may be experienced consecutively: "It is generally the case that some ... [objects of focus] are abstracted, separated, isolated. Instead of them being objects of focus simultaneously, they may be separated and experienced one after the other, in sequence. This tells us that certain ways of experiencing are more complex or fuller than others" (Marton and Booth, 1997:113).

This study explores the *experience of learning physics*. It does not look at the experience of learning physics directly, however, but as *mediated* by problem-solving. This orientation brings about exactly the kind of complexity that Marton and Booth refer to in the passage quoted above. When doing a problem, students are not dealing with only one question, but with a variety of questions. The introductory physics problem tasks used to probe first year physics students' experience of learning through problem-solving are multi-faceted in that they would often refer the students to other questions and to other aspects of solving the problem. In other words, the students' way of focusing on the problem (their ways